OECD Information Technology Outlook

ICTs, E-COMMERCE AND THE INFORMATION ECONOMY

INFORMATION SOCIETY

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FOREWORD

The *Information Technology Outlook* 2000 has been prepared by the OECD under the guidance of the OECD Committee for Information, Computer and Communications Policy (ICCP), and in particular its Working Party on the Information Economy. It is the fifth in a biennial series designed to provide Member countries with a broad overview of trends and prospects in the information technology (IT) industry, an analysis of the growing impact of IT on the economy and society, new developments in selected areas of information technology, and a description of IT policy directions.

Building on the1997 edition, the 2000 edition further extends the economic and policy analysis. The first three chapters provide an overview of the growing importance of information and communication technologies (ICTs) in national economies, describe recent market dynamics and examine the links between the use of ICTs and the potential uptake of electronic commerce. The next two chapters highlight the increasing use of electronic payments and describe OECD countries' policies for promoting the use of such systems. The set of four special chapters cover various issues relating to "ubiquitous computing" and current issues and developments such as the growth of the software industry in India; intelligent agents for the Internet; Global Navigation Satellite Systems (GNSS); and flat panel displays. Annex 1 provides for the first time statistical profiles of selected OECD countries using data from official sources. Information technology policy profiles are posted separately on the OECD Web site to enable their widespread diffusion (*http://www.oecd.org/dsti/sti/it/prod/it-out2000-e.htm*).

The IT *Outlook* 2000 was prepared by Graham Vickery, Vladimir López-Bassols, Pierre Montagnier and Masahiro Katsuno of the OECD's Information, Computer and Communications Policy Division and Bénédicte Callan of the Science and Technology Policy Division, with contributions from other experts. It has benefited from valuable contributions from Delegates to the ICCP Committee's Working Party on the Information Economy, under the chairmanship of Mr. Jostein Håøy (Norway), particularly regarding national IT policy developments and up-to-date national statistics on the production and use of IT goods and services.

The report is published on the responsibility of the Secretary-General of the OECD.

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HIGHLIGHTS

Information technology (IT) is significantly affecting the economy, the growth and structure of output, occupations and employment and how people use their time. The *Information Technology Outlook* 2000 describes the rapid growth in the supply and demand for information technology goods and services and their role in the expanding Internet economy, and looks at emerging uses of information technology. It reflects the spread and diversity of a technology that is underpinning economic and social transformation. It makes use of the new official national sources of data which are becoming available as statistical mapping of the information economy improves.

The spread and diversity of IT is transforming the economy, the nature of growth, occupations and how people use their time.

More specifically, Chapters 1 through 3 of the *Information Technology Outlook* 2000 provide a discussion of broad comparative statistics on information technologies across OECD economies, discuss the dynamics of IT markets and explore the factors that influence the uptake of IT. Chapters 4 and 5 take a closer look at the development of electronic financial transactions. The manner in which these develop will critically affect the development of a wide variety of commercial IT applications. Chapters 6 through 9 take a closer look at industries and technologies at the forefront of commercially and/or strategically important IT developments. Annex 1 compiles statistical ICT profiles for OECD countries.

Information technology and the economy

The economic importance of information and communication technology continues to grow. ICT intensity (ICT expenditures/GDP) is rising in OECD countries and reached almost 7% on average in 1997. It is particularly high in English-speaking countries, Sweden, Switzerland, Japan and the Netherlands. The strong growth of ICT is mainly driven by growth in telecommunications equipment and services. Firm-level data suggest that the IT industry (excluding telecommunications) continues to undergo rapid restructuring; although hardware is still the largest segment, data communications play an increasing role. Many traditional IT hardware firms (*e.g.* IBM) are moving towards services, and Asian firms are major players in many hardware segments. The rapid consolidation in the ICT industry, particularly telecommunications, is having an impact on the competitive structure of this sector.

ICT growth is driven by telecommunications equipment and services, while rapid consolidation is transforming the sector's competitive structure.

OECD countries account for more than 80% of world ICT production, a share that has remained stable. Within the OECD region and in terms of markets, the United States (36%) continues

While OECD countries dominate ICT markets, growth is faster in non-OECD countries.

to drive growth. However, in non-OECD countries, ICT markets are growing at more than twice the OECD average, and the largest markets, Brazil and China, are growing rapidly.

ICT growth is driven by both supply and demand factors.

Still modest at the macro level, IT and the Internet are transforming how OECD economies and societies function.

Growth in the ICT industry is driven by various factors. On the supply side, these include the development and introduction of new and improved products through firm-level investments in R&D and innovation, the ready availability of venture capital funds for investments in ICT, the development and rapid growth of new products/services segments and the general shift towards services. On the demand side, there are rapidly declining costs and prices for ICT equipment and the liberalisation of the trade and regulatory framework. Despite rapid growth in the ICT industry and its rising share in output and GDP, IT's broader contribution to economic growth is difficult to quantify. It appears to be modest at macroeconomic level (although the recent contribution appears substantial in some countries – see Annex 1), but increasingly significant at firm level. IT and the Internet in particular are nonetheless transforming how OECD economies and societies function.

Information technology markets

Software and services dominate the IT market, while data communication equipment is the most dynamic sector.

Strong growth in IT markets mirrors and drives the supply side. In information technologies (excluding communications): *i*) the software market has shown rapid growth and, together with services, dominates the IT market (around 55% of the total); *ii*) single-user systems, mainly PCs and workstations, have grown strongly but the decline of other hardware categories has meant that hardware's share of the market has fallen; *iii*) with the rapid growth in the Internet and networks, data communication equipment is likely to continue to be the most dynamic market, but it still has a modest share of around 5% of IT markets. The latest data suggest that general trends have remained stable through 1999. Software and services will continue to drive growth well into 2000. Data communication equipment will continue to grow rapidly and will also increase its share of total IT markets. Between 1990 and 1997, the OECD IT market grew at 8% a year, and accounted for 92% of the world total, a share which has remained relatively stable. The G7 have 86%, and the United States alone almost 50%, of the OECD total. Growth in the European IT market outpaced that in the United States, while the relative share of Japan continues to decline.

The quality of the network infrastructure will affect how the online software market develops.

OECD countries accounted for 94% of the world software market in 1997 and spent on average more than non-OECD countries on packaged software. As for the overall IT market, the United States accounts for almost half of the world software market and drives the strong growth in its software-producing sector. The share of software in total IT spending is relatively high in European countries. The software market is growing rapidly in Canada and Korea. High-speed networks and high bandwidth connections to the Internet are likely to strongly affect both the development of online software sales and the move towards offering some software free on line. However, relatively high piracy rates imply a significant underestimation of the software market. IT services markets are concentrated in the G7 countries (close to 90%), with North America having well over one-half of the total. Growth in services was well above the OECD average in Canada and Mexico, and the US share has jumped to almost half of the OECD total.

Use of computer networks and the Internet are driving hardware markets, and demand for PCs from households and education is strong.

Growing use of computer networks and the Internet has driven hardware markets. PCs and workstations now represent one-half of the hardware market, and data communication equipment is well over 10%. In 1998, one out of every five PCs was shipped to Asia, but the United States remains the main driving force for PC market growth. The business and government sectors still have close to 60% of the total PC installed base. However, widespread demand from the household and education sectors has increased the PC installed base per 100 inhabitants in all OECD countries, and ratios are high in the Nordic countries, Switzerland, Australia, the Netherlands and the United States. A sustained decline in prices, driven by downward microprocessor and component prices, has contributed to the rapid diffusion of PCs.

The United States maintains the lead in total IT expenditures and IT as a share of GDP.

The United States is the lead country in terms of IT expenditures and IT as a share of GDP. Owing to the size of the US market, its IT market structure and growth are similar to those of the OECD as a whole. In the United States, the services sector is a major user of IT, with finance and insurance accounting for more than one-fifth of total IT expenditures, a share larger than their weight in the economy. The education sector is also an "over-user" of IT owing to strong software spending. In contrast, construction and resource industries are relatively low IT users.

E-commerce readiness

The potential of e-commerce is just beginning to be realised…

Rapid growth in the use of the Internet and the emergence of electronic commerce have the potential to transform economic and social activities, but this potential is just beginning to be realised. The diffusion of electronic commerce is likely to follow the usual S-curve for new and pervasive technologies. As the characteristics of electronic commerce evolve, the related policy concerns are likely to evolve as well.

… and readiness for e-commerce depends on network infrastructure, technology diffusion and skills.

Three broad phases in the growth of e-commerce are defined: *i*) readiness: preparing the technical, commercial and social infrastructure necessary to support e-commerce; *ii*) intensity: examining the current situation and identifying early adopters and laggards; *iii*) impact: addressing additionality and multiplier effects and the effect of electronic commerce on the efficiency of economies and the creation of new wealth. These phases are measured with different types of indicators. The main indicators of electronic commerce readiness are network infrastructure, technology diffusion, and skills and human resources. The discussion of electronic commerce "readiness" focuses on the current and potential use of ICTs for online commercial transactions. Emphasis is placed on the combination of PCs and TCP/IP technologies, which are often the extension of or complement to established and widespread electronic data interchange (EDI) systems.

Its growth is fostered by strong growth in infrastructure and in Internet use, but its development will depend on growth of mobile applications, price, service, ease of use, speed and reliability.

Electronic commerce has been fostered by strong growth of infrastructure, including narrow and broadband access, and the accompanying growth of Internet usage. In part, this has been facilitated by declining prices for network access and improved quality of service in most countries, in parallel with the liberalisation and promotion of competition, although "local loop" liberalisation remains to be achieved. New ways of pricing, both for consumers (low access costs are an important factor driving uptake), and for the leased lines used in business-to-business transactions (pricing practices are changing as competition among infrastructure providers increases), have led to increased Internet connection in homes and businesses and the growth of mobile networks, which facilitate the uptake of electronic commerce. However, development will depend not only on low prices but also, increasingly, on improved service, ease of use, speed and reliability.

There is concern about a digital divide, and attention is being paid to offering different routes to the Information Society.

One factor seen as inhibiting the uptake and use of IT and electronic commerce is the widely held idea that an IT worker shortage has developed. For the United States, the major IT market and supplier, data on unemployment rates, wages and graduates suggest that there is no conclusive evidence of a serious shortage of IT workers. However, the structure of available skills may be a concern, and governments are likely to need to foster acquisition of the necessary IT skills. Moreover, there is concern about what appears to be an important and growing digital divide within and between countries. Within countries, access to IT and network resources varies widely; income, education, age, and household type are determining factors, and, to the extent that they may inhibit use of IT and networks, they will also slow the diffusion of electronic commerce. Attention is being focused on other roads to the "Information Highway", including local educational and information routes such as schools, libraries and community access centres.

Issues in electronic settlements

For extending the use of electronic payments, trust is the most important issue.

Information technology is becoming ubiquitous in electronic payment. Trust is the most important issue for extending the use of electronic settlements. Trust is needed at many levels, including hardware and software security, the regulatory regime, familiarity and users' perceptions. Factors affecting the level of trust required and provided include: *i)* where and how payment takes place (whether real or virtual – for virtual settlement, data circulated over the network are recognised as having monetary value or contain payment instructions); *ii*) when settlement takes place (prior to, at the time of, or after the transaction); *iii*) who settles (established incumbents or new entrants); *iv*) whether the transaction is business-to-business or business-to-consumer; and *v*) whether settlement can be traced. These factors affect the choice of the technology used to establish trust (*e.g.* encryption using a smart card), and how trust is perceived by users (*e.g.* consumers may trust the services of incumbent financial service providers more readily than those of a start-up IT firm).

Users rely more on familiarity and ease of use than on technological sophistication when making their choices…

The future of electronic payment can be extrapolated from current non-cash payments. Card-based electronic settlement is likely to be used in countries where use of payment cards is high (North America, United Kingdom, Belgium). The United States, where the use of cheques is high, is likely to develop electronic billing methods. For business-to-consumer transactions, credit cards are the most pervasive means of settlement, using the Secure Socket Layer (SSL) built into Internet browser programmes. In contrast, electronic purse/money alternatives have not taken off, neither have Secure Electronic Transaction (SET) technologies, a more secure method for online credit card use. Perceived trust appears to be an important factor in uptake of alternative settlement methods. Users rely more on familiarity and ease of use than on technological sophistication when choosing what is most appropriate for them.

… but many security factors also affect whether users find electronic settlement acceptable.

There are a number of policy issues related to trust in methods of electronic payment. Bandwidth (to ensure security and rapid operation), hardware and user security, and logical security (passwords, PINs, etc.) help make electronic payment more trustworthy and usable. Furthermore, issues of certification and authentication, encryption, privacy, liability and consumer protection, financial regulation and market development and competition all affect whether electronic settlement is acceptable to users.

Policies to promote electronic financial transactions

Governments can help familiarise users with these new technologies and help increase trust in them.

IT policies relevant to electronic financial transactions generally emphasise technology diffusion as a complement to private-sector technology development. These policies often take the form of government-led test-bed projects or government use of new technologies. Through such efforts, governments can help familiarise users with new technologies and increase the level of perceived trust. Government use of the technologies may also help demonstrate that they are functional and trustworthy.

All OECD governments are strengthening their use of online transactions to increase efficiency and demonstrate the viability of electronic payment.

Examples of government-led projects include test beds in co-operation with the private sector in Japan [electronic money (Internet Cash) and integrated circuit (IC) cards to test electronic transaction options], various electronic payment projects in Europe, and government-sponsored smart-card pilots for the

United States military. All OECD governments are increasing their use of online transactions to demonstrate the viability of such transactions and improve the efficiency of government services. Among other examples, the US electronic fund transfer (EFT99) requires most federal payments except tax refunds to be made electronically from January 1999. Other governments also have started to use electronic financial transactions to settle and receive payments, mainly for tax collection but also for payment of government services.

Existing regulations in relevant areas may need to be reviewed.

The regulatory environment also affects the development and use of electronic payment. Existing regulations in areas such as certification and authentication, privacy, liability and consumer protection, as well as in financial services regulations, may be inadequate to promote trust in electronic payment. Some governments have started to tackle these policy issues: for example, new regulations on electronic banking in the United States, proposed legislation in Japan and the EC recommendation on electronic payment instruments.

While technology development is led by the private sector, government can help ensure competition and encourage interoperability.

The experience with government policies to promote electronic financial transactions clearly indicates the importance of encouraging diffusion by testing a variety of technological solutions and using them for government business to demonstrate their reliability and trustworthiness. Technology development is primarily led by the private sector. Governments nonetheless have an important policy role in ensuring competition to develop new and improved technologies and solutions and in encouraging interoperability among competing standards. The legal/regulatory framework for electronic financial transactions needs to be technology-neutral and provide a stable, forward-looking framework for developing payment systems.

Software development in non-member economies: the case of India

Non-member countries are playing an increasing role in some areas of software services and development…

OECD countries still retain the major share of the software industry, but non-member economies are increasingly important in some areas. India is most often cited in the area of outsourcing software development, with an estimated USD 3.8 billion in revenue in 1998-99, and 50% annual growth in revenue over the past few years. However, India's software industry faces a number of challenges as its labour cost advantage shrinks, and it provides an excellent case study of recent and possible future development paths in a dynamic, highly competitive industry.

… as exemplified by India.

Initial development of India's software industry was closely tied to the indigenous computer hardware industry, which grew because of the availability of skilled workers and the government's nuclear and space policy. Since the late 1980s, the industry has grown rapidly, thanks to a combination of human resource endowments, favourable government policies (including liberalisation and substantial investments in higher education) and good timing. It now focuses on exports (close to 70% of revenue), mostly of software services (85% of exports); the United States is its main export market (over one-half of exports).

The current market leaders in India are relatively new specialised firms…

Growth was initially driven by the diversification of established Indian computer or general firms into software, but current market leaders are relatively new specialised firms, with the top 30 firms accounting for three-quarters of total revenue. There has been little major consolidation and few foreign acquisitions of Indian firms, as the work offers few opportunities for economies of scale and growth rates are very high. Large firms from OECD countries are using India as a platform for outsourcing, usually through long-term service agreements with local firms. In most cases, projects are routine work (low value added) owing to lower labour costs (between one-third and one-fifth of comparable US wage costs). The major sources of competition are other Indian firms or firms from advanced countries (*e.g.* US firms set up by Indian nationals).

… but few firms are expected to move to higher value-added segments.

Few firms are expected to manage the transition to higher value-added segments. Compared to other countries with spectacularly growing software industries (*e.g.* Israel, Ireland), the nature of the service projects means that revenue per employee is low. Major challenges to be overcome include emerging skill shortages, with highly skilled workers being attracted to higher-paying jobs, mainly in the United States. Inadequate infrastructure is another obstacle for Indian firms trying to move up the value chain. The Indian experience suggests that governments wishing to use IT industries as part of development strategies need to address areas such as skills development, investment in infrastructure, effectiveness of the financial sector, R&D, IPR protection and procurement.

Intelligent agent technologies for the Internet

The spectacular growth of the Web has created the need for intelligent agents as a tool for e-commerce.

Intelligent agent technologies for the Internet are of growing importance. The spectacular growth of the World Wide Web as an information base and marketplace has made such technologies crucial for identifying, sorting and managing the vast quantities of online data. Intelligent agents (IAs) are fast becoming an important tool for facilitating e-commerce by helping users to find information, services and products.

Their prevalence and importance are likely to increase rapidly…

Internet-based IAs are barely five years old, yet they have already been put to many uses: performing product searches and making price comparisons, keeping track of financial information, and scanning newsgroups for postings. With the World Wide Web at 800 million pages and growing, programmes to personalise and organise relevant information will multiply. There is likely to be a rapid increase in the prevalence and importance of IAs in the near future. The next generation of IAs will have much more autonomy for decision making. They may eventually become independent economic entities capable of negotiating, collaborating and transacting. In sufficient number and if widely used, they may transform Web-based marketplace dynamics. Governments may need to be aware of and begin to track the impact of IAs on online market dynamics.

... but, like electronic payment, they raise policy and trust issues.

The increasing presence of IAs raises a number of user issues and policy considerations. As for electronic financial transactions, consumers must trust them if they are to grant them some autonomy and decision-making power. Issues of trust, privacy and consumer protection need to be addressed and there must be an appropriate legal and commercial environment for tackling the challenges that these non-human economic actors present for the Web.

Global navigation satellite systems and the IT infrastructure

Global navigation systems and location technologies are of growing commercial and strategic interest.

The increased ability to combine information about location anywhere on the globe with communications capabilities has opened a broad range of new markets for goods and services. It is now possible to provide tailored geographic information in real time for car navigation, emergency rescue, or remote co-ordination of the activities of multiple platforms, such as aeroplanes in flight. Location technologies are an integral part of the global information infrastructure.

World markets for these systems grew at over 50% a year in the 1990s...

The private sector is rapidly implementing global navigation satellite system (GNSS) technologies, and world markets for GNSS-based products have grown at over 50% a year in the 1990s. GNSS technologies are being widely exploited, and industries as varied as transport, utilities and agriculture are reaping productivity benefits from these applications. As the price and size of receivers diminish, location is likely to be a feature of any device with an electronic component. Furthermore, the highly precise information on time and location that is provided globally, 24 hours a day, is making the GNSS a critical infrastructure for transport, as well as a time synchronisation tool for financial, utility and telecommunications networks.

... driven by civilian applications.

Civilian uses are the driving force behind future GNSS architectures. Governments have an interest in removing obstacles to the further commercial exploitation of GNSS in order to reap the promised safety and security benefits and to encourage applications which increase productivity and offer social benefits. Most OECD governments are making important investments in augmentation systems to improve signal quality, and the European Union is considering building an entirely new satellite system for civilian use.

The architecture of the next generation of the global satellite and positioning system is currently under discussion.

The architecture of the next-generation global navigation satellite and positioning system is currently being debated. As control passes from purely US and military hands to a more international consortium, international discussions are necessary to develop standards, keep international markets open, co-ordinate systems of infrastructure governance to make them global and resolve the security and commercial issues which emerge as GNSS becomes a shared infrastructure.

The future of flat panel displays

Flat panel displays are also of high commercial, strategic and policy interest.

Flat panel displays are of high commercial, strategic and policy interest. Their convenience (the hang-on-the wall display) and potential portability (cellular phones, automobile navigation displays) combine with their increasing use as interactive devices. The diffusion of these devices is a noteworthy example of the working through of the technological feasibility of a new application, its successful commercial exploitation in a range of new applications and the social acceptability of the uses to which it can potentially be put.

New applications for these displays are being developed for many consumer products.

Flat panel displays are catching up with conventional cathode ray tube (CRT) technologies in market value, but CRTs are projected to retain their lead over active liquid crystal displays (the most common flat panel display technology) over the next few years. However, the market share of all flat panel displays combined is projected to exceed that of CRTs. In value terms, portable computers are the current major use. Desk-top monitors are expected to become major applications as screen size increases to 14 inches or more, information capacity continues to increase exponentially and prices continue to fall dramatically. New, and expanded, television applications are likely as flat panels attain bigger screen sizes. New display applications are appearing for mobile phones with Internet capabilities, digital organisers, electronic books, and, if they are accepted, wearable head-mounted displays.

In terms of individual firms, the supply industry is not highly concentrated. One firm (Sharp, Japan) supplies 15% of liquid crystal displays and seven other firms have 5-10% of the market. All major producers are either Japanese, the dominant suppliers, or Korean, and price competition is intense. Among non-Asian companies, only IBM and Philips have significant capacity via a joint venture and a majority holding with Asian firms, respectively.

Policy focus has shifted from industry and defence to issues of distribution, privacy and social acceptance.

The policy focus in the early 1990s was on conventional industry policy and defence policy views of the importance of domestic manufacturing capacity in what were seen as critical technologies. Since then, new concerns have emerged, such as the distribution of new technologies (part of the "digital divide" issue), privacy and confidentiality issues related to the increasing ubiquity of information technology made possible by low-cost, portable, flexible and convenient flat panel displays, and issues of social acceptance associated with the introduction of new imaging and display technologies.

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ANALYSIS AND INDICATORS

Chapter 1

INFORMATION TECHNOLOGY AND THE ECONOMY

Information technology (IT) is at the heart of the current debate about economic growth and performance in advanced economies. The pervasive nature of this technology and its widespread diffusion has profoundly altered the ways in which businesses and consumers interact. As IT continues to enter workplaces, homes and learning institutions, many aspects of work and leisure are changing radically. The rapid pace of technological change and the growing connectivity that it makes possible have resulted in a wealth of new products, new markets and new business models, but they also entail new risks, new challenges and new concerns. Information technology is a strong catalyst for growth and efficiency and is affecting many of the social and economic characteristics of OECD countries.

This chapter examines in quantitative terms the growing importance of IT in OECD economies from various angles. Although it focuses on IT, it also looks at the broader group of information and communication technologies (ICT), owing to the growing importance of telecommunications and the difficulty of establishing clear boundaries between technologies that continue to converge. First, it describes these industries and their relative weight in the economy with respect to variables such as production, trade, and employment. Second, it examines worldwide ICT markets, including geographical trends and the dynamics of various broad segments of the industry across countries. Third, it presents a firm-level analysis of the IT sector using data on the 50 largest IT firms. Fourth, it highlights some of the major driving forces behind the strong growth of these technologies, including the structural shift of economies towards services, R&D and innovation, declining prices, new segments such as the Internet and electronic commerce (see Chapter 3), changes in existing regulatory and trade regimes, and venture capital financing. Finally, it addresses questions related to the current debate over how to measure the contribution of computers to output growth and productivity at an aggregate level.

The ICT sector and the economy

The definition of what constitutes the ICT sector is not straightforward. Various definitions are used to address different supply-side aspects of the emerging "digital economy". Commodity classifications at a very disaggregated level are used for production, trade and market statistics, in order to examine specific ICT products, while broader industry classifications are used for production, employment and R&D data when comparing ICT to other sectors (see Annex 2 for methodology).

Although ICT-producing sectors in OECD countries account for a small and stable share of GDP (usually between 2.5% and 4.5%), the economic importance of these industries continues to grow (Table 1). More recent detailed country data using somewhat different national industrial classifications estimate the share of these sectors in GDP to be substantially higher (see Annex 1): almost 8% for the IT-producing sector in the United States in 1998 (US DOC, 1999), 6.1% of Canadian GDP for ICT industries in 1997 (Industry Canada, 1999), 5.2% for France (IT sector) for the same year (INSEE, 1999); 3.5% for Italy in 1996 (see Annex 1).

Production

Table 2 presents production data. It divides ICT equipment into six main product groups: *i*) electronic data processing (EDP); *ii*) office equipment; *iii*) radio communication & radar equipment;

Table 1. **Value added in ICT industries[1] as a percentage of GDP, 1980-97 (or latest available year)**

	1980	1990	1997
United States	3.8	4.1	4.4[2]
Finland	3.9	3.9	3.9[2]
Germany	4.6	4.9	3.8[2]
Netherlands	3.8	3.8	3.8[3]
France	3.2	3.6	3.5
Australia	2.7	2.9	3.3
New Zealand	3.3	3.3	3.3[3]
Portugal	3.1	3.1	3.1[4]
Sweden	3.0	3.0	3.0[5]
Canada	2.9	2.9	2.9[4]
Spain	2.6	2.6	2.6[5]
Italy	1.9	2.3	2.5
Mexico	2.4	2.4	2.4[2]
Denmark	2.1	2.1	2.1[3]
Iceland	1.6	1.6	1.6[3]

1. ICT industries are defined as ISIC Rev.2 classes 3825 (Office & computing equipment), 3832 (Radio, TV & communication equipment) and 72 (Communication services).
2. 1996.
3. 1995.
4. 1993.
5. 1994.

Source: OECD, STAN database, May 1999.

Table 2. **World production of ICT goods, 1997**

Millions of USD

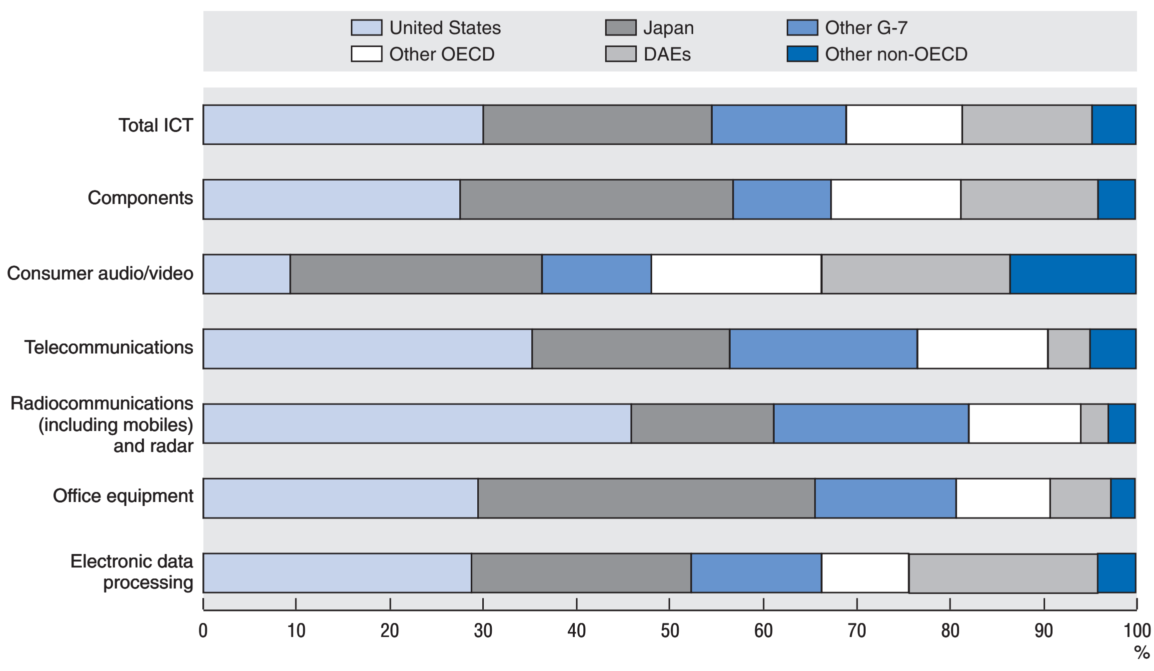
	Electronic data processing	Office equipment	Radio comm. (incl. mobiles) and radar	Telecommunications	Consumer audio and video	Components	Total ICT
United States	82 391	5 058	57 551	36 151	6 435	79 212	266 798
Canada	3 623	118	1 884	2 826	243	591	9 285
Japan	67 686	6 215	19 248	21 752	18 711	84 380	217 992
Korea	7 915	339	3 903	2 297	5 669	28 187	48 310
Australia	1 045	30	746	784	230	376	3 211
Austria	430	47	64	578	658	1 239	3 016
Belgium	1 927	85	534	969	796	925	5 236
Denmark	103	8	291	231	186	758	1 577
Finland	925	5	2 259	1 748	161	624	5 722
France	7 226	521	9 846	4 743	1 898	6 915	31 149
Germany	8 423	913	4 968	6 624	2 343	11 217	34 488
Greece	106	44	66	92	55	37	400
Ireland	7 879	33	318	686	47	1 679	10 642
Italy	5 637	290	1 950	3 623	645	3 940	16 085
Netherlands	3 436	959	731	718	221	1 921	7 986
Norway	243	0	322	354	7	146	1 072
Portugal	399	19	137	211	617	608	1 991
Spain	1 536	73	288	2 606	1 247	1 010	6 760
Sweden	218	16	5 124	2 612	7	1 472	9 449
Switzerland	697	83	310	490	2 739	1 202	5 521
United Kingdom	15 246	762	7 595	2 826	2 987	7 766	37 182
OECD-21	217 091	15 618	118 135	92 921	45 902	234 205	723 872
Hong Kong, China	1 895	337	297	568	2 655	2 695	8 447
Malaysia	7 544	136	996	1 637	6 355	12 667	29 335
Singapore	25 000	335	1 284	419	2 357	13 361	42 756
Chinese Taipei	17 885	51	764	1 473	863	10 331	31 367
Thailand	5 732	264	414	541	1 786	3 323	12 060
India	771	70	554	506	1 689	999	4 589
Indonesia	1 100	77	437	400	2 139	1 680	5 833
Philippines	800	22	350	320	484	4 608	6 584
Brazil	8 150	268	1 300	1 800	4 734	3 132	19 384
Israel	830	8	930	1 650	77	1 163	4 658
South Africa	174	6	137	434	229	52	1 032
Total of above countries	286 972	17 192	125 598	102 669	69 270	288 216	889 917

Source: Reed Electronics Research (1999).

iv) telecommunication equipment; *v*) consumer equipment; and *vi*) electronic components (see Annex 2 for methodology). In 1996-97, production increased slightly in value terms – by 0.6% for the OECD area – driven mainly by the radio communication and telecommunication equipment segments. Some countries experienced particularly strong growth: among them, Sweden (20.6%, mostly from radio communication equipment); Finland (15.9%, mostly from telecommunications); Ireland (14.1%, mostly from EDP); and the United Kingdom (11.7%). On the other hand, production of consumer electronics declined slightly in the OECD area (down 0.9% from 1996 in current USD), as non-member economies (NMEs) such as Malaysia, Brazil, Hong Kong (China), Singapore and Indonesia continue to strengthen their position as major world producers of these goods.

In 1997, OECD countries produced more than 80% of all ICT equipment and almost 95% of all radio, communication and radar equipment (Figure 1). Specialisation patterns vary widely among OECD countries: Ireland concentrates on production of EDP, the Netherlands on office equipment, Finland on radio communication and telecommunication equipment, and Portugal on consumer electronics. Some NMEs have taken an increasing role in world production: Singapore, Chinese Taipei and Malaysia each account for more than 3% of world production of ICT goods and an even higher share in certain segments such as EDP or consumer electronics.

Figure 1. **Breakdown of worldwide ICT production by region, 1997**



1. DAEs (Dynamic Asian economies) are: Chinese Taipei, Hong Kong (China), Malaysia, Singapore and Thailand.
Source: OECD calculations based on Reed Electronics Research (1999).

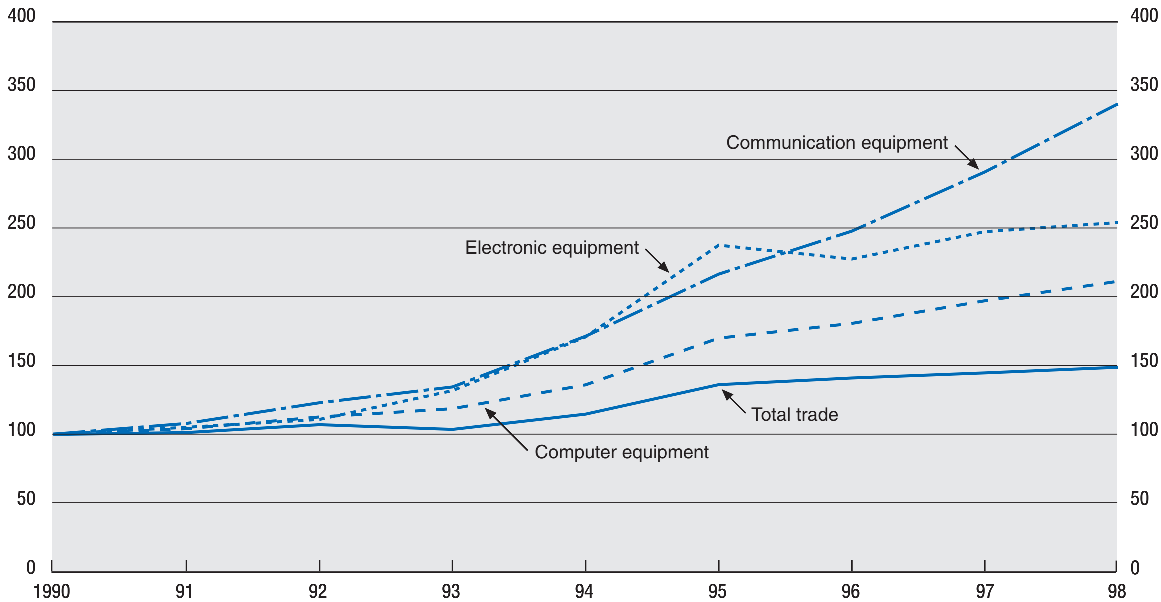
Trade

This section describes the main trends in OECD trade of ICT products and services. For the purpose of trade comparisons, ICT goods have four main segments: computer equipment, communication equipment, electronic components and software goods (see Annex 2 for methodology). Owing to the use of different classification systems, software is treated separately and is not included in this description of overall ICT trade trends.

OECD trade in ICT products continues to grow rapidly: in 1990 these products accounted for 6.4% of trade in goods; by 1998 the share had reached 10.4%. The largest segment is computer equipment, which still accounts for almost 45% of total ICT exports of OECD countries. The fastest growing segment is communication equipment: both imports and exports more than tripled between 1990 and 1998, growing more than twice as fast as total trade (Figure 2). Trade in electronic components also continues to grow after a decline in 1996 due to production over-capacity and a temporary slowdown in demand.

Figure 2. **OECD trade[1] in ICT goods, 1990-98**

Index: 1990 = 100



1. Trade is defined as the average of imports and exports.

Source: OECD, FTS database, December 1999.

Computer equipment

Trade in computer equipment has increased steadily during the 1990s. OECD exports almost reached USD 178 billion in 1998 while imports grew to USD 232 billion (Table 3). Although still high, the share of OECD imports from both the United States and Japan declined from a combined 41% in 1990 to around 25% in 1998. The share of imports from the non-OECD region has increased, doubling from 17.4% in 1990 to 35.8% in 1998. Most of the increase is due to growth from Asian economies. China, Hong Kong (China) and particularly Chinese Taipei have become major worldwide exporters of these goods (Table 9).

Exports remain mostly intra-OECD: 84.9% in 1998 compared to 90.3% in 1990. Along with the United States, the European Union continues to be a major market for OECD exports, accounting for about half

Table 3. **OECD trade in computer equipment by partner country/region, 1990 and 1998**

Shares in percentage and value in billions of current USD

	Exports to		Imports from	
	1990	1998	1990	1998
OECD	90.3	84.9	82.6	64.2
United States	16.7	17.0	23.4	14.4
Japan	4.1	3.3	17.7	10.9
EU	57.6	51.8	35.1	29.2
Other	11.8	12.8	6.4	9.7
Non-OECD	9.7	15.1	17.4	35.8
Asia	6.4	9.7	17.0	35.3
Europe	1.0	1.1	0.0	0.1
South America	1.0	2.6	0.2	0.0
Other	1.3	1.7	0.3	0.4
Total	100.0	100.0	100.0	100.0
Value in USD billions	86.5	177.8	99.6	232.2

Source: OECD, FTS database, December 1999.

of all exports of computer equipment in 1998. Although their share is still low, non-OECD Asian countries are becoming an important market for OECD exports (9.7% in 1998 *vs.* 6.4% in 1990).

The United States and Japan, which are home to the main manufacturing companies, continue to be the strongest exporting countries, accounting for 40% of all OECD exports in 1998 (Table 9). Despite strong export growth in these countries, the OECD area as a whole has increased its trade deficit with the non-OECD area from USD 8.9 billion in 1990 to USD 56.3 billion in 1998.

Communication equipment

This is the fastest-growing ICT segment. OECD exports grew at an average of almost 18% annually between 1990 and 1998. Europe and the United States are increasingly the major importers, accounting for more than two-fifths and one-fifth of OECD imports respectively (Table 4). The share of NMEs (mostly in Asia) is declining, accounting for less than one-fifth of OECD imports in 1998. However, these economies continue to be a primary destination for OECD exports, accounting for almost 30%, more than half of which were directed to Asian countries.

In addition to the G7 countries, Sweden and Finland have become major exporters of communication goods owing to the strong presence worldwide of two national firms: Ericsson and Nokia (Table 9).

Table 4. **OECD trade in communication equipment by partner country/region, 1990 and 1998**

Shares in percentage and value in billions of current USD

	Exports to		Imports from	
	1990	1998	1990	1998
OECD	67.5	70.5	79.1	82.1
United States	15.0	14.1	12.3	20.4
Japan	2.3	1.8	23.1	5.8
EU	34.9	41.0	31.3	41.5
Other	15.4	13.6	12.4	14.5
Non-OECD	32.5	29.5	20.9	17.9
Asia	18.1	16.5	17.9	16.9
Europe	2.5	3.3	0.2	0.4
South America	3.1	5.3	0.1	0.1
Other	8.8	4.4	2.7	0.4
Total	100.0	100.0	100.0	100.0
Value in USD billions	21.6	79.8	17.6	64.3

Source: OECD, FTS database, December 1999.

The United States is still the leading import market (almost one-quarter of OECD imports), but its relative share has decreased (down from one-third in 1990). This is mostly due to expansion in Japan and other non-EU markets, with no significant change in the share of the EU region (around one-half).

Electronic components

OECD trade in electronic components is also growing rapidly (almost 15% a year between 1990 and 1998). Nevertheless, the relative share of intra-OECD trade has decreased: almost 42% of exports now go to NMEs, particularly Chinese Taipei and Hong Kong (China) (Tables 5 and 9), owing both to demand from Asian companies and to off-shore production needs of OECD firms abroad. As OECD companies continue to relocate production facilities to Asia and Asian firms strengthen their position as world-class producers, the share of OECD exports from all G7 countries except the United States continues to decline (the United States is now the leading exporting country, ahead of Japan). The United States is by far the largest importing country (almost one-third of OECD imports in 1998), followed by Korea and then Germany. OECD imports increasingly originate from non-OECD Asian economies (28% in 1998).

Table 5. **OECD trade in components by partner country/region, 1990 and 1998**

Shares in percentage and value in billions of current USD

	Exports to		Imports from	
	1990	1998	1990	1998
OECD	67.1	58.3	77.8	68.8
United States	15.5	14.7	17.3	23.8
Japan	2.8	4.0	16.7	12.4
EU	32.6	23.5	29.4	19.8
Other	16.1	16.0	14.4	12.8
Non-OECD	32.9	41.7	22.2	31.2
Asia	27.8	36.1	19.6	28.0
Europe	1.1	0.9	0.9	0.6
South America	0.9	0.8	0.2	0.1
Other	3.0	3.9	1.5	2.6
Total	100.0	100.0	100.0	100.0
Value in USD billions	47.9	145.8	46.9	134.3

Source: OECD, FTS database, December 1999.

Software goods

Tracking software imports and exports in trade statistics is fraught with measurement problems (OECD, 1998*a*). First, as border valuations are currently based on physical supports (CD-ROM, diskettes) rather than content, the value of software has been significantly underestimated. Second, the bundling of software with computer hardware creates the potential for significant mismeasurement. Third, trade statistics do not measure the value of copyrighted works sold in foreign markets (the gold-master problem). Fourth, trade statistics do not measure the value of software electronically transmitted to and then subsequently sold by a foreign affiliate of a company. This last point is part of a larger problem related to the transition towards the electronic distribution of intangible goods, since measuring domestic and international transactions involving such goods (*e.g.* software) is much harder than measuring those involving tangible goods.

Nevertheless, trade statistics can give an indication of the relative size and geographical distribution of cross-border sales of software goods (see Annex 2 for methodology). Software remains a relatively small share of traded goods for OECD countries: exports reached USD 9.7 billion in 1998, while imports were slightly more than USD 9 billion, or 0.2% of all traded goods (Table 6). Trade in software is mostly an intra-OECD phenomenon: 92.8% of OECD imports come from OECD countries and 85.4% of exports are directed towards them.

Table 6. **OECD trade in software goods by partner country/region, 1998**

Shares in percentage and value in millions of current USD

	Exports to	Imports from
OECD	85.4	92.8
Japan	5.6	2.2
United States	4.6	28.0
Canada	8.4	1.9
EU	55.1	58.6
Non-OECD	14.6	7.2
Asia	7.0	6.8
Europe	1.5	0.2
South America	3.4	0.0
Total	100.0	100.0
Value in USD millions	9 676	9 096

Source: OECD, FTS database, December 1999.

The United States and Ireland are by far the main exporting countries, accounting for almost two-thirds of OECD exports of software goods in 1998 (Table 7). Import markets are concentrated in the G7 countries which together account for more almost 60% of OECD imports. Canada and the EU account for more than one-half of US exports, while exports from Ireland are mainly directed to other EU countries (Box 1). Japan is the only OECD country for which NMEs (particularly in Asia) represent a significant export market (almost 40%). Non-OECD Asian economies are an important source of US imports (35.2%), slightly below EU countries (35.7%).

Table 7. **Software goods: leading exporting and importing countries, 1998**

Value in millions of current USD

Exports by		Imports by	
Ireland	3 290	United Kingdom	1 056
United States	2 956	Germany	966
United Kingdom	664	France	864
Netherlands	608	Canada	806
Germany	513	United States	639
France	320	Italy	620
Japan	173	Switzerland	498
Belgium-Luxembourg	162	Australia	358
Switzerland	116	Japan	349
Austria	115	Netherlands	335
EU	5 927	EU	5 453
OECD	9 631	OECD	8 941

Source: OECD, FTS database, December 1999.

Services

Trade in services is more difficult to quantify given their immaterial nature and the increasing complexity of delivery channels. Table 8 highlights the importance of this type of trade for both communications and computer services. After the United States, the United Kingdom and Germany were the largest exporters of computer services, while Japan and Germany were the main importing countries.

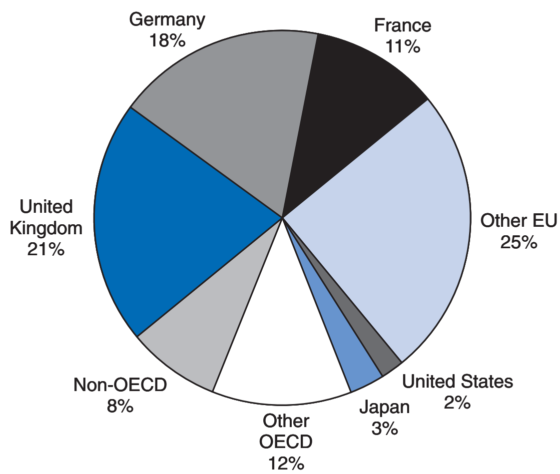
US exports of information services exceeded USD 3.0 billion in 1997, or 1.3% of all (private) services exports (BEA, 1999). This includes both computer and data processing services (USD 1.6 billion), and database and other information services (USD 1.4 billion). Smaller in size than exports of financial services (USD 11.1 billion) and education (USD 8.3 billion), exports of information services were lower than

Box 1. The Irish software industry

The Irish software sector is often cited as an example of the success of national policies aimed at developing a world-class high-tech industry. By 1997, the Irish Government's strategy of encouraging foreign direct investment had attracted over 1 100 foreign firms, one-tenth of them in the software sector. Through the combination of a favourable economic environment (low inflation, financial support schemes, tax concessions, low operating costs), a skilled, young, and relatively inexpensive labour force, and the development of a nation-wide software-oriented support infrastructure, Ireland has become the second largest packaged software exporting country in the world. In 1998, the sector comprised 760 companies employing 21 630 persons, generated revenues in excess of USD 7.4 billion and exported USD 6.6 billion (including both goods and services) (NSD, 1998).

A significant number of large multinational corporations (MNCs) have recently located software operations in Ireland. In 1997, seven of the world's top ten independent software companies (Microsoft, Computer Associates, Oracle, Informix, Novell, SAP and Symantec) had facilities in Ireland (NSD, 1997). Even though they represent a relatively small share of the total (120 out of 760), foreign-owned firms accounted for 83.5% of revenues and 87.6% of the sector's exports in 1998. The Irish government has recently announced a series of initiatives to ensure that both national and foreign-owned software firms can take advantage of new opportunities offered by the worldwide growth of e-commerce activities (Forfás, 1999).

Breakdown of Irish software goods exports by destination, 1998



Total : USD 3 290 milion

Source: OECD, FTS database, December 1999.

those of construction and engineering services (around USD 4 billion in 1997). Nonetheless, these data do not include sales by foreign subsidiaries, which in the case of information services can amount to much more: 1996 sales of information services by US affiliates were more than USD 28 billion (US DOC, 1999), almost four times their value in 1990. In 1995, almost three-quarters of information services sales by US

Table 8. **Trade in computer and communications services, 1998**

Value in millions of USD

	Communications services		Computer and information services	
	Imports	Exports	Imports	Exports
Australia	867	835	223	356
Austria[1]	374	316	156	79
Belgium-Luxembourg[1]	502	1 285	769	1 265
Canada	1 380	1 451	736	1 089
Czech Republic[1]	55	61	39	39
Finland	200	164	649	1 051
France[1]	667	636	517	553
Germany	2 877	1 775	3 339	2 817
Hungary[1]	41	51	80	79
Iceland[1]	25	24	0	1
Italy[1]	1 055	687	592	235
Japan[1]	1 714	1 363	3 483	1 414
Korea[1]	865	652	66	3
Mexico	361	1 043	..	..
Netherlands[1]	665	652	686	815
New Zealand[1]	..	..	72	40
Norway	157	188	179	59
Poland[1]	234	386	86	20
Portugal[1]	116	235	100	42
Spain[1]	454	551	848	1 414
Sweden	716	475	853	971
Switzerland[1]	681	489	..	..
United Kingdom	2 290	1 794	985	2 826
United States	9 003	4 008	434[1]	3 047[1]

1. 1997.
Source: IMF, *Balance of Payment* (BOP) *Statistics*, 1999 and US Bureau of Economic Analysis (BEA), 1999.

foreign affiliates took place in Europe. In addition, these data do not include software-licensing agreements: fee receipts were nearly USD 2.5 billion in 1997.

The United States is by far the main importer of communications services, since most international calls between the United States and other countries originate in the United States. After the United States, Germany has the second largest trade deficit in communications services, at more than USD 1 billion in 1998.

Employment

Employment levels in the ICT manufacturing sectors increased significantly in the OECD area during the early 1980s. They have gradually declined since 1990 and in 1996 reached roughly the level of 1980 (Figure 3). Nevertheless, high-technology industries in general and ICT in particular have been much less affected than other manufacturing sectors by job losses in the 1990s. ICT manufacturing industries' share in total employment remains relatively small, usually between 1% and 3% in most OECD countries. This share was relatively stable during the 1980s except in countries such as the United States and Australia, which experienced a slight decline.

ICT industries have seen growing demand for skilled workers and changing skill requirements. As IT-related occupations become increasingly important in many sectors, including services, firms are addressing the problem of a tight labour market by hiring non-IT specialists or graduates with degrees outside strictly IT fields (see Chapter 3).

ICT *markets*

In this section, data on ICT markets are divided into three main categories: *i)* IT hardware; *ii)* IT services and software (including internal IT spending); and *iii)* telecommunications (see Annex 2 for methodology). Chapter 2 provides detailed data on the narrower IT sector which excludes both telecommunications and internal IT spending.

Table 9. **ICT goods: leading exporting and importing countries, 1990-98**

Value in billions of current USD

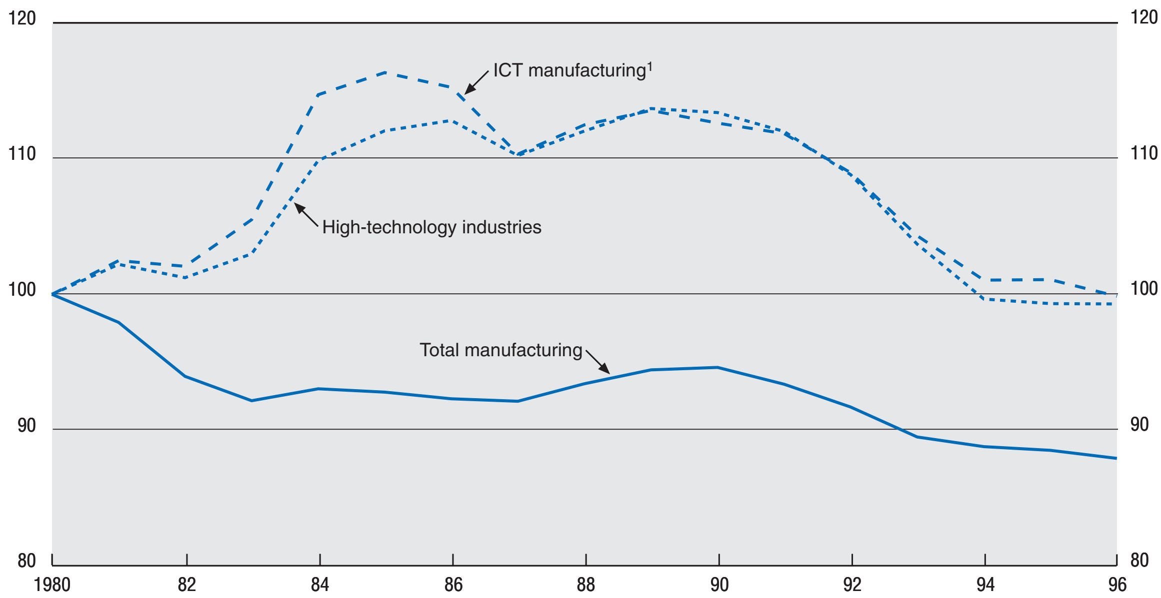
Computers	Exports by				Imports by		
	1990	1995	1998		1990	1995	1998
United States	23.0	34.5	44.6	United States	23.4	57.4	71.5
Japan	18.9	29.5	26.8	United Kingdom	12.1	17.7	24.0
United Kingdom	9.2	16.6	18.9	Germany	13.2	19.5	22.2
Netherlands	5.7	10.4	18.8	Netherlands	7.8	11.6	21.1
Ireland	4.5	8.9	13.4	Japan	5.0	15.4	15.9
Germany	8.1	11.0	11.9	France	8.4	11.4	14.0
France	5.0	7.8	9.9	Canada	4.5	7.9	9.2
Mexico	0.5	2.5	7.0	Ireland	1.7	5.5	8.7
Korea	..	4.7	5.2	Italy	4.8	5.9	6.8
Canada	2.1	4.8	4.8	Australia	2.4	4.0	4.0
EU	41.2	66.1	83.8	EU	60.1	87.5	114.6
OECD	86.9	144.5	177.4	OECD	100.1	185.0	230.3
Chinese Taipei	4.6	15.6	18.4 (96)	Chinese Taipei	1.4	2.4	3.0 (96)
Hong Kong, China	..	7.6	10.8	Hong Kong, China	..	7.2	11.7
China	..	3.7	10.2	China	..	2.4	5.3
Communication equipment	1990	1995	1998		1990	1995	1998
United States	4.1	10.9	15.0	United States	6.0	10.6	15.4
United Kingdom	1.4	3.9	10.4	United Kingdom	1.6	3.8	7.7
Germany	2.3	6.6	8.1	Germany	1.2	4.0	4.7
Sweden	1.8	4.3	7.7	Italy	1.1	1.8	3.9
France	1.4	3.1	5.9	Japan	0.8	3.0	3.4
Japan	5.6	6.9	5.8	France	0.7	1.7	3.3
Finland	0.7	2.7	5.5	Canada	0.8	1.9	3.0
Canada	1.1	2.6	4.0	Netherlands	0.7	1.4	2.4
Mexico	0.0	1.2	3.0	Mexico	0.6	0.8	2.3
Italy	0.5	1.3	2.4	Spain	0.9	1.2	2.1
EU	10.1	26.5	47.5	EU	8.4	18.2	32.4
OECD	21.6	51.2	79.5	OECD	18.2	40.5	63.8
Chinese Taipei	1.0	1.7	1.7 (96)	Chinese Taipei	0.7	0.7	0.6 (96)
Hong Kong, China	..	3.4	4.4	Hong Kong, China	..	5.1	6.7
China	..	1.6	2.6	China	..	4.1	4.2
Components	1990	1995	1998		1990	1995	1998
United States	13.8	27.7	44.2	United States	15.7	44.3	38.7
Japan	14.7	43.3	31.7	Korea	0.0	10.0	13.0
Korea	0.0	19.5	19.0	Germany	5.7	11.3	11.6
Germany	5.5	9.3	9.8	Japan	3.6	12.6	11.3
France	2.7	5.9	7.8	Mexico	0.2	6.2	10.5
United Kingdom	2.5	8.1	7.5	United Kingdom	3.9	10.2	8.9
Netherlands	1.5	4.3	6.0	France	3.8	5.9	7.6
Canada	2.3	2.4	3.4	Canada	3.8	7.2	7.2
Mexico	0.1	2.8	3.3	Netherlands	1.2	3.2	4.2
Italy	1.8	3.1	2.7	Italy	3.5	4.9	3.7
EU	16.7	36.3	41.5	EU	22.4	44.8	47.9
OECD	48.0	133.3	145.4	OECD	47.1	128.6	133.9
Chinese Taipei	3.3	12.1	12.6 (96)	Chinese Taipei	4.5	15.0	14.5 (96)
Hong Kong, China	..	8.8	9.1	Hong Kong, China	..	14.0	14.2
China	..	2.3	3.8	China	..	4.8	9.4

Source: OECD, FTS database, December 1999.

In 1997, the world ICT market was worth almost USD 1.8 trillion, compared to less than USD 1.3 trillion five years earlier (Figure 4). Since 1992, the world total has grown on average by 7.0% a year (in current USD terms), mainly driven by the US market, which remains by far the largest market (around 36% in 1997). Japan and NMEs were the second largest contributors to market growth, with about one-fifth of total growth each. Although their relative share is still small (11% in 1997), NMEs experienced the fastest growth, more than twice the world average.

The breakdown of worldwide ICT expenditures reveals that telecommunications now has the largest share, ahead of IT services and software (Figure 5). More than half of the total growth in 1992-97 is attributable to sales of telecommunication equipment and services.

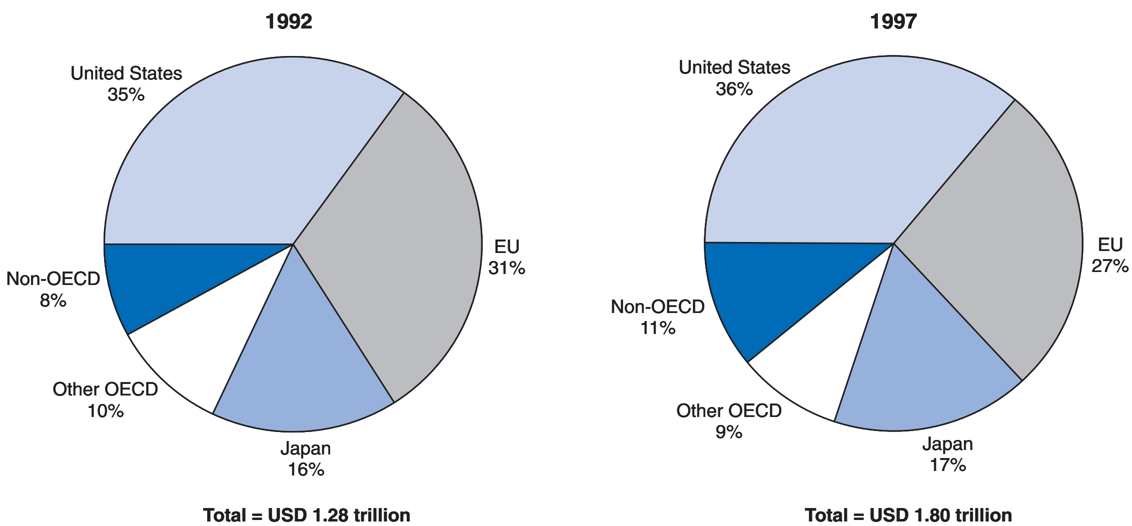
Figure 3. **Employment trends in 14 OECD countries**
Index: 1980 = 100



1. ICT manufacturing industries are: Office machinery and computers (ISIC Rev. 2 3825) and Radio, TV and communication equipment (ISIC Rev. 2 3832).

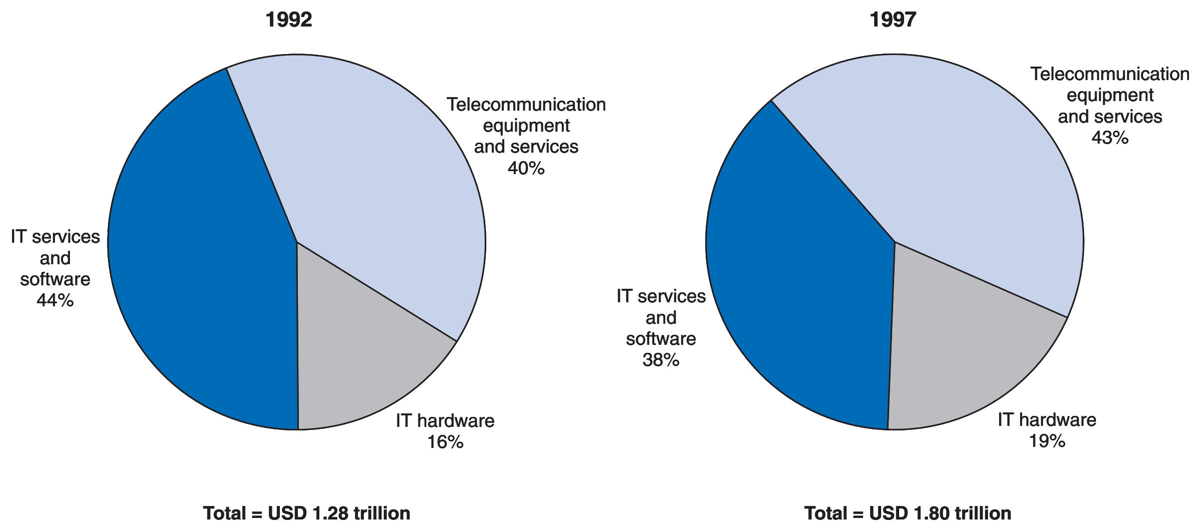
Source: OECD, STAN database, May 1999.

Figure 4. **Breakdown of worldwide ICT markets by country/region, 1992 and 1997**



Source: OECD calculations based on World Information Technology and Services Alliance (WITSA) and International Data Corp. (IDC) (1998).

Figure 5. **Breakdown of worldwide ICT markets by segment, 1992 and 1997**



Source: OECD calculations based on World Information Technology and Services Alliance (WITSA) and International Data Corp. (IDC) (1998).

These global market data hide wide variations among regions with respect to different product segments. Telecommunications is the largest segment in Japan (almost 49% of all ICT), while IT services and software are the main segments in the United States and Europe (around 43%). The rapid worldwide growth of the telecommunications segment is due both to steady growth in the OECD area, which accounts for over 83% of the world market (in Japan and to a lesser extent in the United States), and to the very strong expansion of non-OECD markets, which more than doubled in value between 1992 and 1997.

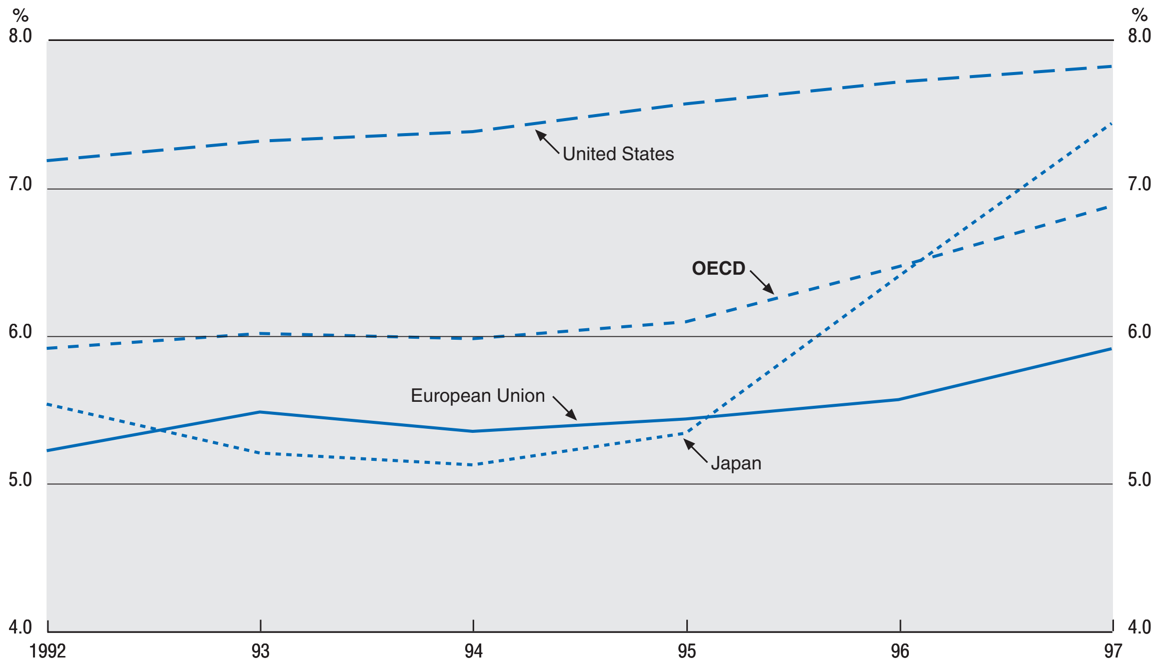
Growth in software and services was also driven by the US market, which accounts for over 40% of the world total in 1997 and grew by an average of 5.9% annually between 1992 and 1997. Software and services remain heavily concentrated in the OECD area, which accounts for about 95% of the world market. Although software is the fastest growing sub-segment [11.0% compound annual growth rate (CAGR) between 1992 and 1997], almost two-thirds of the growth at world level is due to increases in sales of IT services. Internal IT spending remains the largest category in this segment (around 44% in 1997) but has remained virtually constant since 1992.

ICT *intensity*

In 1997, OECD countries spent on average almost 7% of GDP on ICT, up from 6% in 1992. ICT intensity (ICT expenditure/GDP) in the United States continued to increase during the 1990s and remains 2 percentage points higher than in the European Union (Figure 6). ICT intensity grew significantly in Japan during 1996-97, owing to a high real increase in telecommunication expenditure and a decline in GDP in dollar terms. ICT intensity has risen in virtually all OECD countries since 1992, at an annual average of almost 2.5%.

ICT intensity is particularly high in English-speaking OECD countries as well as in Sweden and Switzerland and to a lesser extent in Japan and the Netherlands (Figure 7). Telecommunications accounts for the largest share in about half of the OECD countries. This share is particularly high in countries with

Figure 6. **ICT expenditures as a percentage of GDP in major OECD zones, 1992-97**



Source: OECD, ADB database and IDC, March 1999.

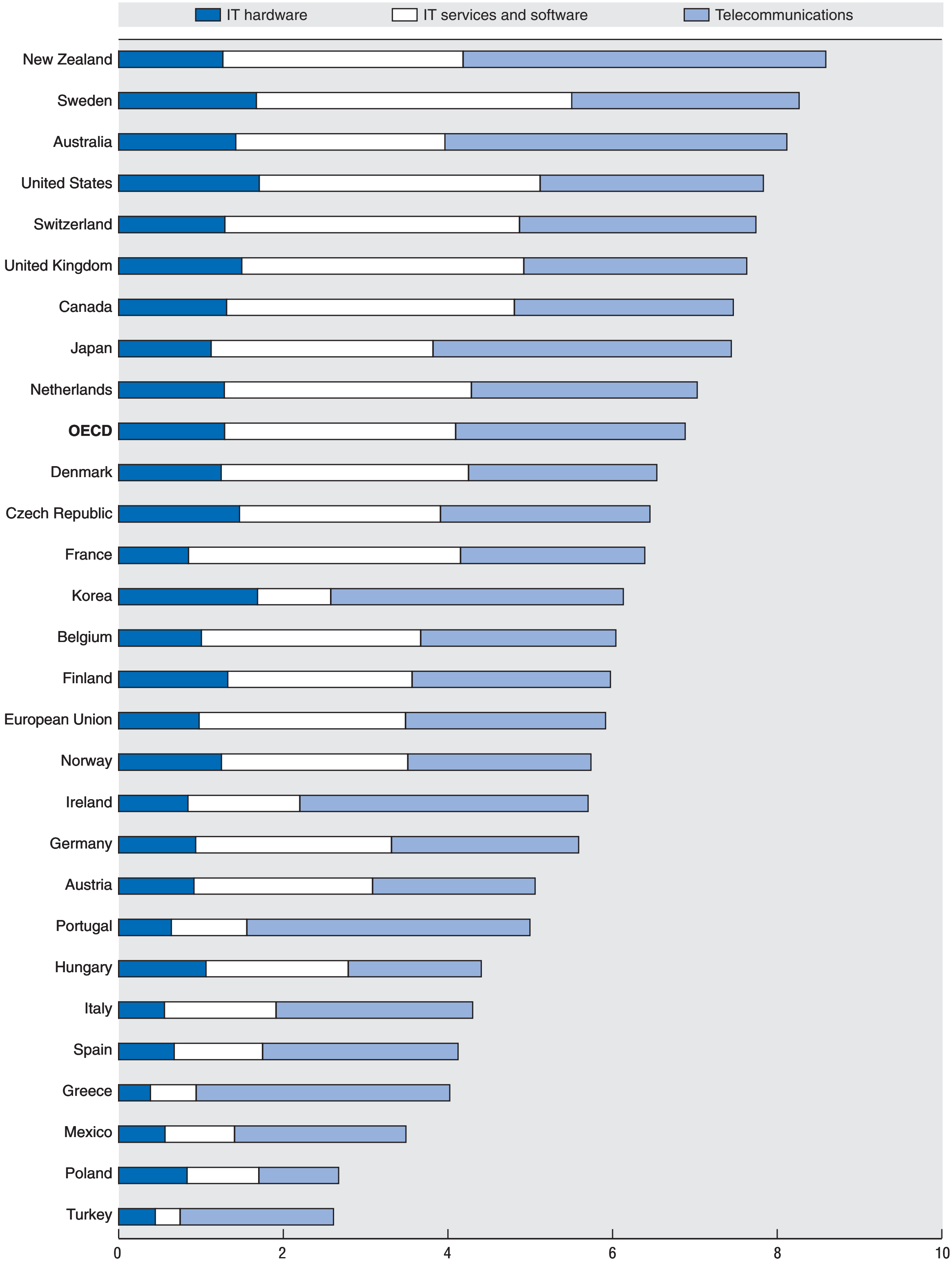
a relatively low ICT intensity such as Turkey, Poland, Mexico, Greece and Spain, mostly because of strong spending to modernise their infrastructure. It is also high in OECD countries in the Asia-Pacific region (Australia, Japan, Korea, New Zealand) owing to their strong reliance on global communication networks. In all other countries, IT software and services are the largest segment, accounting for more than 45% of all ICT expenditure in Canada, Denmark, France, Sweden and Switzerland.

Non-member economies

Although OECD countries account for an overwhelming share of world ICT markets, certain NMEs have experienced very rapid growth over the last few years, and some have now reached levels comparable to those of OECD countries such as Australia, Korea and the Netherlands. The total ICT market in the 20 largest NMEs reached almost USD 170 billion in 1997, growing at an average annual rate of 15.5% since 1992, more than twice the OECD average (Figure 8). ICT markets in NMEs are dominated by Brazil and China, which together accounted for more than one-third of the total in 1997. In 1997, telecommunications expenditure accounted for more than half of total spending on ICT and more than two-thirds in Argentina, China, Colombia, Hong Kong (China), Indonesia and Vietnam. IT hardware was the second largest segment (around one-fifth of the total) and exceeded one-quarter of ICT expenditure in China, the Philippines and Russia.

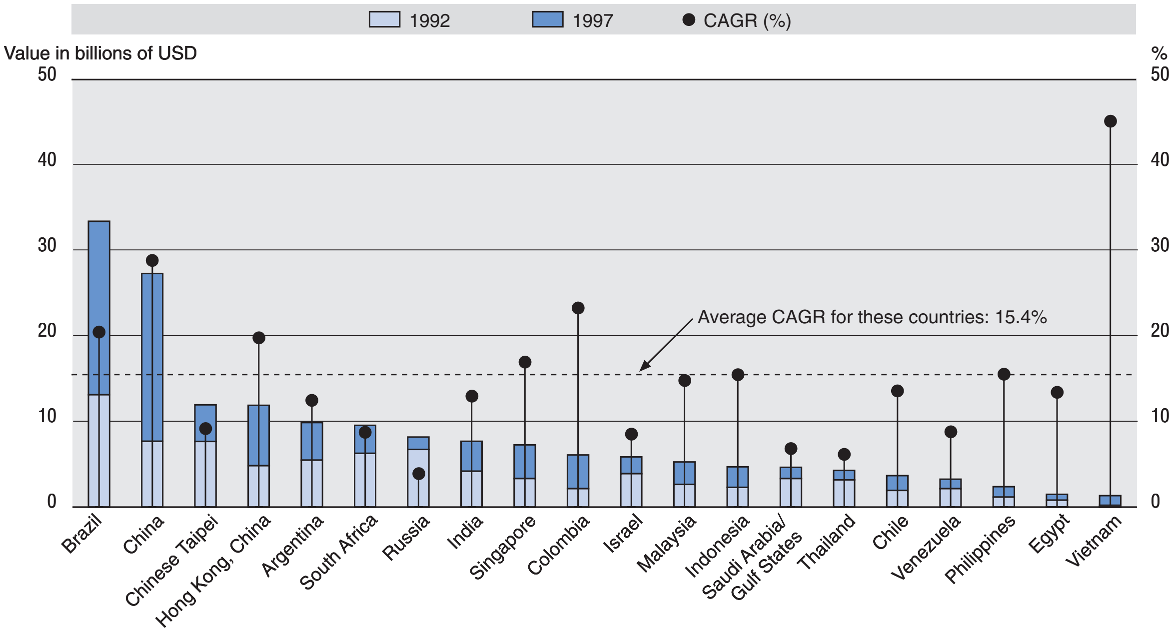
Brazil is still the largest market in the NMEs, but the Chinese market has grown at an extremely rapid 28.9% a year since 1992, mostly owing to telecommunications spending which increased more than four-fold. Telecommunications is indeed the major driver of growth for all the countries, with an average of two-thirds of ICT market growth between 1992 and 1997. IT hardware was the second largest contributor, averaging about one-fifth of total growth.

Figure 7. **ICT expenditures as a percentage of GDP, 1997**



Source: OECD, ADB database and IDC data, March 1999.

Figure 8. **ICT markets in selected non-member economies, 1992 and 1997**
Total in billions of USD and annual growth rate in percentage



Source: OECD calculations based on WITSA/IDC (1998).

The IT industry: a firm-level view

Market structure

As the IT market continues to grow, the sector's structure appears to be shifting. With the increasing importance of the Internet, major firms that traditionally dealt in hardware are shifting their focus to ser-

Box 2. **Methodology for firm-level analysis**

This section is based on a compilation of corporate data on the top 50 IT firms worldwide, selected on the basis of McKinsey & Company's 1997 *Report on the Computer Industry*. The sample comprises the 50 firms with the highest extended computer industry revenue (including semiconductors sold to the computer industry, distribution and online services) in 1996. Thus, it gives a view of a particular group of the largest IT firms in 1996, tracked over the period 1994-98. The methodology has some limitations as it excludes a number of major firms in the telecommunications equipment and semiconductor components industries, but it has the advantage of providing a dynamic picture of major companies.

The revenue figures presented in Table 10 represent total revenue for each firm, including non-IT-related revenue. For the purpose of analysis, each company was classified by its primary IT function into one of the following categories: hardware, software, services, distribution (including retail and wholesale) or data communication, based where possible on the company's US SIC classification. It should be noted that this categorisation only reflects the main segment of IT revenue. Many of the firms also gain substantial revenues from other IT segments and from non-IT sectors. Non-IT revenue is particularly important for Siemens, and most of the large Japanese IT firms.

Three of the 50 firms from the 1996 ranking have since been acquired by other top 50 firms and so are listed as having no revenue in 1998. These are Digital Equipment Corp., which merged with Compaq in June 1998, Intelligent Electronics, which was acquired by Xerox in May 1998, and Computer 2000, which was bought by Tech Data in 1998. Data for 1998 include fiscal years ending 31 January 1999 and earlier.

Table 10. **Top 50 IT firms**

Company	HQ country	Main IT function	Total revenue USD millions		Net income USD millions		Employees Thousands	
			1997	1998	1997	1998	1997	1998
IBM	United States	Hardware	78 508	81 667	6 093	6 328	333	350
Siemens	Germany	Data comm	61 667	66 896	1504	1 511	386	416
Hitachi	Japan	Hardware	70 439	64 305	730	27	330	331
Matsushita	Japan	Hardware	63 437	60 285	1 139	715	271	276
Hewlett-Packard	United States	Hardware	42 895	47 061	3 119	2 945	122	125
Toshiba	Japan	Hardware	45 635	41 703	554	56	186	186
Fujitsu	Japan	Hardware	37 219	38088	381	43	167	180
NEC	Japan	Hardware	41 858	37 976	757	316	152	152
Compaq[1]	United States	Hardware	24 584	31 169	1 855	–2 743	41	90
Motorola	United States	Data comm	29 794	29 398	1 180	–962	150	133
Mitsubishi	Japan	Hardware	30 787	29 042	70	–809	113	115
Intel	United States	Data comm	25 070	26 273	6 945	6 068	64	65
Ingram Micro	United States	Distribution	16 582	22 034	194	245	12	14
Canon	Japan	Hardware	22 818	21 593	982	837	79	80
Xerox	United States	Hardware	18 144	19 449	1 452	395	92	93
Dell	United States	Hardware	12 327	18 243	944	1460	16	24
EDS	United States	Services	15 236	16 891	731	743	110	120
Microsoft	United States	Software	11 358	14 484	3 454	4 490	22	27
Tech Data	United States	Distribution	7 057	11529	89	129	5	8
Sun Microsystems	United States	Hardware	8 598	9 791	762	763	22	26
Texas Instruments	United States	Data comm	9 750	8 460	1 805	407	44	36
Cisco	United States	Data comm	6 440	8 459	1 049	1 350	11	15
Andersen Consulting	United States	Services	6 647	8 307			53	65
Gateway 2000	United States	Hardware	6 294	7 468	110	346	13	19
UNISYS	United States	Hardware	6 636	7 208	–854	387	33	33
ORACLE	United States	Software	5 684	7 144	821	814	29	37
Seagate	United States	Hardware	8940	6 819	658	–530	111	87
Computer Sciences	United States	Services	5 616	6 601	192	260	42	45
NCR	United States	Services	6 589	6 505	7	122	38	33
Apple	United States	Hardware	7 081	5 941	–1 045	309	10	10
Oki Electric	Japan	Hardware	6 051	5 842	27	–62	21	24
Quantum	United States	Hardware	5319	5 805	149	171	6	6
MicroAge	United States	Distribution	4 379	5 520	25	–8	4	6
3Com	United States	Data comm	5 606	5 420	501	30	14	13
CompUSA	United States	Distribution	4 611	5 286	94	32	14	19
First Data	United States	Services	5 235	5 118	357	466	36	32
ADP	United States	Services	4112	4 798	514	605	30	34
Computer Associates	United States	Software	4 040	4 719	366	1 169	10	11
Merisel	United States	Distribution	4 049	4 553	–16	19	2	3
InaCom	United States	Services	3 896	4 258	29	43	4	6
Bull	France	Services	4 217	4 226	103	3	21	21
Olivetti	Italy	Services	3 882	3 916	9	138	23	17
Western Digital	United States	Hardware	4 178	3 542	268	–290	13	13
Silicon Graphics	United States	Hardware	3 663	3 101	79	–460	11	10
Nihon Unisys	Japan	Services	2 444	2 239	13	14		7
Acer	Chinese Taipei	Hardware	6509	6 717	89	13	23	28
Computer 2000	Germany	Distribution	4 746	..	–41	..	3	..
Digital Equipment Corp.	United States	Hardware	13 047	..	141	..	55	..
Intelligent Electronics	United States	Distribution	558	..	–45	..	2	..
Packard Bell NEC	United States	Hardware	5 000	n.a.	n.a.	–600	8	6
Total			829 232	835 848	40 341	33 768	3 359	3 447

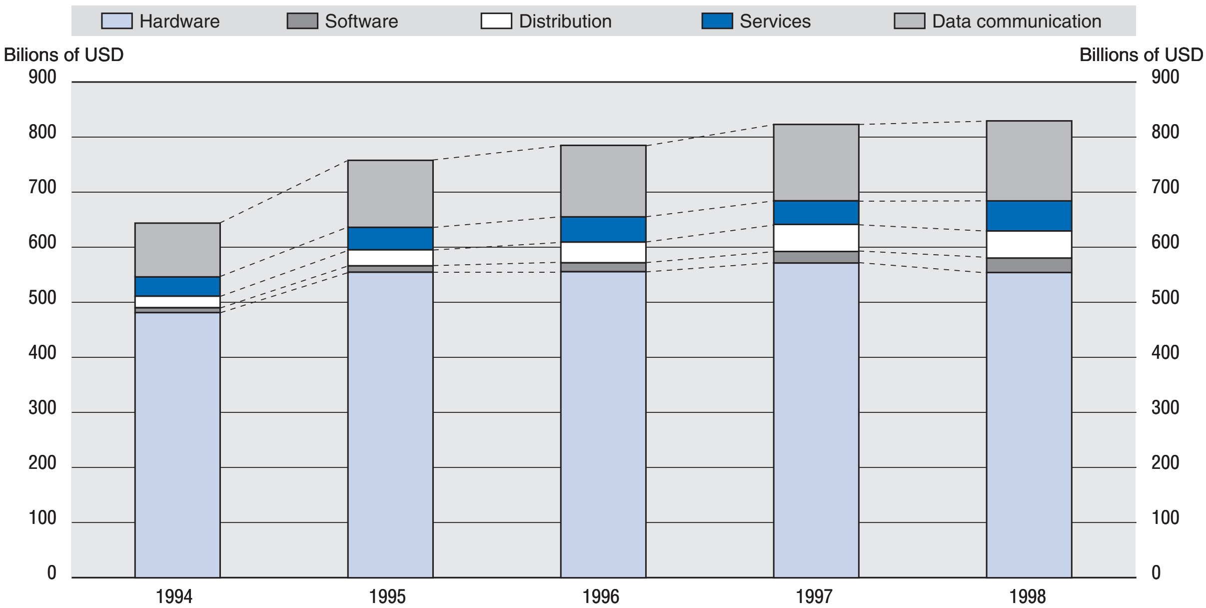
1. Compaq acquired Digital Equipment Corp. in mid-1998. Revenue and income figures reported for Compaq in 1998 do not include those generated by DEC before the merger.

Source: OECD based on annual reports and SEC filings.

vices, particularly Web-based or e-business services (OECD, 1999a). Mergers and acquisitions (M&As) now surpass initial public offerings (IPOs) for large IT transactions (those over USD 50 million, excluding divestitures), a sign that the industry is restructuring (Broadview, 1999). In order to look at the dynamics, a firm-level approach was adopted (see Box 2).

Figure 9 illustrates the breakdown of revenues by segment for this sample of IT firms for which the hardware sector continues to dominate the market. However, despite the fact that hardware firms still retain 66% of total revenues, over the five-year period from 1994 to 1998, their CAGR was only 3.3%. Software, the smallest of the five segments for this group of firms, grew at a rate of 31.6% a year during that time. The slowdown in the hardware market may have been due in part to the Asian economic crisis. Figure 10 shows that, for this sample, Asian firms make up the bulk of the hardware market.

Figure 9. **Total revenues for the top 50 firms[1] by primary IT function**

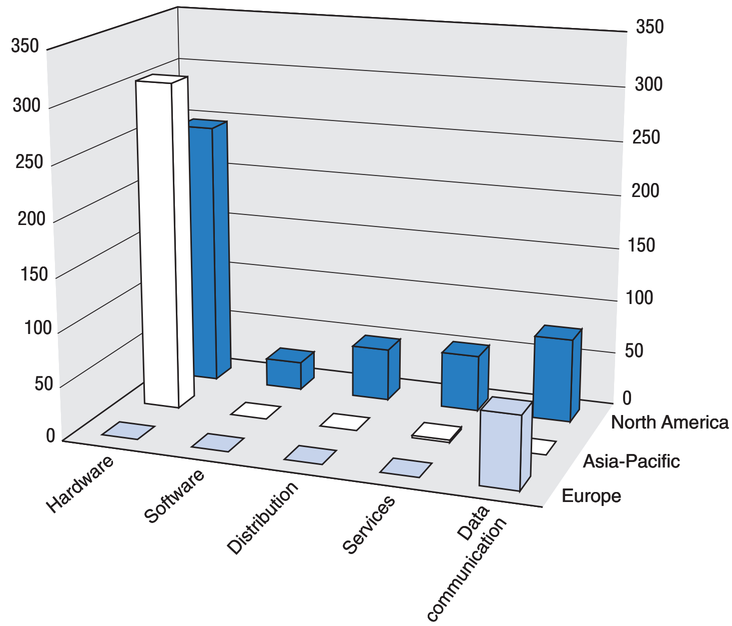


1. Data for 1998 do not include Packard Bell NEC.

Source: OECD, based on annual reports and SEC filings.

Figure 10. **Revenues for the top 50 IT firms by segment and by country of headquarters, 1998**

Billions of USD



Source: OECD.

Table 11. **Major European IT firms**

Company	Country	Year founded	Revenue USD millions		Net income USD millions		Employees Thousands	
			1997	1998	1997	1998	1997	1998
Siemens	Germany	1847	61 667	66 896	1 504	1 511	386.0	416.0
SAP	Germany	1972	3 470	4 811	534	5 981	12.9	19.3
CapGemini	France	1975	3 457	4 397	163	242	31.1	38.3
Bull	France	1933	4 217	4 226	103	3	21.3	20.7
Olivetti	Italy	1908	3 882	3 916	9	138	22.7	17.0
BAAN	Netherlands	1978	680	736	77	–315	4.3	5.1

Source: OECD, based on annual reports.

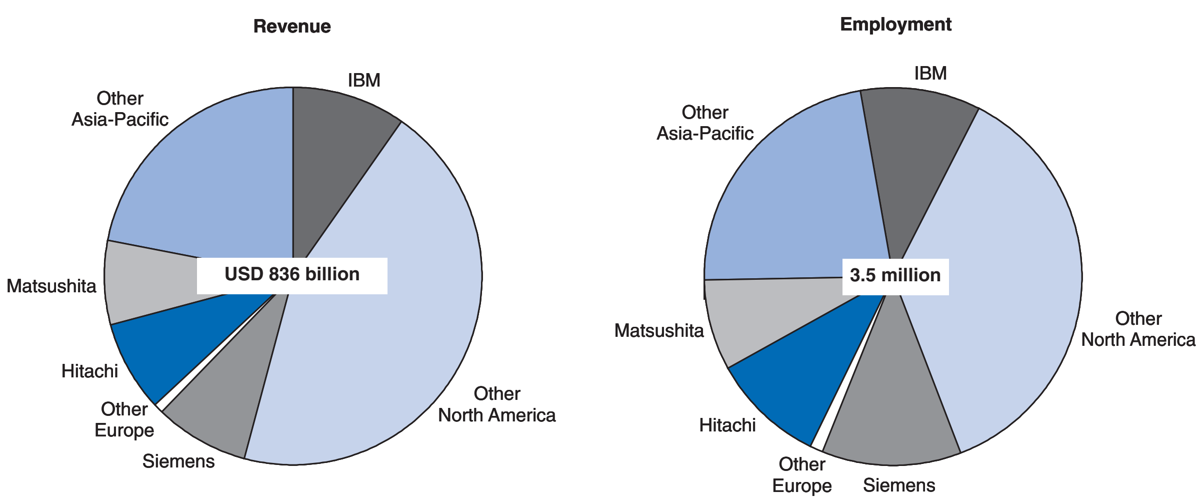
The next largest industry segment is data communications, where Siemens (classified in data communications despite substantial hardware and component activities, as well as other activities) represents almost half. It is the second largest firm in this group of 50 firms and by far the largest European company in the IT market, although data for this company are boosted by its activities in areas other than IT (Table 11).

Currently, revenues from firms that deal mainly in IT services are small compared to other segments. However, as traditional hardware firms begin to use the Internet not only to market their products but also to develop new e-business services, the services segment is likely to expand.

IBM is one of a number of major hardware companies that has started shifting its business focus from hardware to services. According to the GartnerGroup, 46% of IBM's revenues in 2003 will come from this segment. Hewlett-Packard, well known for its PCs, is also expanding its services. In 1998, services, including systems integration, networked systems, Web-based applications, management outsourcing, consulting, education, product financing, rentals and maintenance, accounted for 15% of its overall revenue. As other major hardware firms adapt their business strategies, a more even split between revenues from hardware and from other segments within the IT industry is likely.

Figure 11 highlights the major players in each of the three main regions. IBM represents 10% of the total for this sample and 18% of the North American sample in terms of total revenue. Matsushita and

Figure 11. **Revenue and employment in the top 50 IT firms by geographical area, 1998**



Source: OECD.

Hitachi each account for about 20% of Asia-Pacific revenues in the IT sample and a total of 45% of employees. Both Matsushita and Hitachi, however, had annual growth rates between 1997 and 1998 below the median for the top 50 firms. Growth rates for IBM and Siemens fell just above the median. Disaggregated by geographical area, the median for revenue growth rates in North America from 1997 to 1998 is 9%; in the Asia-Pacific region, overall revenues declined by 7%.

In 1990, the top ten firms in Japan's IT sector had a market capitalisation of USD 380 billion, compared to USD 230 billion in the United States (Broadview, 1999). However, in recent years the weight has shifted considerably: by 1997, the market capitalisation of the top ten US IT firms was USD 915 billion, compared to USD 362 billion for Japanese firms. The difference in market capitalisation between Microsoft and IBM is of interest: Microsoft's revenues in 1998 were still dwarfed by those of IBM by a factor of six but its market capitalisation was almost twice as large.

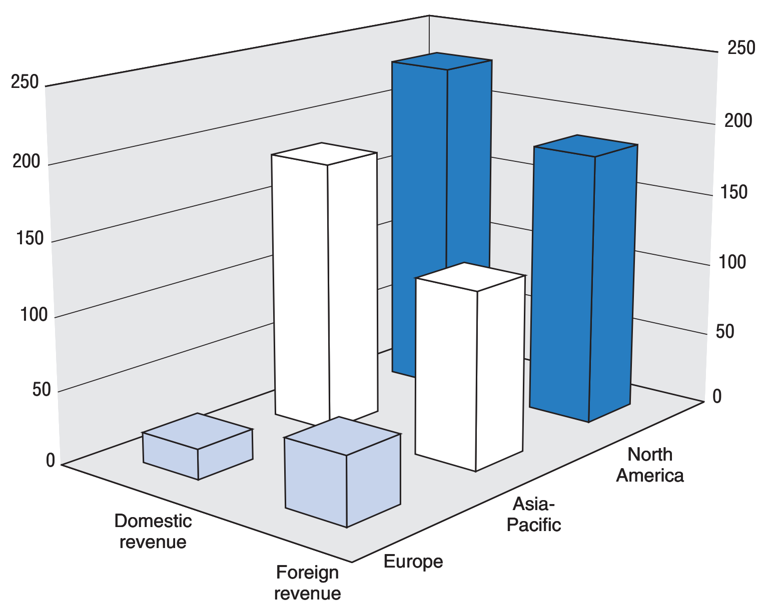
Domestic and foreign markets

When companies' revenue is broken down by domestic and foreign markets, revenue sources vary considerably depending on the location of firms' headquarters (Figure 12). Siemens relies to a large extent on international sales owing to a smaller domestic market than that of the United States and Japan and ease of trading with other EU countries. It is also apparent that companies in the Asia-Pacific region mainly depend on domestic revenues. While North American firms also have a higher share of domestic revenues, the split is more balanced. In 1998, 45% of their sales were foreign, compared to 38% for Asian firms.

An analysis of the breakdown of domestic and foreign revenues by firms' main IT function (Figure 13) shows that data communications is the only segment where foreign revenues surpass domestic ones (because of Siemens). Certain segments lend themselves more easily to doing business at home. When dealing with domestic customers, retail and wholesale distribution benefits from lower sales costs, after-

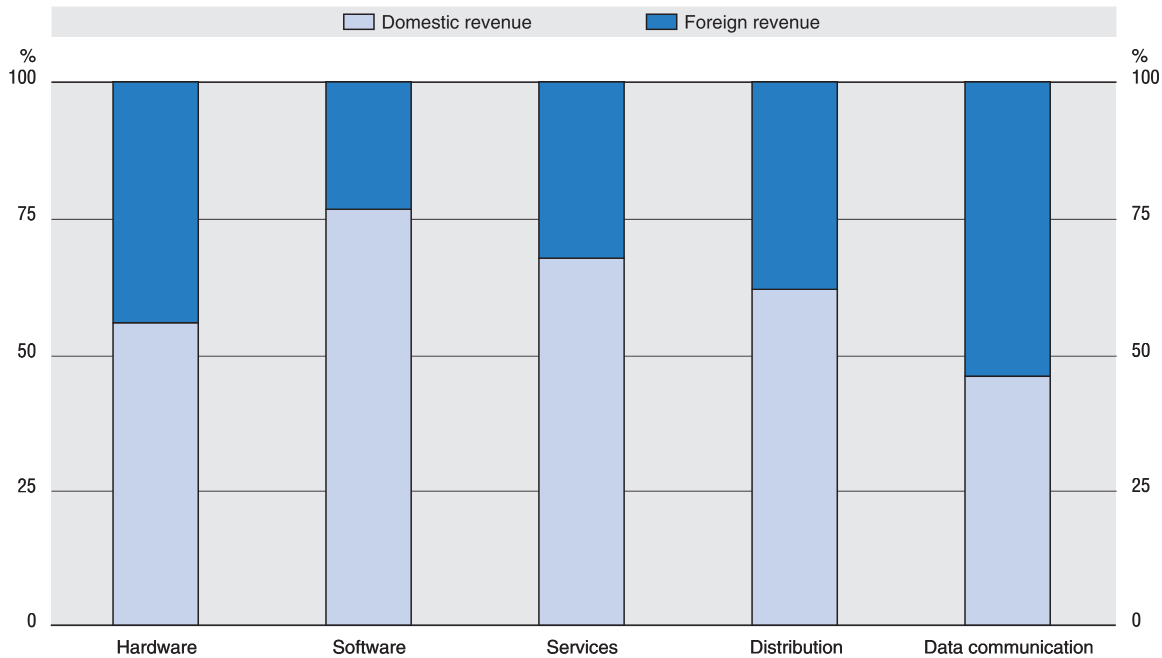
Figure 12. **Revenue breakdown of the world's largest IT firms by domestic and foreign revenue, 1998**

Billions of USD



Source: OECD.

Figure 13. **Breakdown of sales by segment and revenue source, 1998**



Source: OECD.

sales service, customer contact, etc. The software industry also focuses more on domestic sales, and the language used in these products may play a part in keeping revenues from growing internationally. For similar reasons, the services market also has higher domestic than foreign sales.

Research and development

Trends in research and development (R&D) expenditures for the top 50 firms appear fairly stable. Table 12 shows R&D spending by 20 of the top 25 IT firms. The average share of revenue spent on R&D

Table 12. **R&D as a percentage of total revenue for 20 of the top 25 IT firms and R&D growth, 1994-98**

	1994	1995	1996	1997	1998	1994-98 CAGR of R&D expenditure	Main IT function
IBM	5.3	4.7	5.8	5.5	5.5	7.2	Hardware
Siemens	8.9	8.2	7.7	7.6	7.7	2.8	Data communications
Hitachi	6.5	6.5	6.1	5.9	6.1	–4.7	Hardware
Matsushita		5.4	5.9	5.7	6.1	..	Hardware
Hewlett Packard	8.1	7.3	7.1	7.2	7.1	13.4	Hardware
Toshiba				6.0	5.9	..	Hardware
Fujitsu	10.5	9.9	9.2	7.8	7.8	–2.2	Hardware
NEC	7.2	6.9	6.7	6.9	7.7	3.3	Hardware
Compaq	3.6	3.3	3.5	3.3	4.3	31.1	Hardware
Motorola	14.9	15.6	10.6	9.2	9.8	–3.4	Data communications
Intel	9.6	8.0	8.7	9.4	9.5	22.6	Data communications
Canon	6.3	5.8	5.9	6.2	6.3	3.3	Hardware
Xerox	5.9	5.7	6.0	5.9	5.4	3.9	Hardware
Dell	1.1	1.2	1.1	1.2	1.1	51.8	Hardware
Microsoft	13.1	14.5	16.5	16.9	17.0	42.3	Software
Sun Microsystems	10.7	9.5	9.3	9.6	10.4	19.3	Hardware
Texas Instruments	6.7	7.4	11.9	15.8	14.3	20.2	Data communications
Cisco	8.0	9.4	9.7	10.8	12.1	75.9	Data communications
Andersen Consulting					7.1	..	Services
UNISYS			5.4	4.6	4.1	..	Hardware

Source: OECD, based on annual reports and SEC filings.

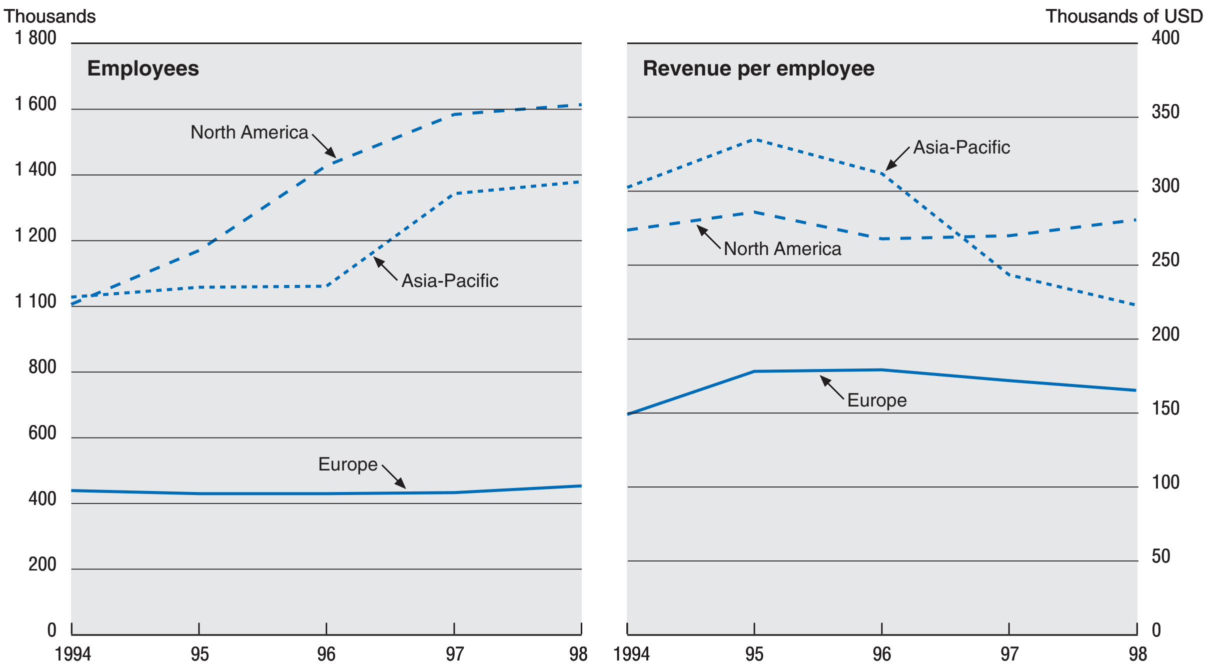
is about 7%. Some companies' spending as a share of revenue dropped slightly between 1994 and 1998, but a number of others showed large increases (see also Table 15).

Microsoft, with the highest R&D spending in terms of revenue at 17.3% in 1998, had a CAGR for R&D of 7% between 1994 and 1998. Much of Microsoft's increased spending in 1998 can be attributed to new development staff and costs of third-party development.

Employment

Figure 14 illustrates the considerable increase in employment rates in the top IT firms in recent years in North America and the Asia-Pacific region. However, productivity, as measured by revenue per employee, has declined sharply in Asia-Pacific firms since 1996. This trend may have largely been due to the Asian economic crisis, which caused both USD revenue declines and labour hoarding in many firms. During the same period, revenue per employee in North America increased only slightly. Figure 15 shows the annual growth rate of revenue per employee between 1996 and 1998 for selected major IT firms.

Figure 14. **Employees and revenue per employee by geographical zone for the top 50 IT firms, 1994-98**



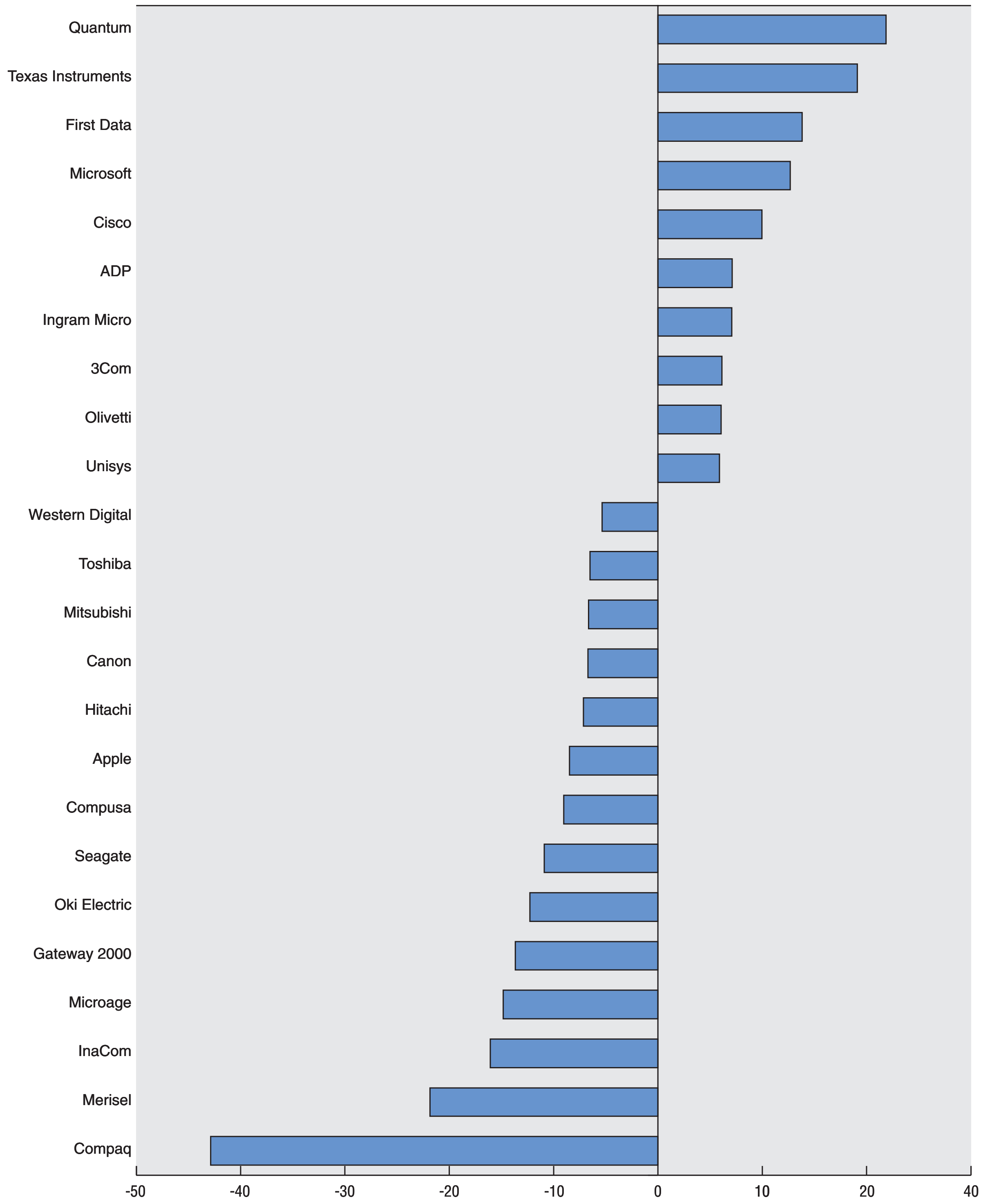
Source: OECD.

Industry restructuring

Figure 16 tracks acquisitions against IPOs to illustrate the tremendous increase in the number of acquisitions over the last five years. Acquisitions have a number of causes. Some transactions enable a company to expand its product or service offering into another area. In other cases, a smaller company may be bought up as a fast track to marketing a new product under development. Another reason is the elimination of competitors; as IT start-ups may eventually pose a competitive threat to the buyer, the larger firm acquires the smaller in its early stages of development, instead of risking a fight for market share.

Figure 15. **Revenue growth per employee from 1996 to 1998 for selected IT companies**

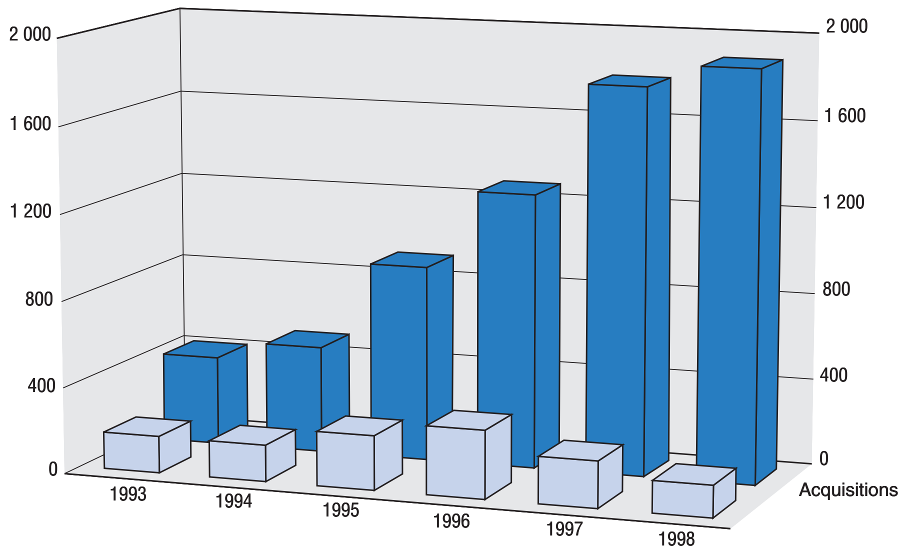
CAGR in percentage



1. Only companies with growth rates greater than 5% or less than -5% are included.

Source: OECD.

Figure 16. **North American acquisitions and IPOs in the IT, communications and media sectors**



1. Acquisitions include private sellers sold in their entirety.
2. The figure includes all reported acquisitions and IPOs, not just those related to the top 50 IT firms.

Source: Broadview (1999).

Mergers and acquisitions can be a reason for declines in productivity as measured by revenue per employee. Typically, after an acquisition, there may be an excess of personnel before restructuring. For instance, the merger of Compaq and DEC in mid-1998 caused a considerable fall in Compaq's revenue per employee figures. In 1997, Compaq had revenue per employee of USD 593 000, whereas DEC's was only USD 238 000. Consequently, Compaq experienced a large decline in revenue per employee immediately following the merger. Prior to that transaction, Compaq merged in 1997 with Tandem, which in 1996 had revenue per employee of only USD 46 000. Despite the potential short-term disadvantages of certain mergers and acquisitions, such transactions are increasingly favoured by firms in the IT industry.

In terms of value of transactions, the telecommunications industry was by far the largest segment with a total of USD 256 billion in 1998 (Figure 17). With this industry's continuing deregulation worldwide, mergers and acquisitions are redefining the structure of the market. In the hardware sector, the three largest North American transactions amounted to more than all 217 European transactions combined. In all, there were 337 North American transactions in the hardware market, down 14% from 1997, but their value rose 8% from the previous year to USD 52.7 billion. The software M&A market remains dominated by US firms. In 1998, there were 446 software transactions in Europe, worth a total of USD 6.8 billion. In North America, 1998 saw 1 076 transactions amounting to USD 49.7 billion. In ICT-support services, Europe outranked North America in 1998 with a total value of transactions of USD 6 billion. With 312 M&As, North America had slightly more than Europe with 301, but a lower value (USD 5.3 billion, down 35% from 1997).

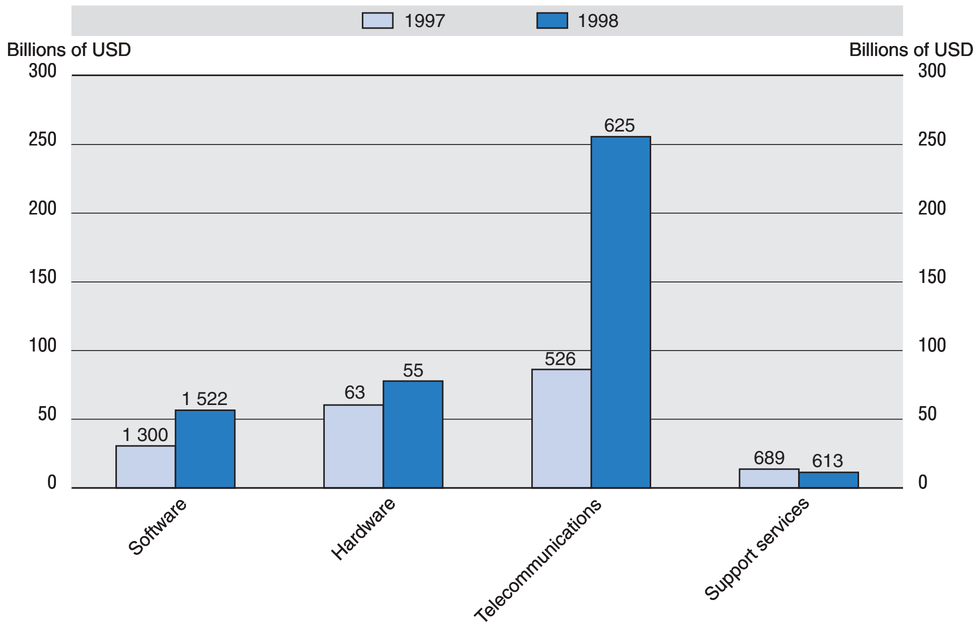
Figure 18 breaks down European transactions in the IT, telecommunications and media sectors by acquiring and target country. The United Kingdom is clearly a major player, in both terms of sales and purchases. The United States is also a major acquiring country for European firms.

Firm-level analysis of these companies suggests that North American firms continue to dominate the sector as Asian IT companies are still recovering from an unfavourable business climate. Although software and services are growing rapidly, hardware is still the largest segment. Rapid industry restructuring is taking place, mostly through M&As, as companies enter new market segments and react to competitive threats.

As expectations about the future impact of ICTs continue to rise and the US stock market continues to outperform even the most optimistic forecasts, investors, driven by prospects of future profits, have been

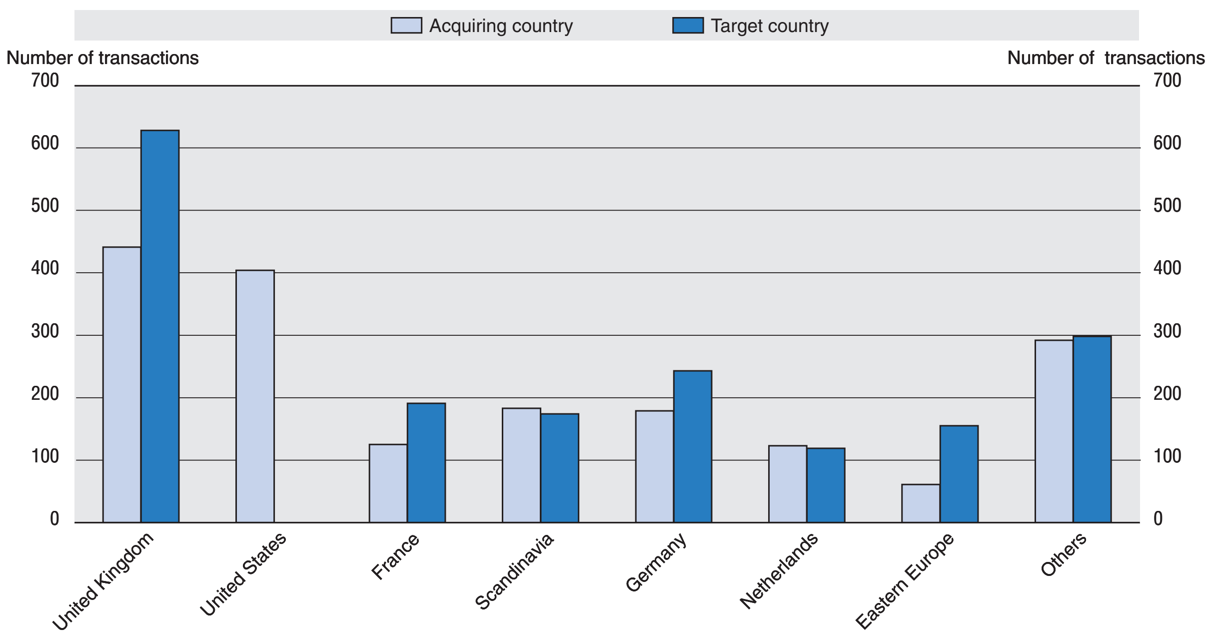
Figure 17. **Mergers and acquisitions by sector in Europe and North America, 1997 and 1998**

Value of transactions in billions of USD and number of transactions



Source: Broadview (1999).

Figure 18. **European mergers and acquisitions in 1998**



Source: Broadview (1999).

Box 3. ICT stocks: "irrational exuberance"?

Yahoo!, eBay and Amazon stocks prices (USD), June 1998-November 1999

ICT and particularly Internet stocks have seen unprecedented growth. In the United States, 35 IPOs of Internet companies were launched during May 1999 alone (www.TheStreet.com). An index created by *Wired*, which comprises 40 companies in various ICT segments, has grown by more than 80% in one year, twice as fast as the Dow Jones, and 70% faster than the NASDAQ composite index. The price-earnings (PE) ratio of the companies in this index averages about 80, while for those in the Standard & Poor's Index (S&P 500), it is around 34 (*Wired*, June 1999).

Yahoo!, eBay and Amazon are three recent examples of Internet companies that have launched IPOs and whose stock prices have seen unprecedented growth owing to high revenue expectations.

On 1 June 1999, eBay's market capitalisation of USD 22.2 billion was 472 times its 1998 revenues. Yahoo!'s capitalisation of USD 30.2 billion was more than one-third Dell's, while its 1998 sales were 90 times smaller. Amazon's (market capitalisation/sales) ratio of 31 was still ten times that of IBM.

Microsoft's capitalisation of almost USD 412 billion made it the world's largest company, a full 24% more than General Electric, the next largest firm by this measure.

Despite these success stories, a recent study by Broadview shows that of the 724 technology companies that went public in the United States in 1992 or later and remained independent, 58% were trading at less than their IPO price in October 1998, with a median annualised return of –10.5% (Crisci and Strausch, 1999).

flocking to ICT stocks. The explosion of online brokerage has rendered trading much more accessible and affordable: in early 1999 there were more than 5 million online brokerage accounts in the United States (*The Economist*, May 1999). Today, 500 000 share trades a day, or one in every six, takes place over the Internet. Box 3 describes the recent boom in high-technology stocks and highlights the potential for substantial market fluctuations due to unreasonable expectations and unprecedented market over-valuations.

Main drivers of ICT growth

The shift towards services

Although the increased use of IT in all sectors is not directly responsible for the gradual shift towards service economies, it has certainly reinforced this structural trend. Services currently account for about two-thirds of GDP in OECD countries (Table 13). As other chapters will show, IT is increasingly used in services sectors, some of which, such as finance and business services, rank very high in terms of IT penetration.

Table 13. **Value added in manufacturing and services as a percentage of GDP in selected OECD countries/regions, 1985 and 1996**[1]

	Manufacturing		Services	
	1985	1996	1985	1996
United States	19.8	17.7	64.2	69.8
Japan	29.5	24.3	61.0	67.6
France (1997)	22.0	19.3	51.6	55.9
EU (1986-93)	24.4	20.8	52.1	57.4
OECD-14 (1985-93)	22.9	19.9	58.5	63.6

1. Or nearest year.

Source: OECD, Main Industrial Indicators (MII) database, May 1999.

R&D and innovation

ICT industries invest extensively in R&D in order to develop increasingly sophisticated products. In 1997, ICT sectors accounted for more than one-quarter of all business R&D in several OECD countries (Table 14), and more than one-third in Ireland and Finland.

In most countries, the R&D intensity of these industries as a whole is significantly higher than the manufacturing average, often twice as high (Figure 19).

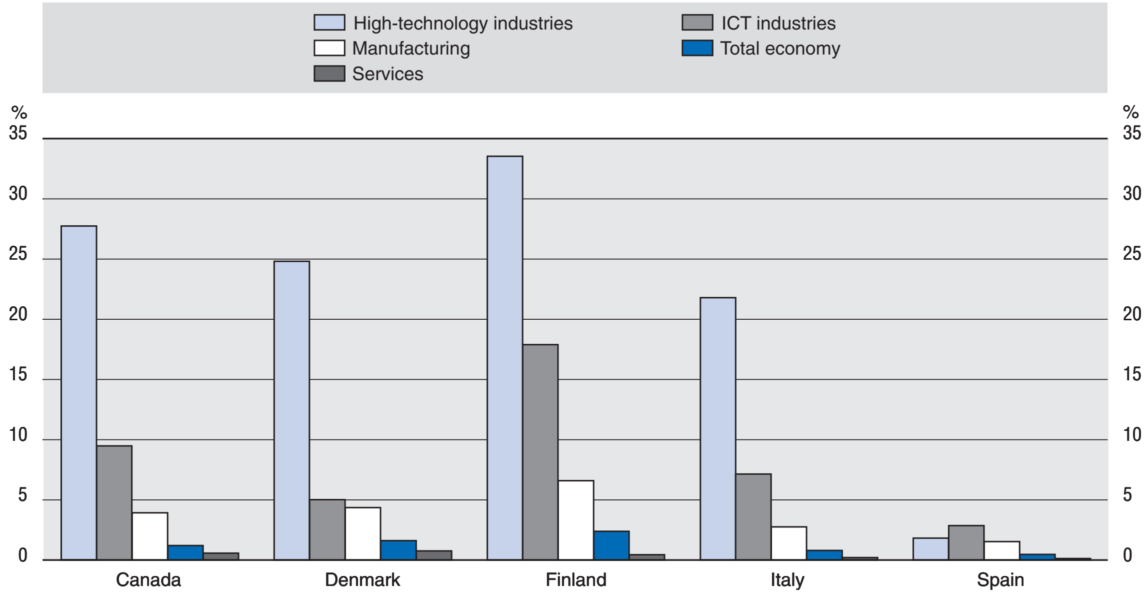
Table 14. **Share of ICT sectors**[1] **in total business enterprise expenditure on R&D (BERD), 1997**

	ICT industries	Communications services
Finland	40.9	4.9
Ireland	35.5	4.3
Canada	28.0	2.1
Japan	26.0[2]	..
France	22.7[2]	..
United States	22.1[2]	..
Sweden	21.3[3]	2.5[3]
Italy	20.9	5.7
Netherlands	16.2[2]	..
Norway	15.2	6.7
Germany	13.9[3]	..
Spain	13.7[2]	4.0[2]
Australia	10.7[4]	..
United Kingdom	10.6	5.2
Denmark	7.2	2.4

1. ICT industries are: Office machinery and computers (ISIC Rev.2 3825) and Radio, TV and communication equipment (ISIC Rev.2 3832). Communications services = ISIC Rev.2 72.
2. 1996.
3. 1995.
4. 1994.

Source: OECD, ANBERD database, August 1999.

Figure 19. **R&D intensity[1] in ICT and other industries (selected OECD countries, 1997 or latest available year)**



1. R&D intensity = Business enterprise expenditure on R&D (BERD) / value added.
Source: OECD, ANBERD database, May 1999.

Firm-level data reveal that ten of the world's top 15 (and seven of the top ten) companies in terms of R&D spending in 1998 (R&D expenditure in excess of USD 3.3 billion) were in the electronics and IT hardware sectors. Table 15, which lists some of the most R&D-intensive companies among large ICT firms, shows that the world's main manufacturers of telecommunication and networking equipment, software, components and hardware continue to make large investments in R&D in order to maintain their competitive positions.

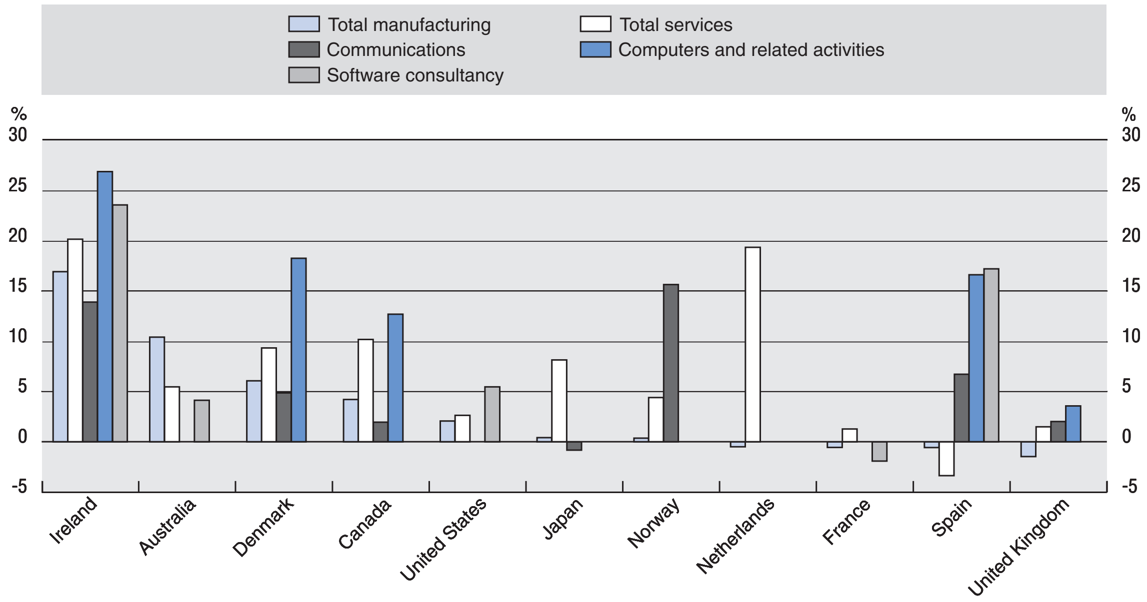
Although R&D intensity in services sectors is quite low on average, R&D in these sectors is still only partially measured in many OECD countries. Available figures show a steady growth in services R&D in all countries (partly owing to improved statistical coverage) and strong growth in some ICT-related services sectors, such as computer and related activities and software consultancy (Figure 20). A significant

Table 15. **Selected R&D-intensive[1] ICT firms, 1998**

	Country	1998 R&D intensity (%)
Advanced Micro Devices	United States	22.3
National Semiconductor	United States	19.0
Microsoft	United States	17.0
ST Microelectronics	France	16.4
Applied Materials	United States	15.9
Ericsson Telefon	Sweden	15.2
Silicon Graphics	United States	14.8
Texas Instruments	United States	14.3
Nortel Networks	Canada	14.0
SAP	Germany	13.3
Lucent Technologies	United States	12.2
Cisco Systems	United States	12.1
Sun Microsystems	United States	10.4
Oracle	United States	10.1

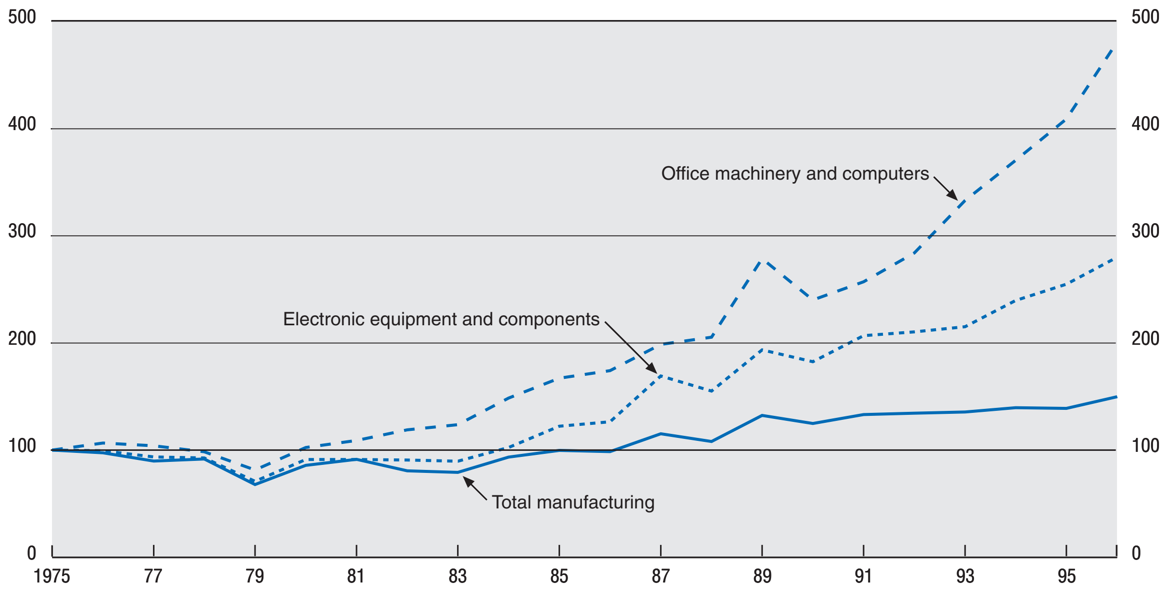
1. R&D intensity is defined as R&D expenditure/sales.
Source: *Company Reporting* (1999) and annual reports.

Figure 20. **R&D growth in selected service industries and total manufacturing, 1990-97**
CAGR



Source: OECD (1999*b*).

Figure 21. **Patenting[1] in manufacturing and ICT-goods sectors, 1975-96**
Index: 1975 = 100



1. Patenting refers to the number of patents granted by the US Patent and Trademark Office (USPTO) to inventors from all OECD countries.
Source: OECD, ANPAT database, May 1999.

portion of R&D in many services sectors (including sectors not directly related to ICT) can be attributed to software development activities.

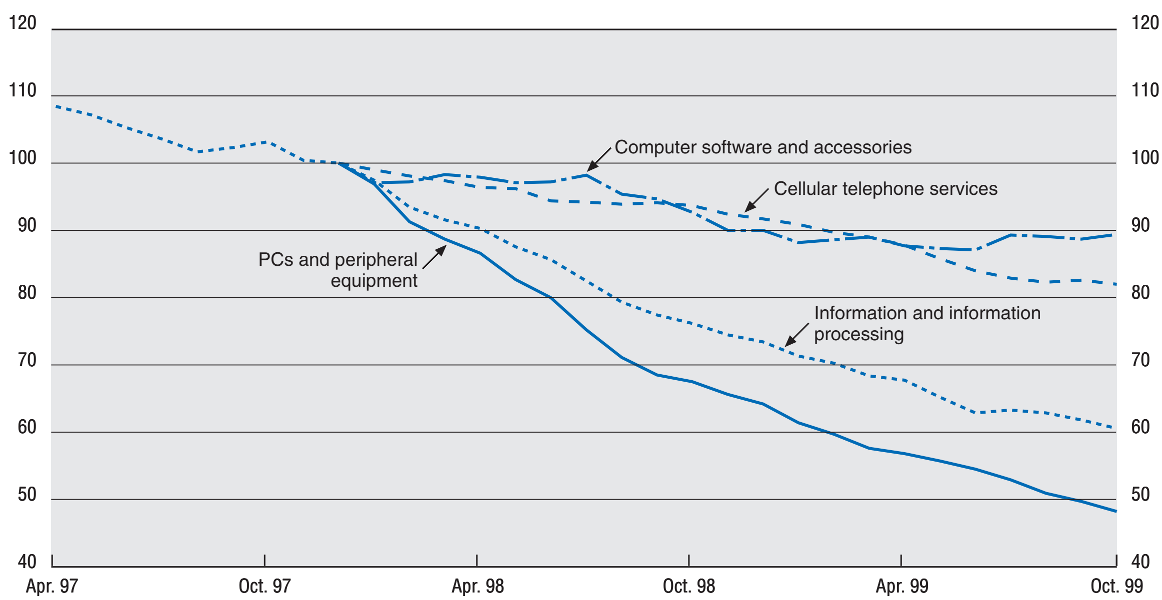
Patenting activity is another useful indicator of innovative activity. Figure 21 compares growth in patenting by two ICT manufacturing sectors to that of the manufacturing sector as a whole. As can be seen, the office machinery and computers sector has seen the fastest growth, more than three times the manufacturing average. Although patents from ICT sectors still represent a small share of all manufacturing patents, their importance has been increasing: in 1996, one in four industrial patents came from these two sectors, compared to only 13% in 1980. For both sectors, growth is mainly driven by the United States and Japan, which in 1996 accounted for over 80% of worldwide patents in these sectors.

Costs and prices

As prices continue to drop sharply, computers become more and more affordable for both businesses and consumers. The US quality-adjusted index for computers shows a drop of almost 90% in (producer) prices of personal computers (PCs), workstations and laptops over a six-year period, compared to a decline of 40% for large-scale computers. More recent data on US consumer prices for various ICT goods and services confirm the sharp decline in the cost of both PCs and information processing services. These dropped by 43.2% and 32.3%, respectively, over the last two years. Figure 22 shows that prices of software and cellular telephony services declined at a much slower pace.

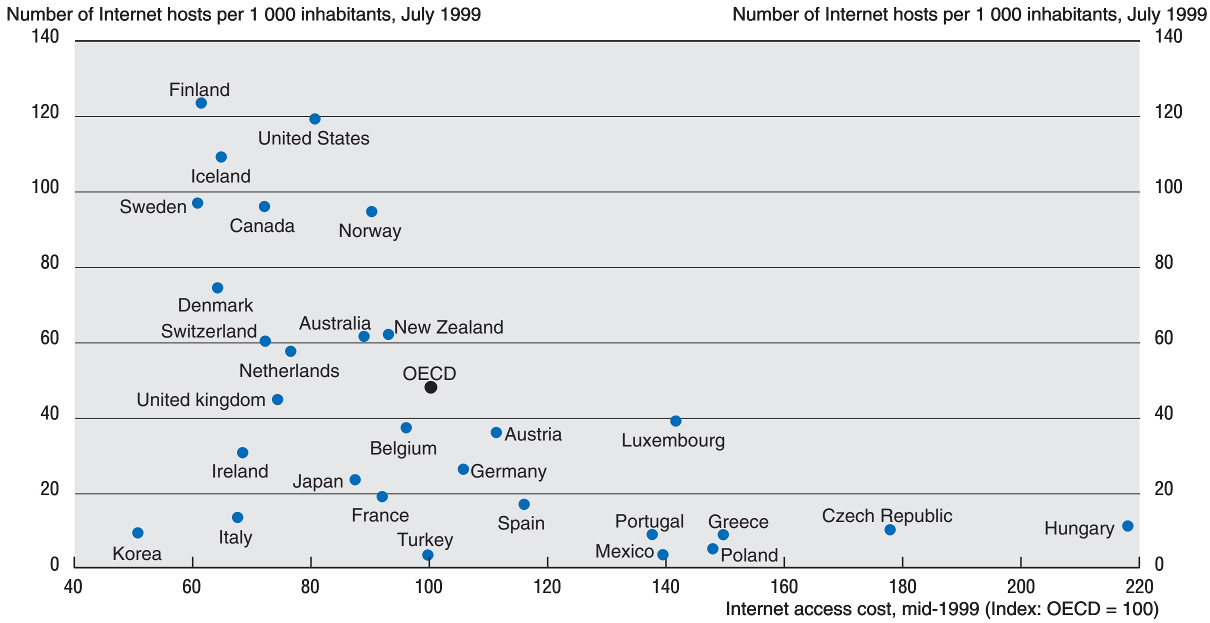
Likewise, communication costs and those of Internet service provider (ISP) subscriptions continue to fall, resulting in more affordable access to the Internet for households. Although cost is not the only factor to influence uptake, countries with relatively high Internet host density also tend to have lower access costs (Figure 23). The Nordic countries, the United States and Canada are the leading nations in terms of Internet host density, with 8 to 12 hosts for every 100 inhabitants. Some OECD countries con-

Figure 22. **US consumer price index for selected ICT equipment and services,[1] 1997-99**
Index: December 1997 = 100 (not seasonally adjusted)



1. Information and information processing does not include telephone services.
Source: US Bureau of Labor Statistics (BLS), November 1999.

Figure 23. **Internet access costs[1] and Internet host density,[2] 1999**



1. The Internet access cost index is based on the 20 hour/month peak rate Internet basket as calculated by the OECD. See OECD (1999*c*) and <http://www.oecd.org/dsti/sti/it/cm>.
2. In addition to country domains (.fr for France, .uk for the United Kingdom, etc.), Internet hosts also include generic top-level domains (gTLDs) such as .com and .org which have been redistributed to countries based on registrations.

Source: OECD (1999*c*) and OECD calculations based on Internet Software Consortium (ISC) data.

tinue to have a low number of Internet hosts (less than 20 per 100 inhabitants) despite relatively low access costs.

While residential users connect to the Internet mainly via dial-up connections, leased lines are the preferred mode of access for businesses. A recent OECD study on the cost of leased lines provides an overview of capacity and pricing trends for the most commonly used infrastructure for business-to-business electronic commerce (OECD, 1999d). As traffic and capacity sales increase at an unprecedented rate, competition is beginning to arise, and markets for buying and selling capacity are undergoing radical changes. For example, the price of a 2 Mbit/s link between Paris and London at Band-X, a new online bandwidth trading market, plunged almost one-third between October 1998 and February 1999 owing to the emergence of new competitive networks.

Trade and regulatory background

The on-going process of trade liberalisation has contributed to the development of worldwide ICT markets. In December 1996, 28 countries or territories members of the WTO signed the Information Technology Agreement (ITA) to eliminate tariffs on semiconductors, computer equipment, software and other communication products by the year 2000. The ITA requires signatory countries to incorporate the tariff cuts into both their General Agreement on Tariffs and Trade (GATT) 1994 schedule of commitments and their standard tariff schedule used by importers and exporters. By April 1999, the ITA had 31 participants covering about 93% of world trade in IT products. Follow-up discussions (ITA II) were launched in September 1997 and include an extended list of products as well as non-tariff barriers (*e.g.* standards-related barriers).

The deregulation of telecommunication markets (services and equipment) that took place during the 1990s has greatly contributed to the development of ICT sectors and to the rapid diffusion of the

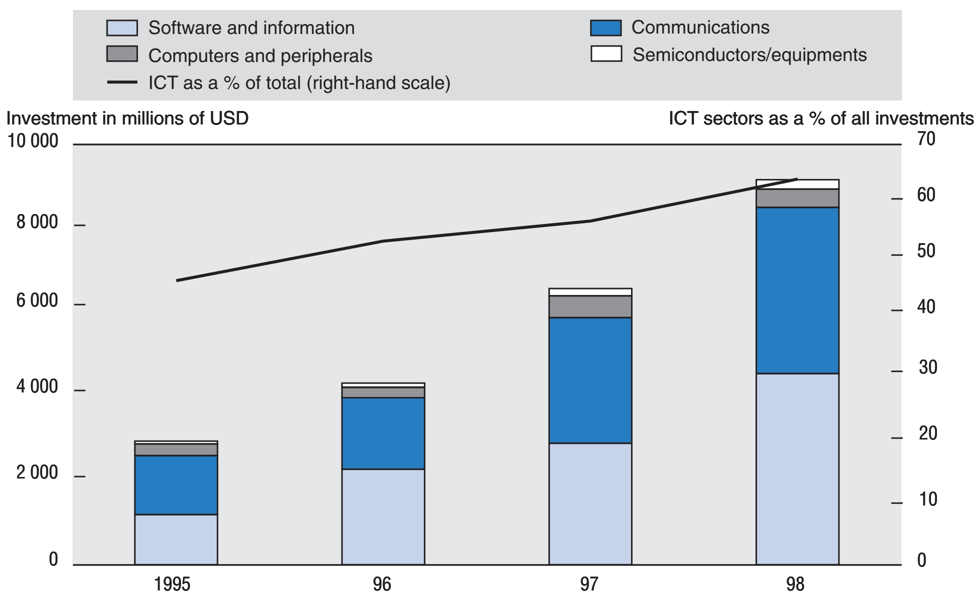
Internet. The gradual disappearance of monopolies granted to public telephony operators (PTOs) has also facilitated the emergence of value-added suppliers that provide information services (OECD, 1999). Within the sector, Internet access is generating new demand for four main categories of services: *i*) longer calls; *ii*) second residential lines; *iii*) higher-speed, high-quality services (*e.g.* ISDN); and *iv*) leased lines. New markets are also appearing for faster and wider Internet access, improved Web content hosting, expanding private intranets and extranets, as well as for the development of a global infrastructure for electronic commerce (electronic payment, authentication, etc.).

Venture capital

Investment in ICT companies continues to grow rapidly: software investments in the United States reached USD 4.6 billion in 1998, while those in Internet-related companies (including Internet software) totalled USD 3.5 billion (PricewaterhouseCoopers, 1999*a*, 1999*b*). The amount invested in ICT sectors has grown at an average annual rate of more than 45% since 1995 and now accounts for almost two-thirds of all venture capital investments (Figure 24).

Figure 24. **Venture capital investment in ICT sectors in the United States, 1995-98**

Millions of USD and percentage of all investments

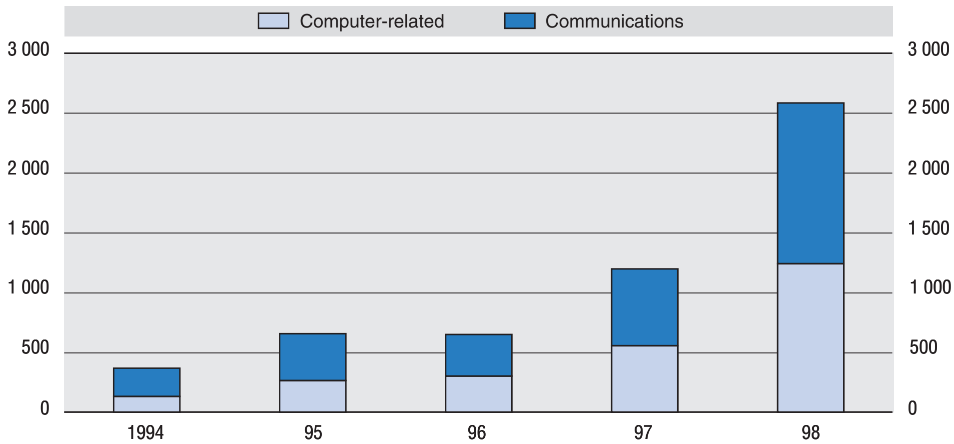


Source: PricewaterhouseCoopers (1999*c*).

In Europe in 1998, ECU 2.6 billion of venture capital were invested in ICT firms, compared to ECU 1.2 billion in 1997 (Figure 25). Communications accounts for the largest share of investments (ECU 1.2 billion in 1998). Software is the second largest segment, accounting for over ECU 1 billion in 1998. There is some variation among countries: in Italy, Norway, Portugal and the United Kingdom, communications was the largest sector, while in Belgium, France, Germany, Ireland, the Netherlands and Spain, it was software.

Figure 25. **Investments in ICT companies in Europe, 1994-98**

Millions of ECU



1. Investments include all private equity and venture capital stages. Private equity includes venture capital, replacement capital and buy-outs. Venture capital includes seed, start-up, other early stage, expansion, bridge finance and rescue/turnaround.
2. "Computer-related" includes hardware, software, Internet and semiconductors.
3. The US and European figures are not strictly comparable owing to differences in classification of venture capital and differences in sectoral coverage.

Source: PricewaterhouseCoopers (1999*c*).

High-growth segments

The software and services sectors continue to be major drivers of industry growth. Within these sectors, communications and networking software are the fastest-growing segments, mostly owing to the booming Internet market (Soft•letter, 1999). Sales of network infrastructure software, including LAN networking, client-server applications and PC-to-mainframe interfaces, continue to grow rapidly. Chapter 3 examines in more detail the emergence of the so-called "Internet economy" and the varying degrees of readiness of OECD economies to embrace the on-going e-commerce revolution.

Contribution of IT to economic growth

As firms in all sectors continue to invest massively in IT, the impact is likely to begin to appear at economy-wide level. The rapid diffusion of IT in individual firms has transformed the organisation of value-added chains, affecting all business aspects from design to distribution and resulting in more efficient production and sales processes. Information and telecommunication networks have become essential tools in global business.

In terms of contribution to economic growth, the overall impact of these technologies is still hard to quantify. Recent econometric analyses from the United States show that because the stock of computer capital is quite small compared to the size of the economy, the impact of computer spending on output growth remains modest and difficult to measure at the macroeconomic level (Moulton, 1999; Haltiwanger and Jarmin, 1999) (Box 4). However, as investment in computers continues to grow and firms adapt their processes to these new technologies, productivity gains can be expected. Indeed, firm-level productivity data reveal that IT has a positive impact on marginal output, although this is highly dependent on factors such as organisational change (Brynjolfsson and Hitt, 1996, 1998; Brynjolfsson and Yang, 1996; OECD, 1998*b*, Chapter 11).

Box 4. Estimating the contributions of computer equipment to output growth

A growth accounting framework can be used to estimate the role of investment in computer equipment on economic growth (Oliner and Sichel, 1994). Under certain restrictive assumptions, the contribution can be estimated using the following formula:

$$\begin{pmatrix} \text{Contribution of} \\ \text{computing} \\ \text{equipment} \end{pmatrix} = \begin{pmatrix} \text{Income share of} \\ \text{computing} \\ \text{equipment} \end{pmatrix} * \begin{pmatrix} \text{Growth rate of the} \\ \text{real capital stock of} \\ \text{computing equipment} \end{pmatrix}$$

Using this method, Haimowitz (1998) estimates that for the United States, computing equipment contributed 0.38 of a percentage point to output growth during 1992-96, compared to 0.20 during 1987-91. Despite the increase, the relative share of computers in total growth actually declined slightly from 0.114 to 0.106 during the same periods. Haimowitz's estimate of a contribution of 0.31 over the period 1972-96 is well below that of researchers using different assumptions, including integrating the effects of externalities (Romer) and allowing for higher nominal net returns from computers than from other capital assets (Brynjolfsson and Hitt). Under these alternative assumptions, Romer estimates a contribution ranging from 0.48 to 0.60 of a percentage point for 1992-96, while Brynjolfsson and Hitt estimate a contribution of 0.45 of a percentage point for the same period (Haimowitz, 1998).

Using a similar framework and more recent data, Sichel (1999) compares the relative contributions to growth of computer hardware and other capital. He concludes that the share of total growth contributed by computer equipment relative to other capital was five times as important in 1996-98 than in 1970-79, and more than twice what it was in 1980-89. He also notes that the rapid spread of IT throughout the economy can be seen as playing an important role in the strong contribution of multifactor productivity (MFP) to output growth during 1996-98. Most observers predict that as IT diffusion continues and firms learn to use these technologies more efficiently, larger productivity gains will be realised (Licht and Moch, 1999).

Recent OECD calculations for the G7 countries show that overall, the contribution of ICT capital to output growth has been significant and rising in relative terms, particularly in the United States, the United Kingdom and Canada, where it accounted for over one-half of the total growth contribution of fixed capital during 1990-96 (OECD, 1999*e*).

Case studies at sectoral and firm level suggest that significant positive rates of return from computer investments are beginning to be observed, although measurement problems are still a major obstacle. Measuring what constitutes IT inputs, how to assign real (quality-adjusted) values to these inputs, how to accurately measure outputs (particularly in services sectors) and how to measure qualitative improvements (such as timeliness, flexibility, accuracy, customisation, etc.) are all important concerns for adequate productivity estimates (Triplett, 1999; NSF, 1998).

Conclusion

As the ICT industry continues to grow in importance and its products continue to diffuse throughout all sectors of activity, the "Internet economy" begins to take shape (US DOC, 1998 and 1999; PPI, 1998). The United States estimates that between 1995 and 1998, IT-producing industries contributed on average 35% of real economic growth (US DOC, 1999). In Canada, the contribution of the ICT sector to growth in 1996-97 was 19.3% (Industry Canada, 1999). In France, IT sectors are estimated to have contributed 15% to real GDP growth in 1998 (INSEE, 1999) [for a more detailed analysis, see Annex 1 (Statistical Profiles) for a selection of OECD countries].

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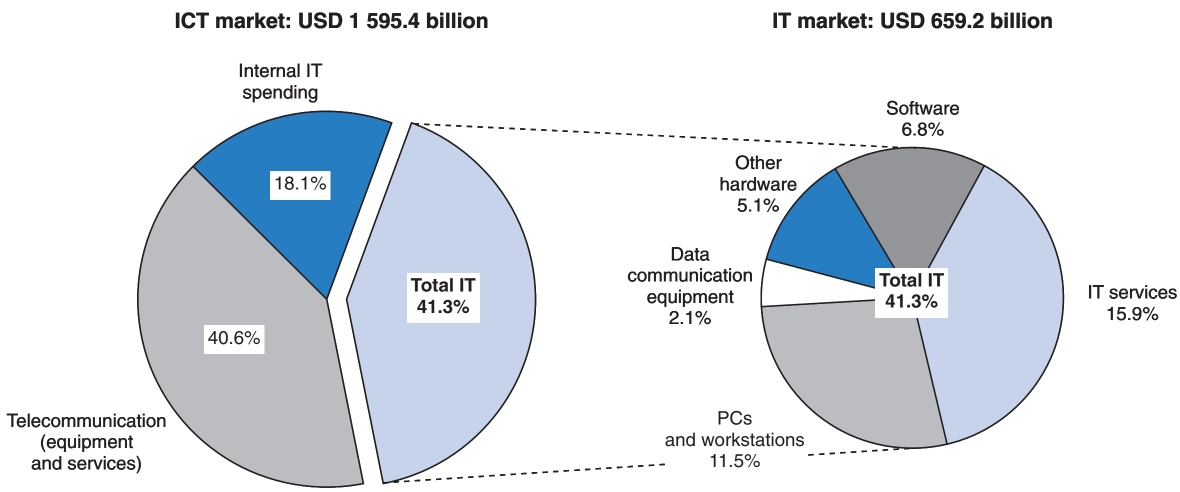
Chapter 2

INFORMATION TECHNOLOGY MARKETS

This chapter examines the main trends in the three segments of the IT industry: *i*) hardware; *ii*) packaged software; and *iii*) services. These categories differ from those used in Chapter 1 in the following ways: *i*) telecommunications expenditure is not included; and *ii*) software and services are examined separately and do not include internal IT spending (see Annex 2 for the methodology followed). The changing dynamics of IT markets in OECD countries during the 1990s are described at a finer level of detail than in Chapter 1. The chapter focuses on IT markets within the OECD which accounted for 41% of OECD ICT markets, slightly more than telecommunication equipment and services markets together (Figure 1).

Figure 1. **Breakdown of OECD ICT and IT markets, 1997**

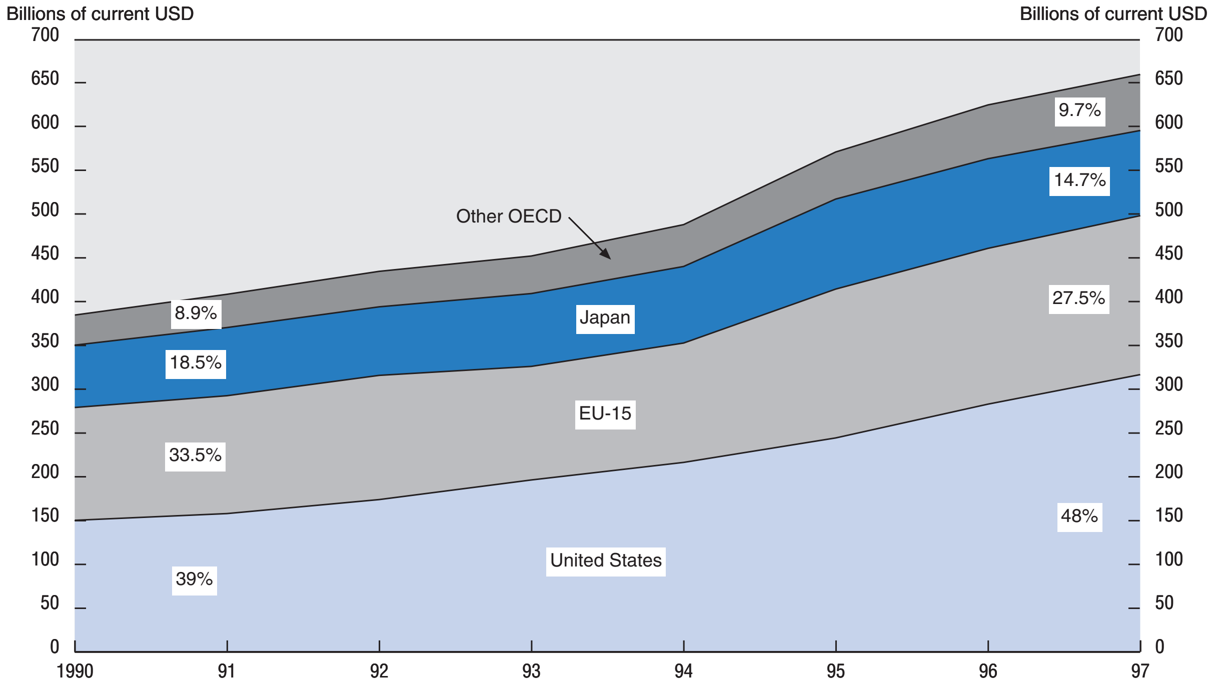


Source: OECD, based on IDC and WITSA.

The OECD IT market: an overview

Between 1990 and 1997, the OECD IT market has grown at an average annual rate of 8% (in current USD) and was valued at USD 659 billion in 1997, accounting for 92% of the world IT market (against 94% in 1990). It remains highly concentrated, with a share of more than 86% of the OECD total in the G7 countries in 1997, a slight increase from 84% in 1990. The United States has been the main driver of the IT market, with one of the strongest growth rates among OECD countries during the 1990-97 period (after Poland, Hungary and Korea). The United States accounted for almost half of the OECD IT market in 1997 (48%), against only 39% in 1990. Canada and the United Kingdom have also shown strong growth. In contrast, France and Japan grew at only around one-half of the average OECD rate, while Italy showed almost no growth in current terms (Figure 2; Table 1).

Figure 2. **OECD IT market by region/country, 1990-97**



Source: OECD, based on IDC data.

The most noticeable change in IT markets is the slow decline of hardware, with very different trends in its main components. The vigorous growth of single-user systems (with a compound average growth rate of 11.6%) has been offset by the decline of other categories (multi-user systems). However, between 1990 and 1997 the most dynamic growth rate of all IT segments has been in data communication equipment, with the rising importance of networking. With an average growth rate of more than 18% a year, its share of the overall OECD IT market doubled to reach 5% in 1997. Software and services together constituted the major part of OECD IT markets between 1990 and 1997, accounting for almost 55% in 1997 due to the strong growth of software (CAGR of 11.2%) (Figure 3; Table 1).

Hardware

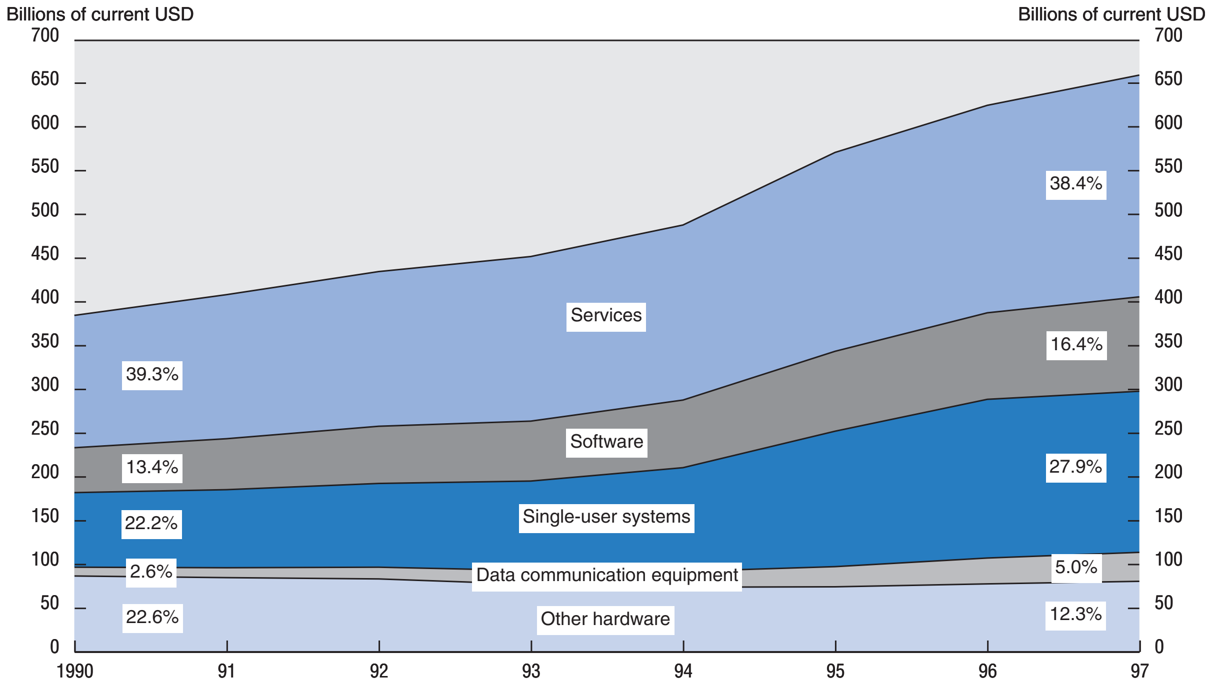
The information technology hardware market in the OECD area was valued at USD 298 billion in 1997, with annual growth averaging 7.3% since 1990. Growth continues to be mainly driven by PCs and workstations, and to a lesser extent by data communication equipment (Figure 4). Growth in this last segment, which has seen its share of the hardware market double from 5.5% to 11.1% over the period, partly reflects increasing use of computer networks[1] and the Internet. The share of PCs and workstations in the

Table 1. **IT market in selected OECD countries, 1990 and 1997**

		1990						1997						
	1997 Level (USD billion)	Breakdown (as a percentage of total market)						Breakdown (as a percentage of total market)						1990-97 CAGR (%)
		Hardware				Packaged software	IT services	Hardware				Packaged software	IT services	
		Multi-user systems	Data comm. equipment	Single-user systems	Total hardware			Multi-user systems	Data comm. equipment	Single-user systems	Total hardware			
United States	316 634	17.2	3.5	22.6	43.4	15.8	40.8	10.0	5.5	28.3	43.8	17.1	39.2	11.2
Canada	20 276	17.6	2.6	27.3	47.6	11.2	41.2	9.8	3.7	26.9	40.5	16.9	42.6	9.5
Mexico	3 720	34.5	1.7	33.3	69.5	8.4	22.2	12.8	5.5	42.7	60.9	11.5	27.6	9.8
Japan	97 233	38.3	2.1	11.3	51.8	6.8	41.5	18.4	3.4	26.7	48.5	10.8	40.7	4.6
Australia	11 611	22.7	4.9	28.2	55.8	13.3	30.9	9.2	9.4	31.1	49.7	17.4	32.9	8.0
New Zealand	1 874	26.4	4.5	16.3	47.2	14.7	38.1	8.7	5.9	28.9	43.5	23.3	33.2	8.7
Korea	9 415	24.6	4.3	40.2	69.2	4.0	26.8	12.5	7.6	59.3	79.3	7.7	13.0	13.7
Austria	4 087	24.8	1.2	24.1	50.2	12.9	36.9	13.5	4.0	28.7	46.2	17.2	36.6	6.4
Belgium	5 621	21.6	1.3	22.1	45.0	20.9	34.2	14.3	4.7	24.3	43.3	23.4	33.3	4.6
Czech Republic	1 459	22.3	2.5	31.5	56.4	10.2	33.4	10.1	7.4	34.9	52.3	13.1	34.6	11.0
Denmark	4 547	20.1	2.3	29.4	51.7	12.3	35.9	11.1	4.3	30.9	46.3	14.4	39.3	5.3
Finland	3 097	11.1	2.0	46.7	59.7	11.4	28.9	12.5	7.1	32.3	52.0	13.5	34.5	0.6
France	33 425	18.9	1.6	24.0	44.6	11.9	43.5	11.5	3.1	20.8	35.4	16.9	47.7	4.9
Germany	43 662	18.7	1.2	24.3	44.3	14.0	41.7	14.5	4.6	25.6	44.8	18.8	36.4	6.2
Greece	889	11.4	3.9	32.8	48.1	10.3	41.6	16.3	2.6	33.3	52.3	13.4	34.4	10.2
Hungary	956	12.2	4.0	33.0	49.1	16.1	34.7	12.0	6.7	31.7	50.3	16.8	32.9	12.8
Ireland	1 166	2.4	0.9	68.8	72.1	7.2	20.7	13.1	2.6	37.0	52.7	15.1	32.2	0.0
Italy	16 432	25.1	0.9	20.8	46.8	17.4	35.8	14.2	3.2	21.3	38.6	19.1	42.3	0.7
Netherlands	9 852	20.1	2.0	27.7	49.8	15.1	35.1	12.2	5.9	29.2	47.3	22.9	29.7	5.4
Norway	4 037	14.9	2.3	33.0	50.1	13.3	36.5	10.1	4.8	32.6	47.5	14.6	37.9	6.3
Poland	1 784	21.6	4.8	45.2	71.7	10.7	17.5	9.9	7.5	45.8	63.2	12.8	24.0	15.2
Portugal	1 168	6.7	3.3	35.0	45.0	14.6	40.4	21.5	2.0	31.9	55.4	13.5	31.1	9.7
Spain	6 984	22.6	1.3	27.9	51.7	14.8	33.5	15.6	4.8	31.0	51.4	14.9	33.8	0.8
Sweden	8 216	19.6	1.4	30.0	51.1	10.1	38.8	10.2	5.2	31.0	46.4	11.5	42.2	1.6
Switzerland	7 702	20.4	1.2	28.6	50.2	18.6	31.2	13.0	3.7	26.2	42.9	19.3	37.9	6.7
United Kingdom	42 213	22.0	3.0	24.3	49.3	17.3	33.4	14.3	6.1	26.0	46.4	20.8	32.8	8.0
Turkey	1 173	70.5	2.6	15.4	88.5	4.0	7.4	16.7	12.8	42.7	72.1	12.0	15.8	7.7
OECD 27	659 232	22.6	2.6	22.2	47.4	13.4	39.3	12.3	5.0	27.9	45.2	16.4	38.4	8.0

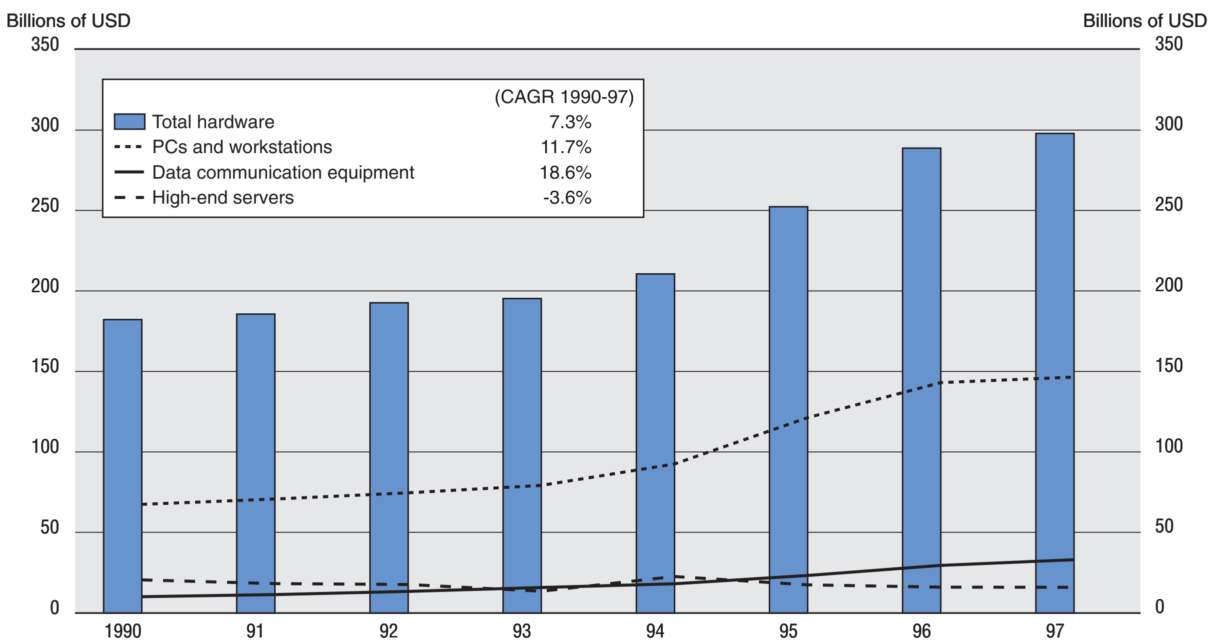
Source: OECD, compiled from IDC data.

Figure 3. **OECD IT market by segment, 1990-97**



Source: OECD, based on IDC data.

Figure 4. **Contribution of high-end servers, data communication equipment, and PC workstations to total OECD area hardware spending, 1990-97**



Source: OECD, based on IDC data.

hardware market has either remained stable or increased significantly in most OECD countries, with the exception of Finland, Ireland and Portugal, where their share was already very high in 1990. Nevertheless, the relative decline in these countries has been partly compensated by the strong growth of the PC server market. In the 27 OECD countries for which data are available, the average share of PCs and workstations jumped from 37% to 49% of the total hardware market during 1990-97, a significant increase of 12 percentage points. It is worth noting that differences among countries in terms of the relative share of PCs and workstations are narrowing: the gap between the highest and lowest shares fell from more than 70 percentage points in 1990 to less than 20 points seven years later.

The progression of small computer systems, mainly PCs, is also reflected in the number of units shipped worldwide every year since 1993 (Table 2). PCs are increasingly shipped towards Asia (one out of every five in 1998). In China, the number of PCs sold has doubled every two years since 1994 and reached over 4% of the world total in 1998. However, the United States remains the main driving force in PC market growth. In 1998, four out of every ten PCs shipped worldwide were sold in the United States. Overall, the strong increase in the total number of PCs shipped results from a combination of continued efforts by firms to upgrade equipment and increased demand from households (see Chapter 3).

Table 2. **Worldwide PC shipments by destination, 1993-98**

Million units

	1993	1994	1995	1996	1997	1998[1]	CAGR 1993-98 %
United States	15.1	18.7	23.0	26.5	31.5	36.3	19.2
Western Europe[2]	10.8	12.7	14.9	16.1	18.4	22.3	15.6
Japan	2.5	3.5	5.8	8.4	7.9	7.9	25.9
Rest of Asia-Pacific[3]	3.2	5.1	6.4	8.1	10.5	10.5	26.5
Rest of the world	7.6	7.3	8.5	9.9	11.9	13.0	11.3
Of which: China	0.5	1.1	1.5	2.1	3.0	3.9	54.2
Total world	39.2	47.2	58.7	69.1	80.3	90.0	18.1

1. 1998 estimated.
2. Austria, Belgium, Denmark, Finland, France, Germany, Italy, Netherlands, Norway, Spain, Sweden, Switzerland and United Kingdom.
3. Australia, China, Hong Kong (China), India, Indonesia, Korea, Malaysia, New Zealand, Philippines, Singapore, Chinese Taipei, Thailand.

Source: IDC.

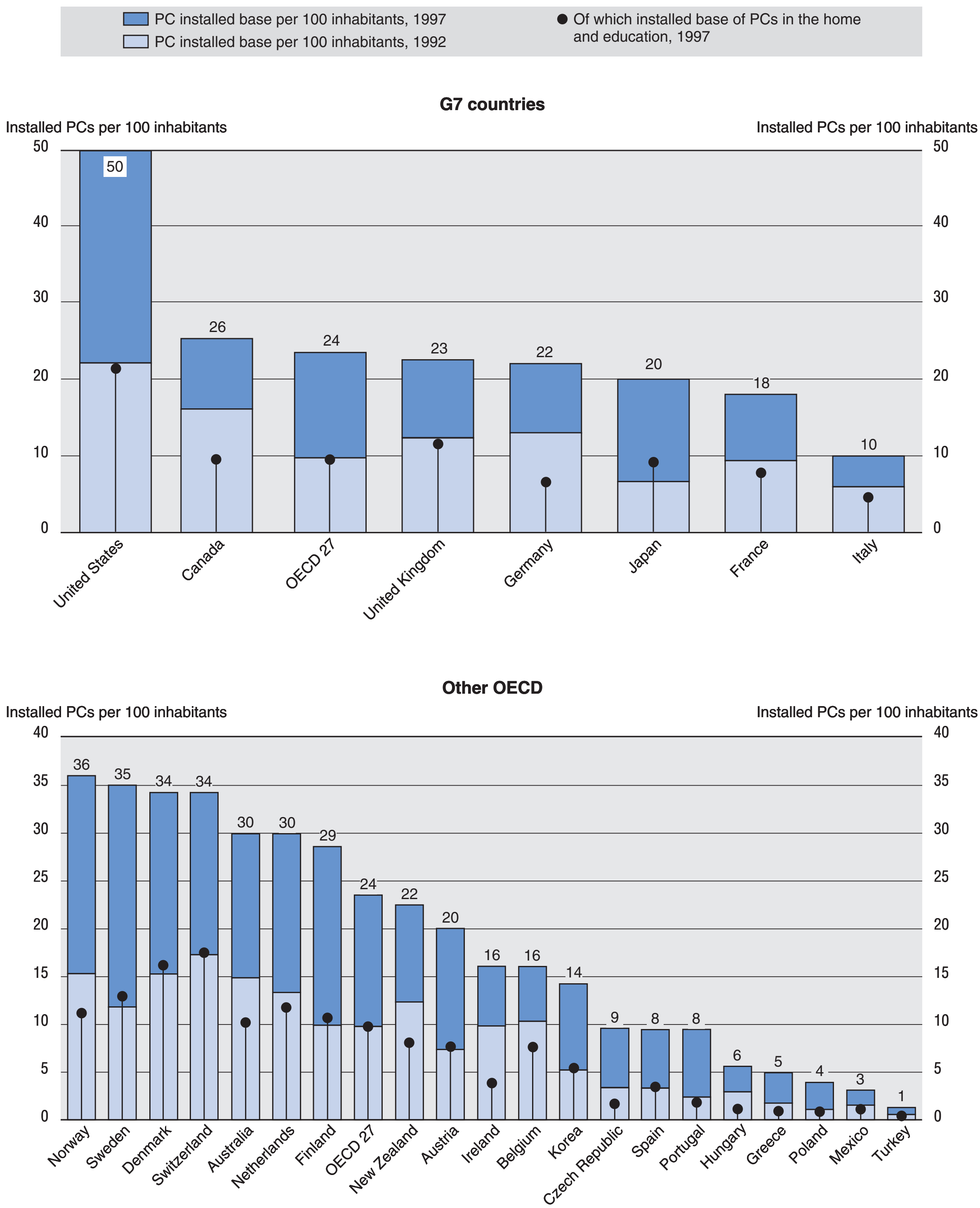
Although wide variations remain with respect to information access, all OECD countries greatly increased their PC base between 1992 and 1997, with an average number of PCs installed per 100 inhabitants in the OECD area rising from ten to 24. In 1997, the Nordic countries, Switzerland, Australia and the Netherlands had a higher ratio than all G7 countries but the United States (Figure 5).

PC sales have been driven by widespread demand, particularly from the household and education sectors. Their combined share of the installed base in the OECD area jumped from around one-third to almost 42% between 1992 and 1997 but varies widely among countries (from 11% to 52%). Countries with the highest shares of PCs in the home and in education are (in descending order): the United Kingdom and Switzerland (both with more than one-half of the installed base), followed by Belgium, Italy, Japan and the United States. Reasons for the growth in the home include declining costs, increasing use of the Internet, and professional and educational demand (see Chapter 3). Nonetheless, the business and government sectors predominate, with close to 60% of the total installed base.

Diffusion is also occurring in the workplace. IT uptake among skilled workers can be measured by the number of PCs per 100 white-collar workers. As Figure 6 shows, at the end of 1997, nine OECD countries had one or more PCs for every two white-collar workers.

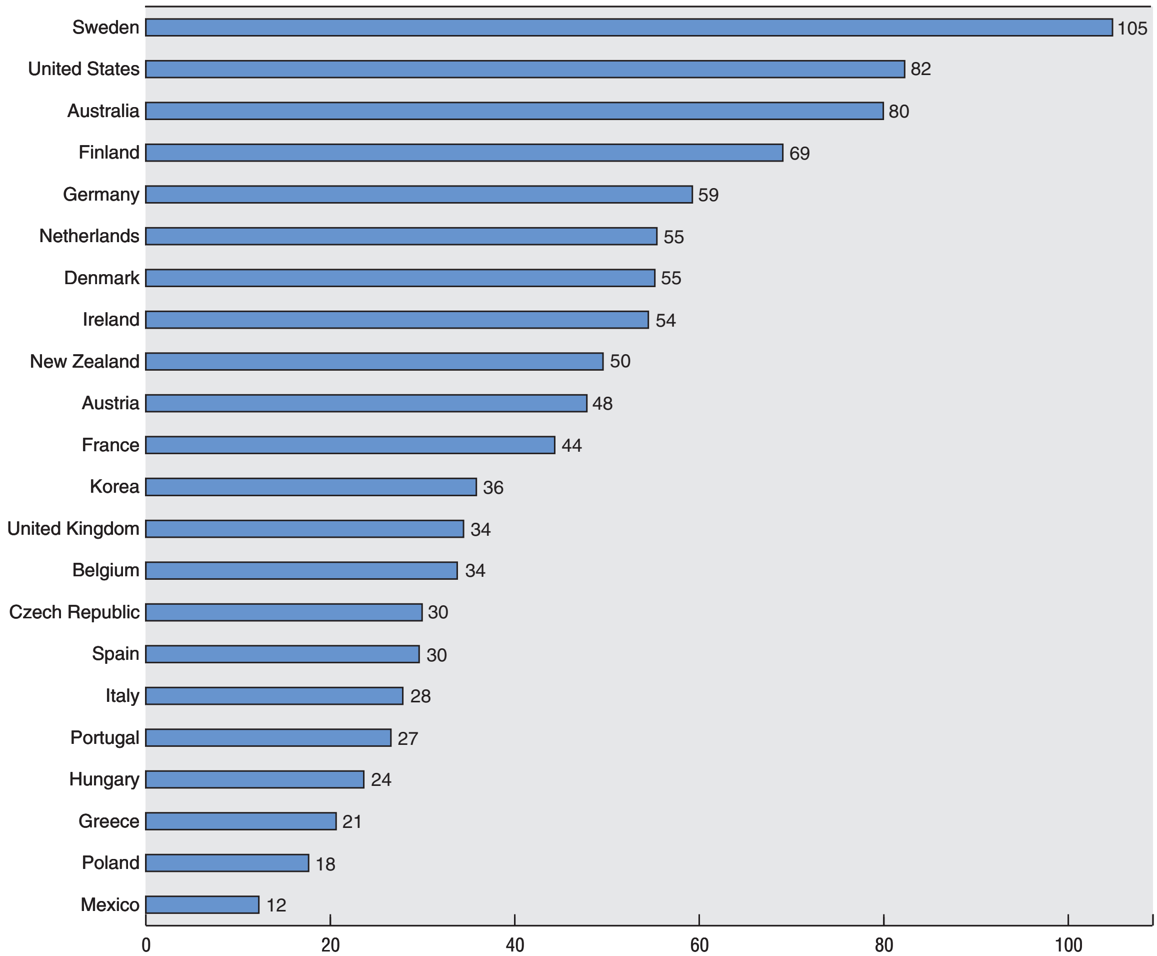
Diffusion has been facilitated by drastic price reductions (Figure 7) driven, in part, by sustained technological advances in semiconductors,[2] especially microprocessors, a key component of PCs and servers. Prices of other components, such as DRAM memories, have dropped sharply in the last two

Figure 5. **Average PC installed base per 100 inhabitants and share in the home and education in the OECD area,[1] 1992 and 1997**



1. Total PC installed base divided by total population. For some countries, 1994 instead of 1992.
Source: OECD, based on IDC data.

Figure 6. **PCs per 100 white-collar workers[1] in selected OECD countries, end 1997**

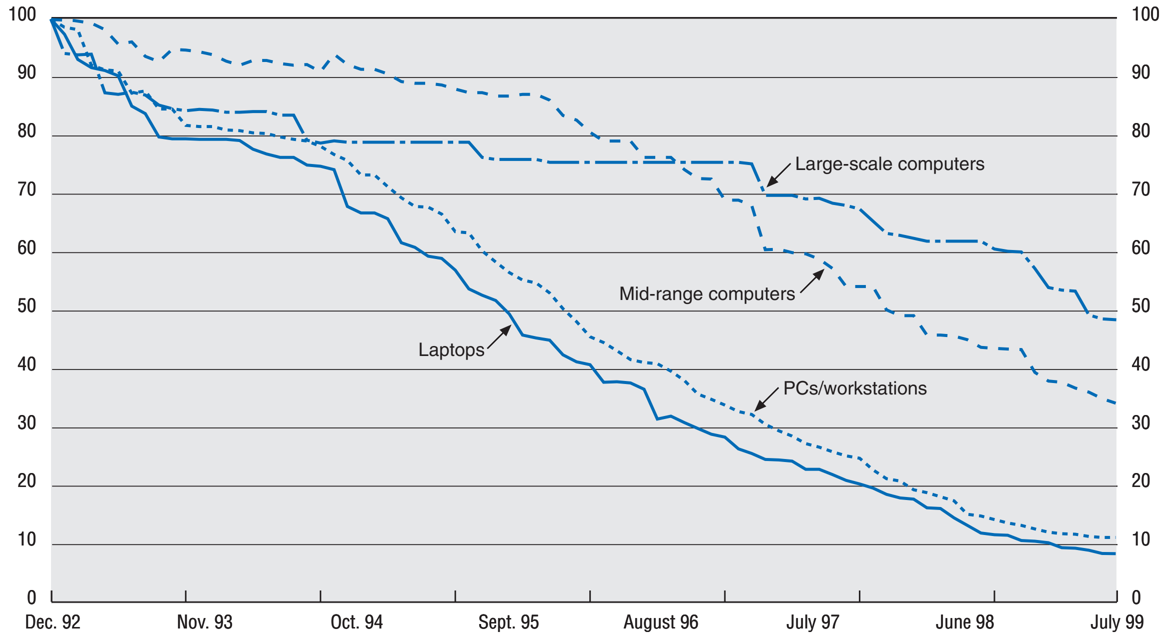


1. PC installed base in business and government, per 100 white-collar workers.
Source: OECD, based on data from IDC, Eurostat, US Bureau of Labor Statistics, and ILO.

years, owing in part to excess production capacity. Price wars among PC producers and distributors have also contributed to the general decline in PC unit prices, for example in European countries such as France and the United Kingdom.[3] The development of the Internet as an important actor in the sale and distribution of ICT products (Dell is an oft-cited example) has also increased pressure on intermediaries' margins.

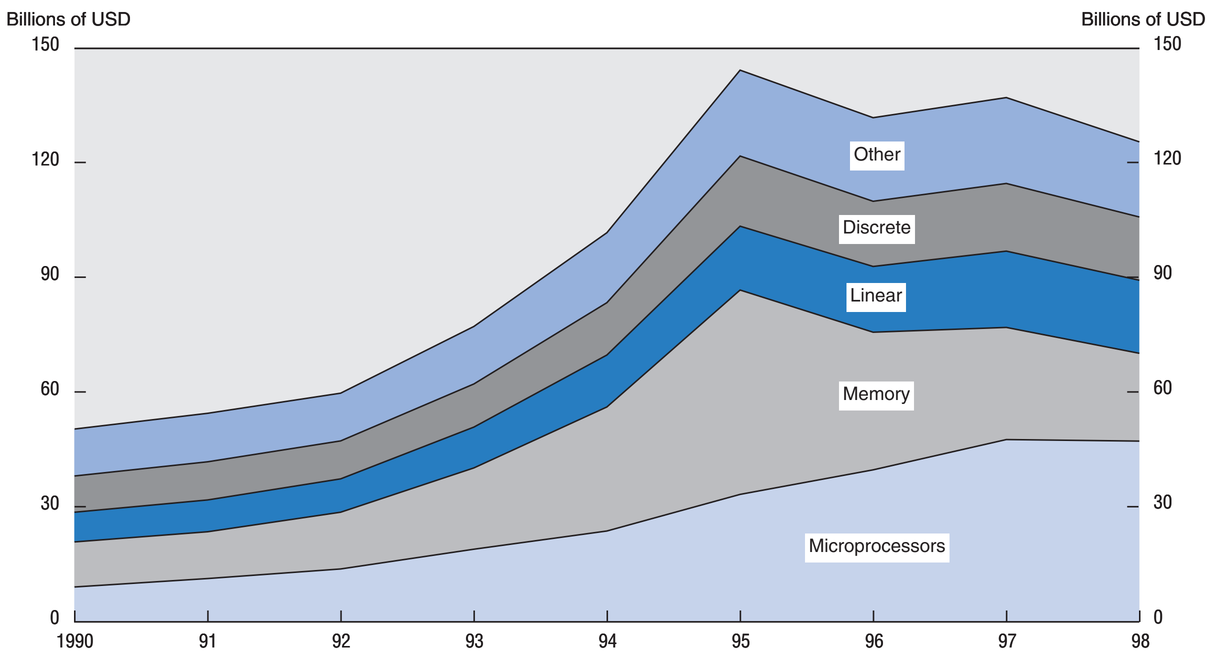
The sustained demand for PCs and workstations is also reflected in semiconductor sales. In 1998, microprocessors, the central component of PCs, accounted for 38% of the world semiconductor market, compared to only 20% in 1990. This is the only semiconductor segment that did not suffer from the general stagnation since 1995 in sales (in value terms), which is due in part to excess production capacity. Markets for memories, in particular DRAM, were hurt by strong price reductions from 1996 to 1998, which had a particularly strong impact in Asia (Figure 8). In 1997, sales to the computer sector accounted for over 50% of the world semiconductor market in terms of value, against around 40% in 1990. The computer industry uses a substantially larger share of semiconductors in North America and in Asia, while communication and consumer electronics account for a larger share in Europe and in Japan, respectively (Figure 9).

Figure 7. **Producer price indices for computer hardware in the United States, 1992-99**
Index: December 1992 = 100



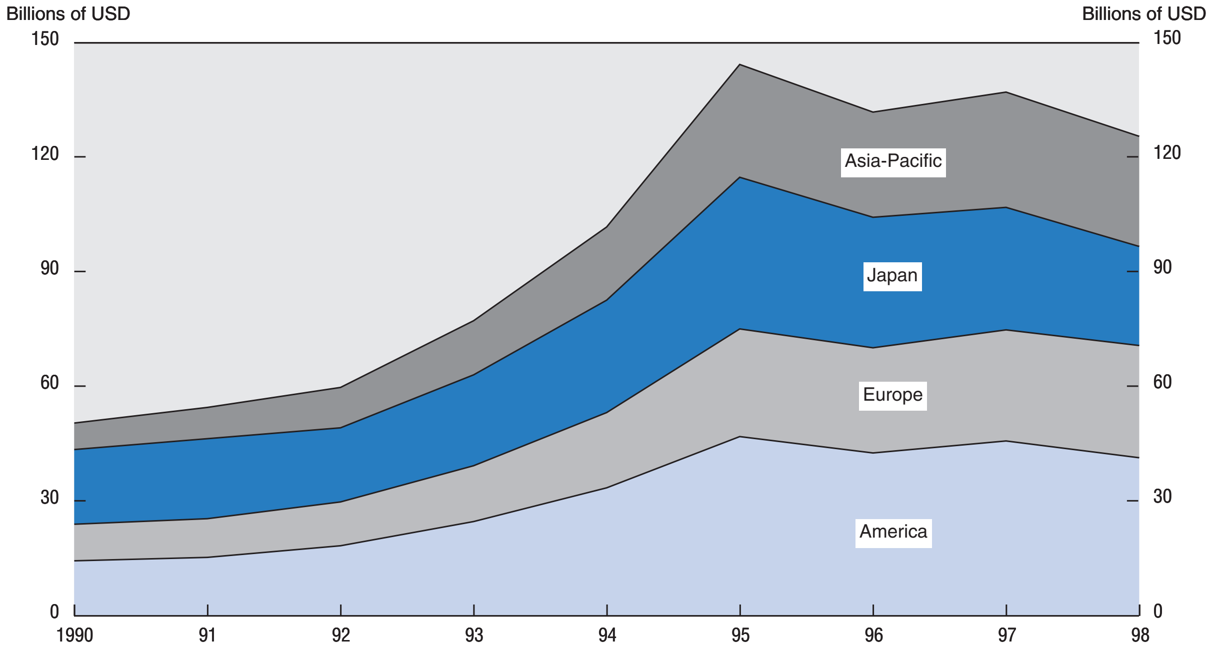
Source: US Bureau of Labor Statistics.

Figure 8*a*. **World semiconductor market by segment, 1990-98**
Value in billions of current USD



Source: OECD, based on World Semiconductor Trade Statistics (WSTS).

Figure 8*b*. **World semiconductor market by region, 1990-98**
Value in billions of current USD



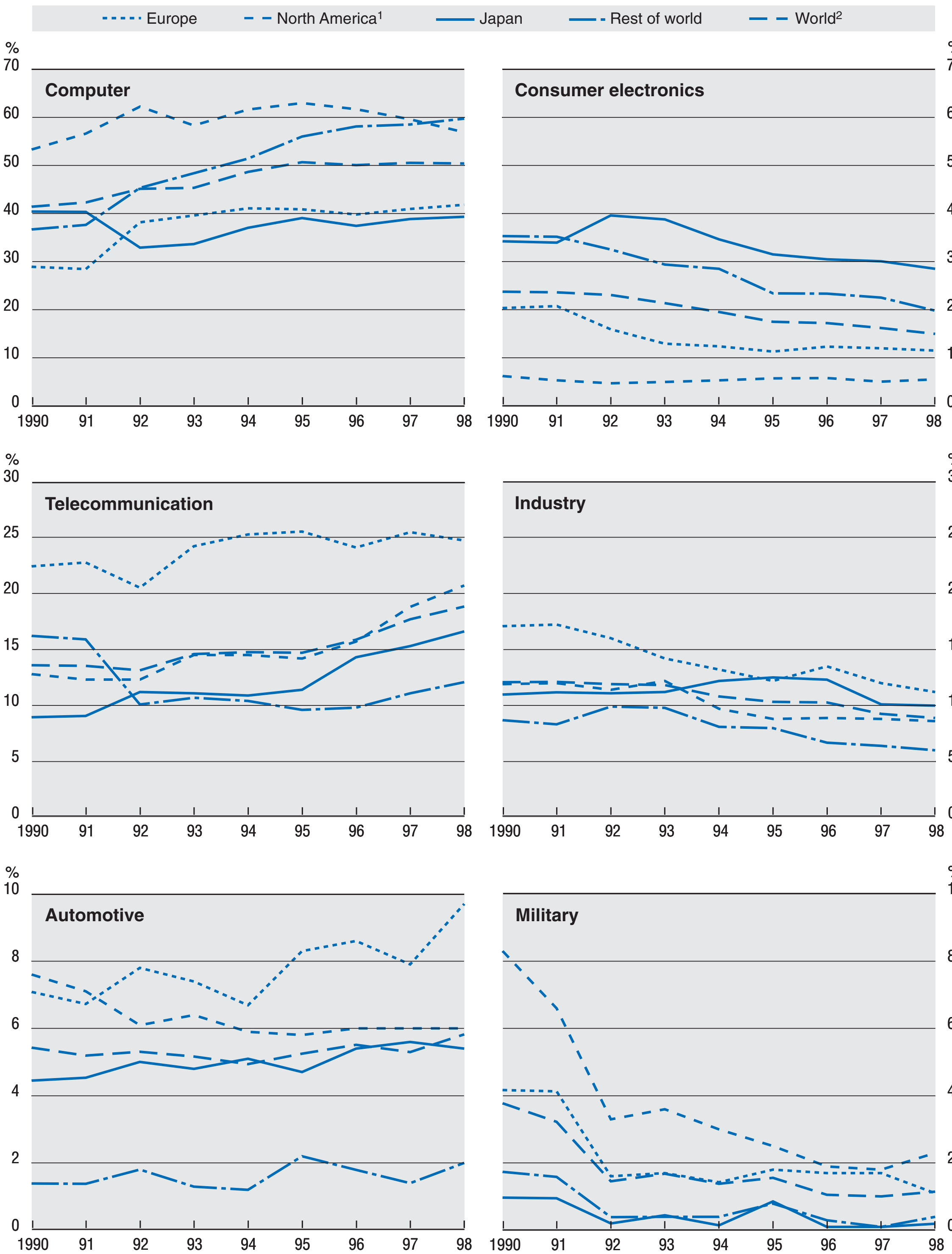
Source: OECD, based on World Semiconductor Trade Statistics (WSTS).

Packaged software

In 1997, the packaged software market in the OECD area represented USD 108 billion, or 94% of the world market, with an annual growth rate since 1990 averaging 11.2% If bundled operating systems (for both servers and PC/workstations), which are currently included in hardware, were added, a further 1.1% would be shifted from hardware to software. In terms of total IT expenditure, the OECD area continues to spend relatively more on packaged software than do non-member economies (16.4 and 12%, respectively, in 1997). The United States is still the leading world market and even increased its share from 44% to 47% of the world total between 1990 and 1997. The dynamism of the US market mirrors the strong growth of its software-producing sector, which created, in the packaged software industry alone, over 240 000 jobs between 1987 and 1998.[4] In the United States, prices of packaged software have seen a slight decline in recent years, much smaller than that of hardware (see Chapter 1, Figure 23).

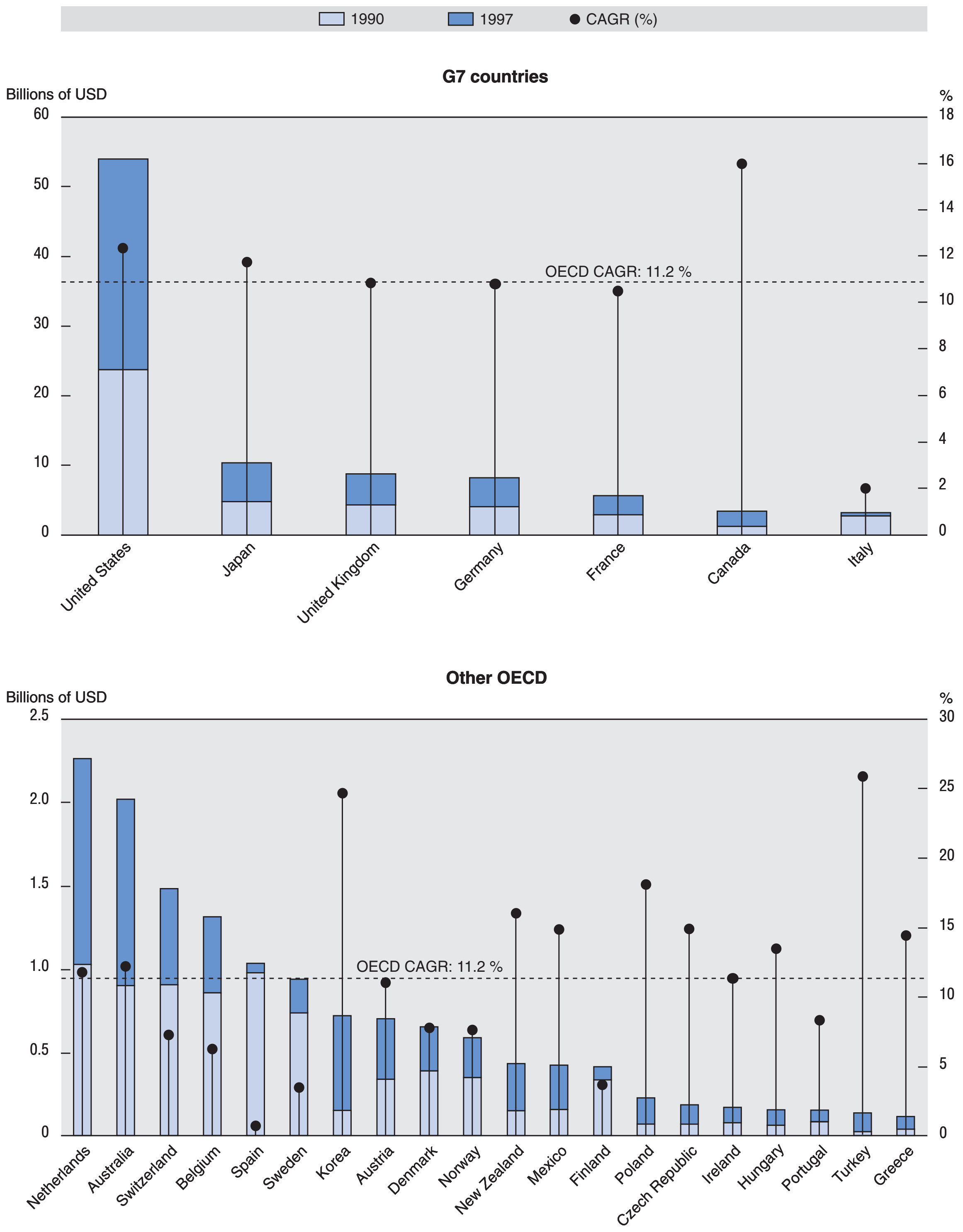
The second largest market, Japan, has grown at a slightly faster pace than the OECD average. However, in 1997, the share of software in Japan's overall IT expenditure remains one of the lowest in the OECD area, along with that of Korea (around 10% and 8%, respectively). Yet, while Korea has the lowest software intensity (software as a share of total IT expenditures) of all OECD countries, it has the second highest CAGR (more than double the OECD average). In 1997, its software market attained the size of that of European countries such as Austria, Denmark and Norway. Among the G7 countries, Canada has the most dynamic software market; in 1997, it equalled in size the Italian market, which had been twice as large in 1990. Most European countries have seen their software markets grow vigorously but significantly below the overall OECD rate, which is mainly driven by the United States and Japan. As a result, the relative share in world software markets of some countries (Belgium, Spain, Sweden, United Kingdom) declined slightly. Nevertheless, it is worth noting that out of USD 100 spent in Europe on IT in 1997, almost USD 20 were spent on software, a higher share than that of all other OECD countries/regions except New Zealand (Figure 10).

Figure 9. **Final use of semiconductor production, 1990-98**[1]
Percentage of regional market



1. Since 1994, includes South and Central America.
2. Until 1994, includes South and Central America.
Source: OECD, based on WSTS data.

Figure 10. **Packaged software markets, 1990-97**
Value in billions of current USD and percentage growh



Source: OECD, based on IDC data.

According to recent figures published by the US Business Software Alliance (BSA), the cost of software piracy is equivalent to between one-quarter and four-fifths of the actual value of software markets in individual OECD countries. At the overall OECD level, the piracy rate, although declining from around 43% in 1994, would still average around 31% in 1998. This would imply a significant underestimation of the economic significance of this IT segment.[5]

The growing importance of high-speed networks and high bandwidth connections to the Internet, (increasingly available in many OECD countries via cable networks) will have a major impact on the development of online software sales. It is estimated that the global market for online software will reach USD 3.5 billion by the end of 1999.[6]

Services

In the OECD area, the IT services market represented USD 253 billion in 1997, with an annual average growth rate of 7.7% since 1990. This market remains extremely concentrated, as the G7 countries have maintained their share at around 88% over the period, owing to strong growth in North America. The United States remains the largest market by far in terms of size and has been the main driver of growth (its share in the OECD area increased from around 41% to 49%). Growth was also well above the OECD average in Canada and Mexico (at 10% and 13.3% a year, respectively). Japan and the major European countries (except the United Kingdom) have experienced only slight growth (Figure 11). It is worth noting that although growth has been slower than for software, services generally remain the second largest IT segment after hardware.

The United States' IT market profile

Given the overwhelming size of the US IT market, a more detailed analysis of its dynamics can provide useful insights for assessing long-term trends and structural changes taking place in the increasingly global IT market.

In 1997, the United States remained the lead country in terms of IT expenditure. This dynamism is also reflected in its IT intensity ratio (IT/GDP), which has increased the most rapidly of all OECD countries since 1990, reaching 3.9% in 1997 (excluding telecommunications). The United States had the highest IT intensity ratio in 1997, ahead of Sweden and Canada (3.6% and 3.3%, respectively).

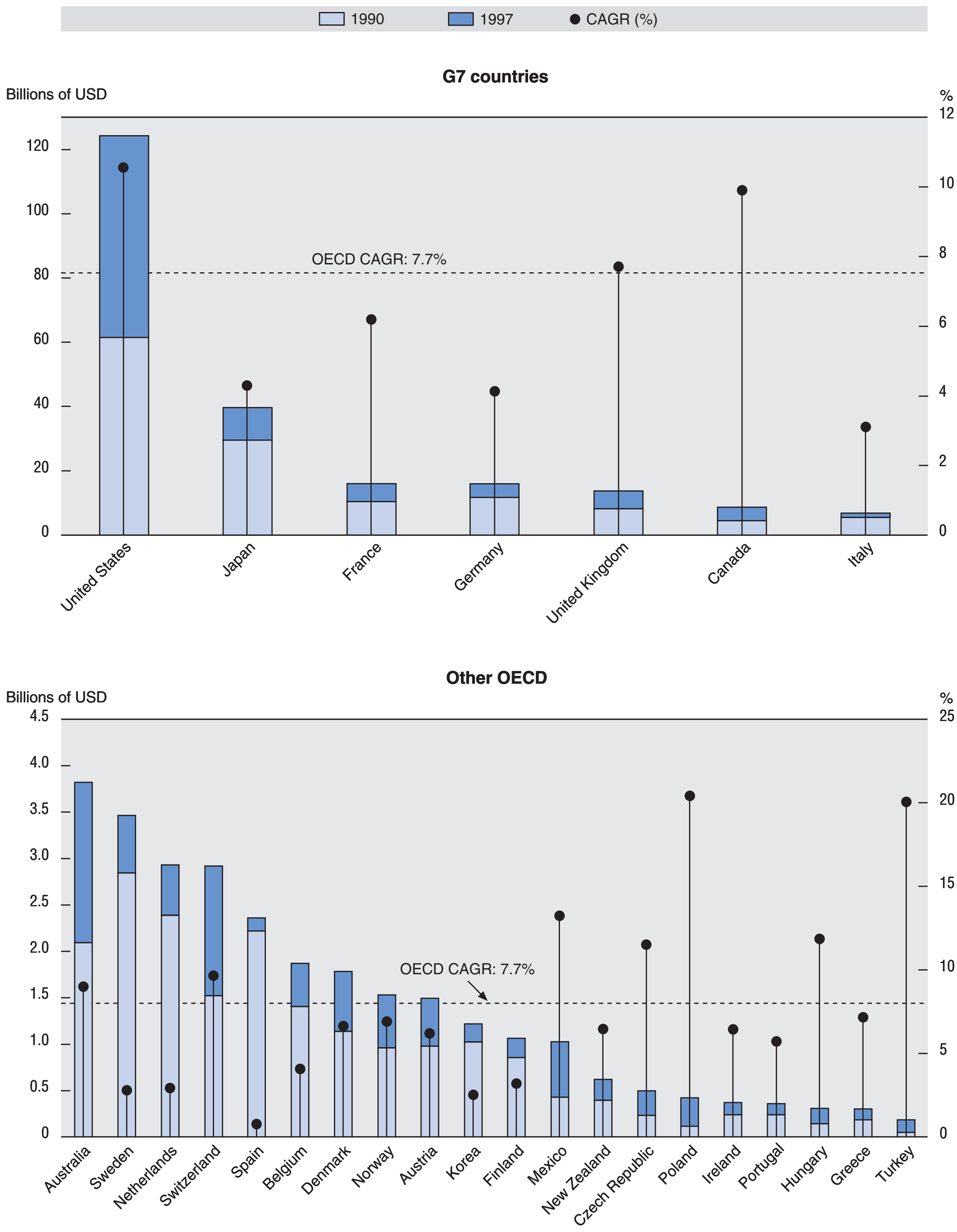
In every IT market segment, the United States has been the main driver of OECD IT market growth since 1990, especially for hardware and IT services (Figure 12).

All segments have been growing at a positive rate, but the most dynamic were data communication, single-user systems (PCs and workstations) and software. As a result, if hardware maintained its share at around 43% of the US total IT market, its composition changed markedly. Single-user systems accounted for almost two-thirds of the hardware market in 1997, compared to only one-half seven years before. Data communication equipment accounted for more than 12% of the hardware market, compared to 8% in 1990. Taken together, software and IT services maintained their combined share at around 56% of the total IT market. Software remained stable at 16% to 17%, while IT services declined slightly from 41% to 39% (Figure 13).

In terms of final use, the US IT market was primarily oriented towards services (70%). Finance and insurance industries accounted for more than one-fifth of total IT expenditure, a share similar to that of manufacturing industry as a whole. The wholesale and retail trade sectors accounted for around 12% of all sales, and business services slightly less (10%). The communications and media sectors spent as much as the government sector, while the remaining sectors accounted for less than 5% (Figure 14).

In addition, it is interesting to look at an index of relative IT specialisation which takes into account each industry's relative share in the economy, as it gives quite a different perspective. First, it shows great disparities, as industries appear to be either large "over-users" or large "under-users" of IT as compared to their share in the economy. Banking and finance industries still appear to be relatively big IT users. The education sector ranks third, mostly due to strong spending on software, which in 1997 represented more than 40% of that sector's total IT spending. Communications and media also appear to be relatively high IT users. The ranking of the business services and the wholesale and retail sectors may seem surprisingly low, but probably hides wide variation across sub-sectors[7] (Figure 15).

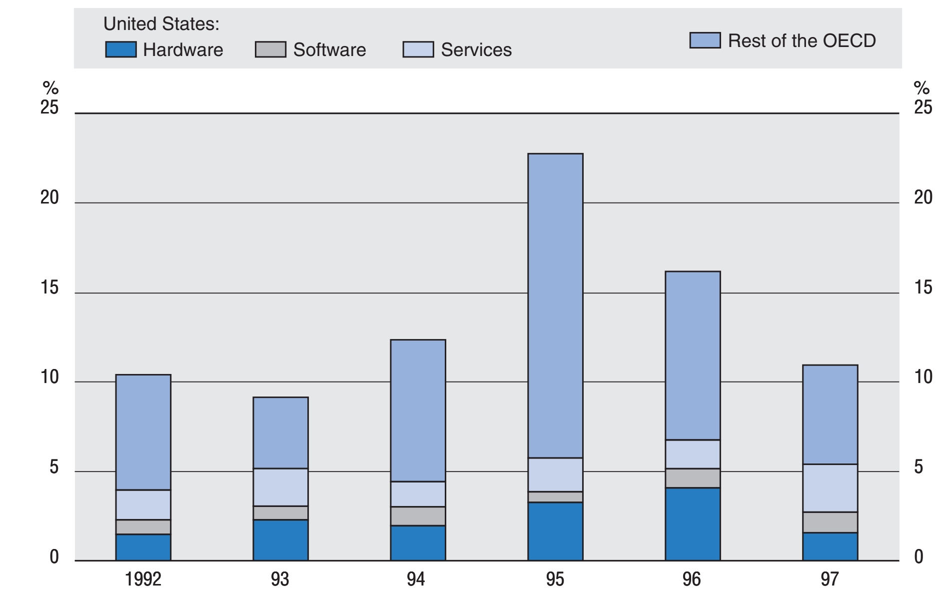
Figure 11. **IT services markets, 1990-97**
Value in billions of current USD and percentage growh



Source: OECD, based on IDC data.

Figure 12. **Contribution of the US IT segments to the growth of total OECD IT market, 1992-97**

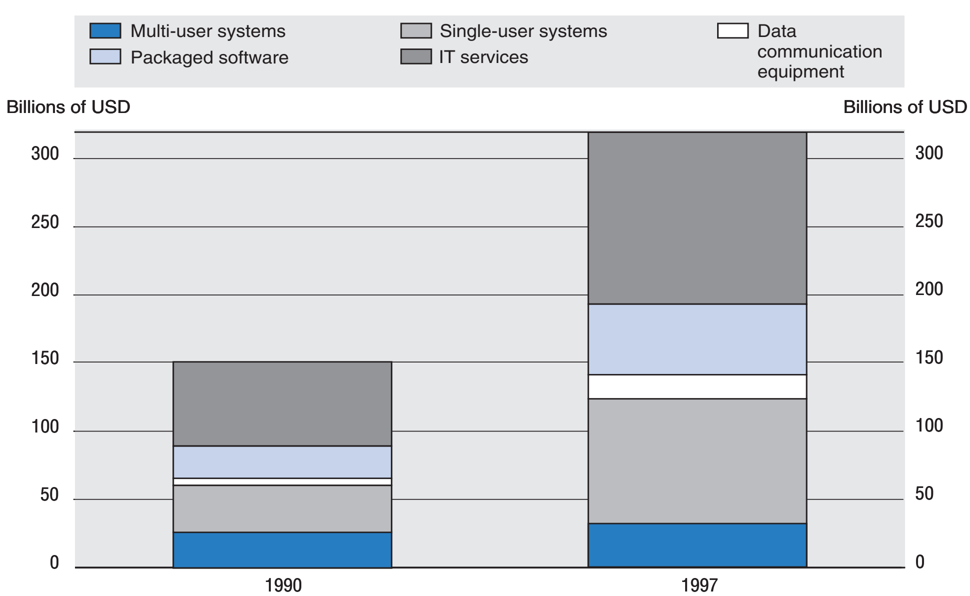
Percentage growth over the previous year



Source: OECD, based on IDC data.

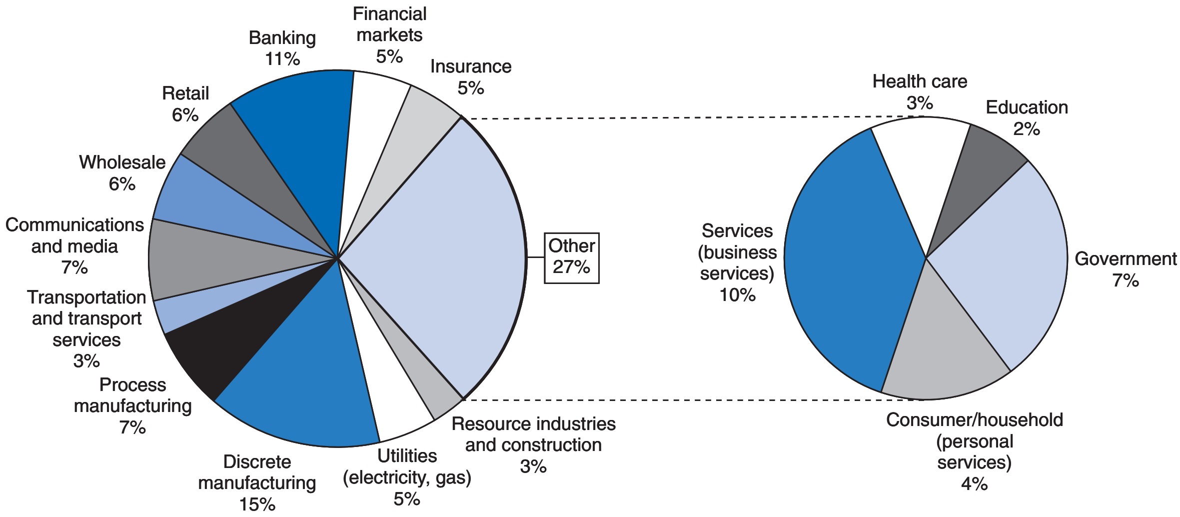
Figure 13. **US IT market by segment, 1990 and 1997**

Value in billions of current USD



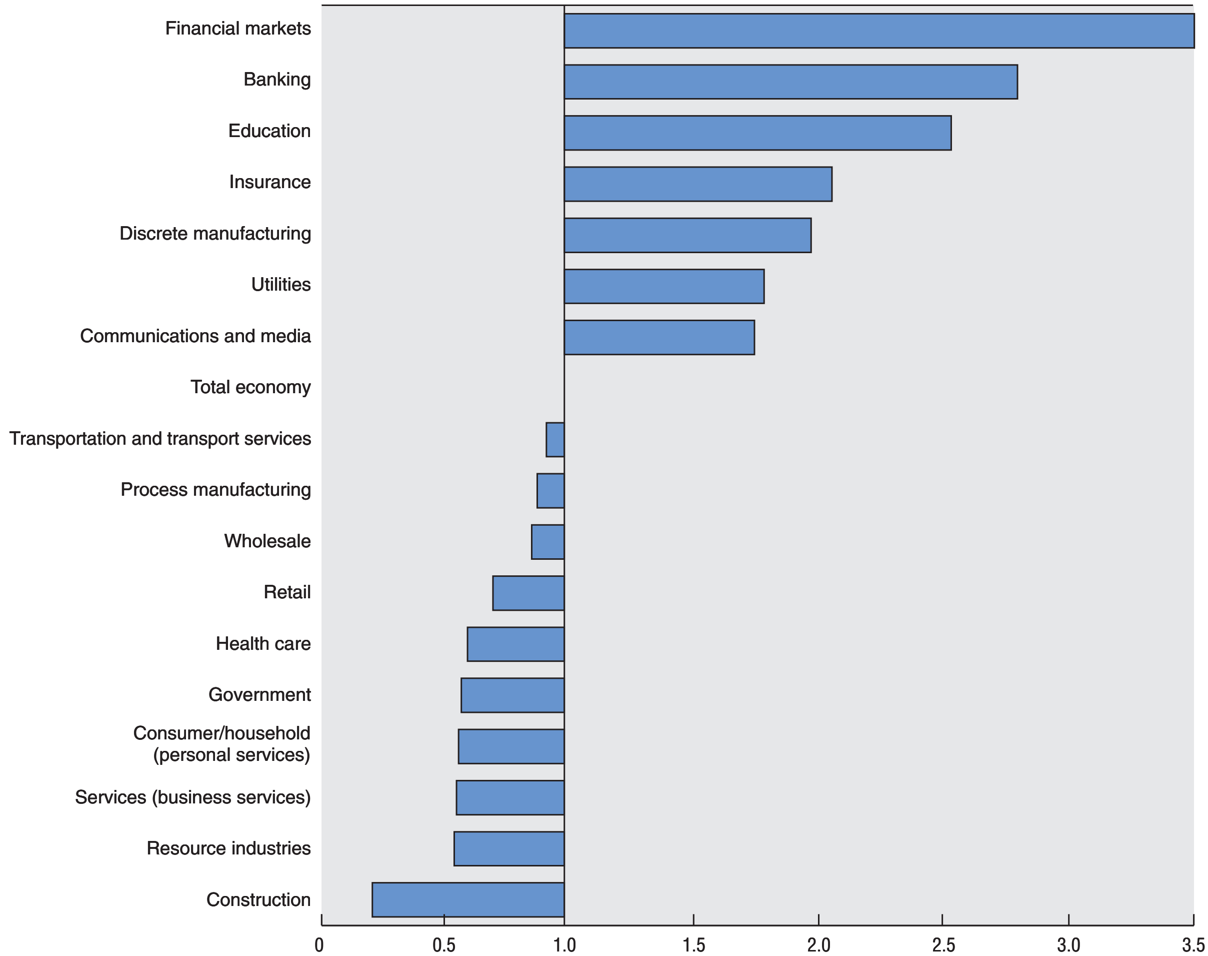
Source: OECD, based on IDC data.

Figure 14. **US IT spending by industry, 1997**



Source: OECD, based on IDC data.

Figure 15. **Relative IT intensity index by industry[1] in the United States, 1997**



1. The relative IT intensity index represents industry's percentage share of information technology expenditures relative to industry's share of GDP. An index of 1 reflects no over- or under-spending in IT relative to the size of the industry.

Source: OECD, based on data from the US Bureau of Economic Analysis and IDC.

IT markets: latest developments

This chapter examines the main structural trends in OECD IT markets in the period 1990-97. More recent trends have been similar.[1] This box briefly summarises the latest developments.

Recent EITO figures[2] indicate that world IT markets grew at around 9.5% between 1998 and 1999, with Europe advancing by 10.7%, followed by the United States (9.1%) and Japan (5.1%). The United States remain the world's largest IT consumer, with a stable 44% market share in both 1998 and 1999.

In 1999-2000, the global IT market is likely to see a slight but noticeable shift towards a greater share of software and services. In hardware, data communication equipment should grow well beyond the 11% level reached in 1997.

The year 2000 problem does not seem to have slowed PC demand, as PC shipments were particularly strong worldwide during 1999. In the first two quarters (generally not the most dynamic), the number of units shipped increased by 24.8% on average over 1998, and the overall increase will be well above 20%. With an expected demand for over 8.74 million units in 1999, Japan was clearly recovering from the previous year's zero growth, mirroring the rebound in the Asia-Pacific region and the pick-up in PC demand in all these countries. In Europe, the year 2000 issue seems to have driven market growth, as SMEs especially have taken advantage of price competition to invest in PCs.

Market values rose strongly, increasing by around 10% in 1999 after almost flat growth (less than 2%) in 1998.[3] The United States continued to drive the PC market, with a growth rate of around 8% in 1999, some 2 percentage points above the 1998 level. In Europe, PC market value was expected to rise by over 6% in 1999, one percentage point less than in 1998.

Price competition in the consumer market, particularly in the retail segment including flourishing Internet demand, is driving demand for PCs. The US growth rate continues to be well above average, partly due to the "free PC" boom accompanying the development of electronic commerce in both the business-to-business and business-to-consumer segments.

Growth of the packaged software market was estimated to exceed 13.4% for 1998,[4] with similar rates forecast for 1999 and 2000.[5]

At global level, IT services were expected to grow at an annual average rate of 12.5% during 1999 and 2000, driven by factors such as e-commerce project implementations and M&As in a number of industries. Growth in IT services was particularly dynamic in Japan in 1998, despite its generally sluggish economic performance. This is mainly due to the outsourcing of IT services by firms. In Europe, at 12.9%, IT services were expected to slightly outpace the world rate, under the combined influence of consulting services linked to the implementation of the euro, the deregulation of certain industries, increased outsourcing and the development of e-commerce.

1. Unless otherwise stated, the trends in market value are based on 1997 constant ECU exchange rates.
2. *European Information Technology Observatory* (EITO) 1999, *Annual Report*, March 1999 And *European information Technology Observatory* 1999, *Update*, October 1999.
3. Estimations have been provided to the Secretariat by the French ministère de l'Économie, des Finances, et de l'Industrie, on the basis of various private sources for the world and US markets. Estimates for the European market are from the *European Information Technology Observatory* 1999, *Update*, October 1999, Table 4, p. 14.
4. In current US dollars. Source: IDC, Press release, 12 January 1999. Available on line at: <http://www.idcresearch.com/Data/Software/content/SW011299CPR.htm>.
5. EITO 1999, *op. cit.*, Table 7, p. 346.

NOTES

1. On the basis of IDC data provided in the WITSA study (*Digital Planet, The Global Information Economy*, Vol. 1, October 1998), it is calculated that the average share of PCs connected to a network in OECD countries increased from 49% in 1994 to 59% in 1997.
2. In 1965, Gordon Moore, co-founder of Intel, predicted that computer power would double every 18 months to two years. This principle, known as "Moore's Law", continues to apply, as engineers are able to squeeze more integrated circuits into chips, thereby constantly increasing calculating capacity while reducing the price of computing power.
3. The producer price index for PCs published by INSEE confirms that the drop in PC prices has also been very sharp in France.
4. US Bureau of Labor Statistics, <http://stat.bls.gov/ceshome.htm>, May 1999.
5. International Planning and Research Corporation for the Business Software Alliance (BSA), 1998 *Global Software Piracy Report*, May 1999, <http://www.bsa.org/statistics/GSPR98/98ipr.pdf>. BSA defines the piracy rate as the ratio between software applications installed (demand) and software applications legally shipped (supply). The total for the OECD area has been calculated based on country-level data published by the BSA.
6. IDC estimate, quoted in NUA Internet surveys. NUA Press Release, 30 July 1999. Available on line at: <http://www.nua.ie/surveys/index.cgi?f=VS&art_id=905355072&rel=true>.
7. In most business surveys, the computer and related services industry appears to be the first consumer of its output and would probably appear, if it were possible to separate it out, as a higher IT user industry than the wider business services sector.

Chapter 3

E-COMMERCE "READINESS"

Electronic commerce has the potential to radically alter a wide range of economic and social activities. Individuals, firms and governments are conducting an increasingly broad spectrum of commercial activities over the Internet (OECD, 1999*a*). The development of electronic commerce is being fuelled by a combination of technological, regulatory, economic and social factors, and the readiness of OECD economies to adopt these new technologies will have a significant impact on their future growth and social well-being. In this context, governments of various Member countries have recently published comprehensive reports highlighting the importance of developing co-ordinated policies and identifying drivers and obstacles in order to foster the development of electronic commerce (US DOC, 1999; UK Cabinet Office 1999; Ministère de l'Économie, des Finances et de l'Industrie, 1999; SIG, 1999; Forfás, 1999). Table 1 presents some of the main policy areas in which electronic commerce is creating new challenges for governments.

Although all observers agree that electronic commerce is growing very rapidly, the lack of common definitions makes it very difficult to compare data from different sources. Measures of electronic commerce are being developed to address various issues, particularly those of concern to policy makers. Using a life-cycle model, it is possible to describe three broad phases in the growth of e-commerce, each of which raises different policy issues:

– *Readiness*. Preparing the technical, commercial and social infrastructure necessary to support e-commerce.

– *Intensity*. Examining the current state: Who are the early adopters? Who are the laggards?

– *Impact*. Addressing additionality and multiplier effects: Does e-commerce have an impact on the efficiency of economies and/or the creation of new wealth?

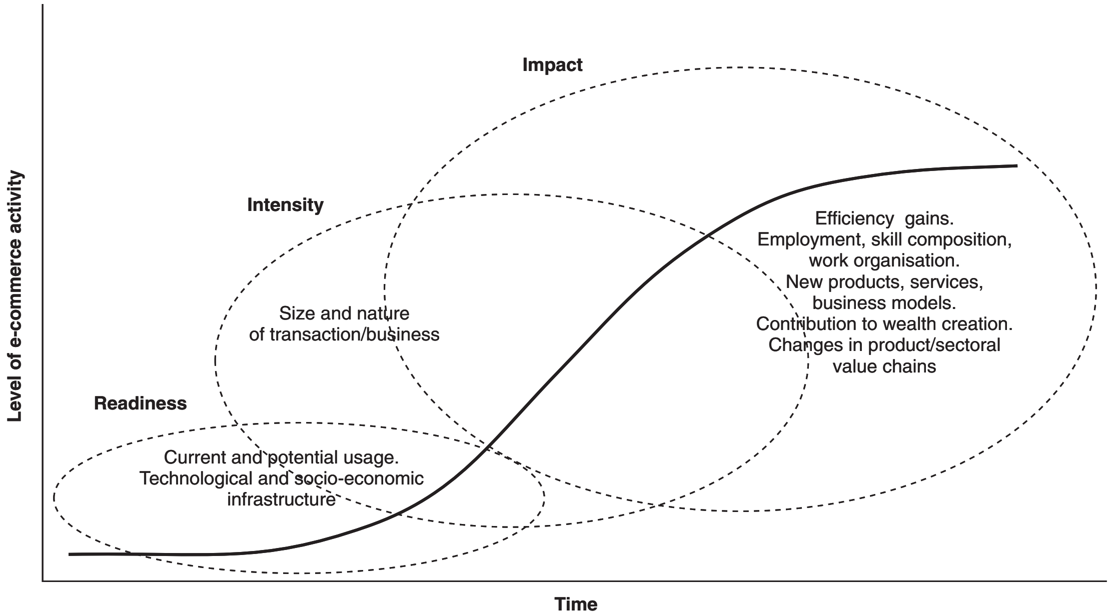
These phases can be measured with different types of indicators (Figure 1) (OECD, 1999*b*). This chapter examines the first phase, e-commerce "readiness", or the current and potential use of ICTs for online commercial transactions. In this chapter, particular emphasis is placed on the combination of PCs and TCP/IP technologies, although in many cases these are only the extension of or complement to more established and widespread EDI systems.

Table 1. **Electronic commerce: main policy areas**

Enabling issues	Diffusion	Business environment
Network infrastructure	Facilitation/demonstration	Competition
Authentication/certification	Training/education	Taxation
Settlement/payment	Small and medium-sized enterprises	Trade
Consumer protection		Standards/intellectual property rights
Privacy		

Source: OECD.

Figure 1. **Maturity of e-commerce markets**



Source: OECD (1999*b*) based on Industry Canada.

This S-curve can be applied to individual sectors as supply chains move on line in successive waves. Although there are differences across countries, some sectors were early adopters (*e.g.* computers, electronics, aerospace), while others are currently being transformed (*e.g.* motor vehicles, shipping, some retail), and still others are expected to adopt e-commerce in the future (*e.g.* pharmaceuticals, food, industrial equipment).

In focusing on the first phase, this chapter highlights differences in the propensity of individuals, sectors and countries to adopt e-commerce. It examines three sets of interrelated areas in which e-commerce readiness in OECD countries and potential for future growth can be measured: infrastructure, diffusion and human resources/skills.

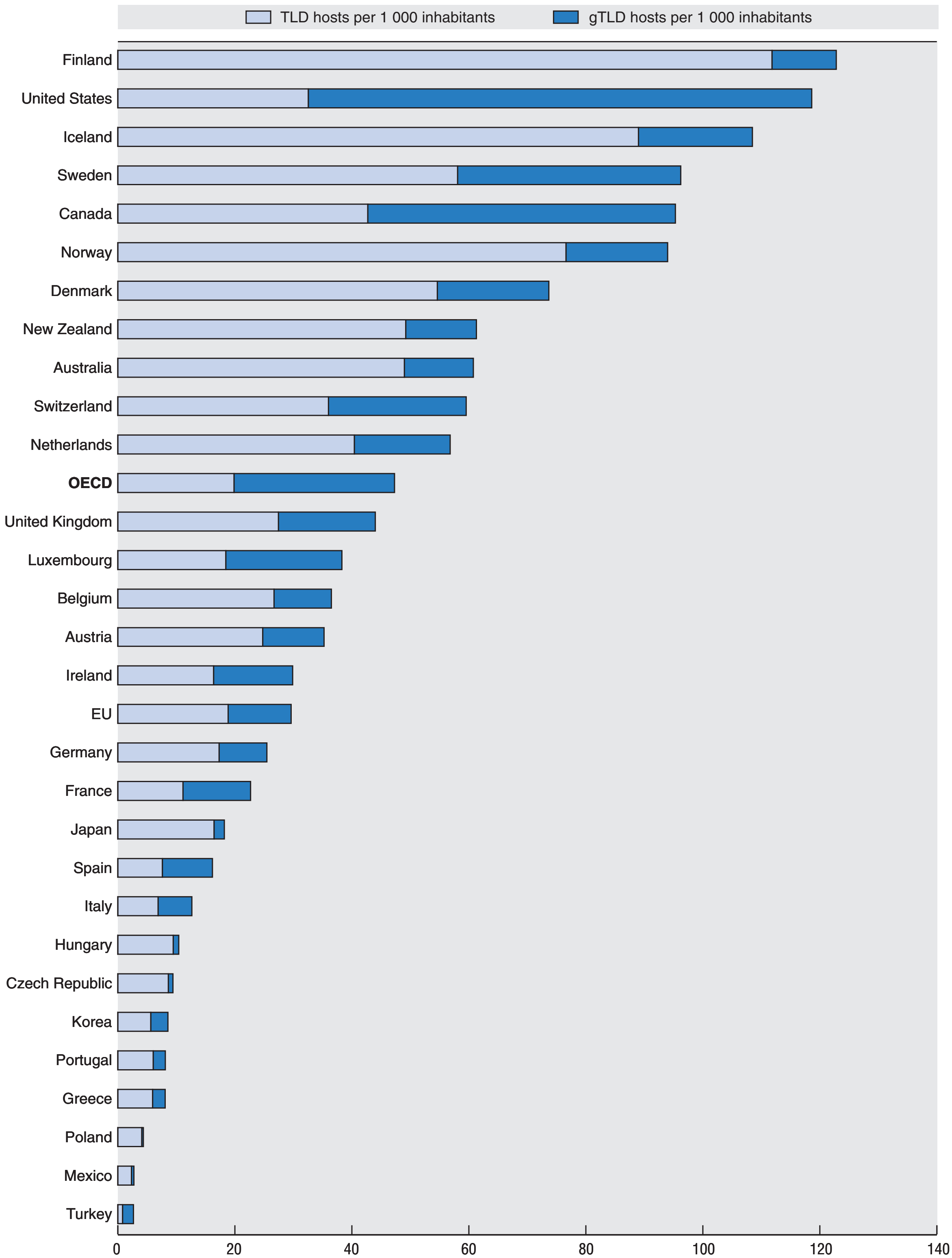
Infrastructure

This first category of indicators can be used to measure the supply and uptake of the technologies used in conjunction with e-commerce activities: the two main areas are the Internet (hosts, Web servers) and telecommunications (infrastructure, access, cost).

Network growth

Several indicators can be used to assess the supply of information available through the Internet. One of the most widely used is the number of Internet hosts[1] (OECD, 1998). Data published by the Internet Software Consortium (ISC, 1999) show that the total number of hosts is growing rapidly. With growth at 80% annually over the last six years, Internet hosts numbered over 52 million by July 1999 in the OECD area, which accounted for 93% of the world total (Figure 2). This indicator is also used to estimate the total number of Internet users, currently around 3.5 per host on average. Nordic and English-speaking countries have the highest intensity (more than 60 hosts per 1 000 inhabitants). Although the overall

Figure 2. **Internet hosts per 1 000 inhabitants, July 1999**



Source: OECD, based on Internet Software Consortium <http://www.isc.org/>.

density of Internet hosts continues to increase, there is a wide disparity among OECD countries: 11 out of 29 have a density of less than 20 hosts per 1 000 inhabitants.[2]

Although it is not possible to measure the "size" of the Internet exactly, it is estimated that by June 1999, there were more than 3.6 million Web sites worldwide, of which 2.2 million were publicly accessible (Table 2).

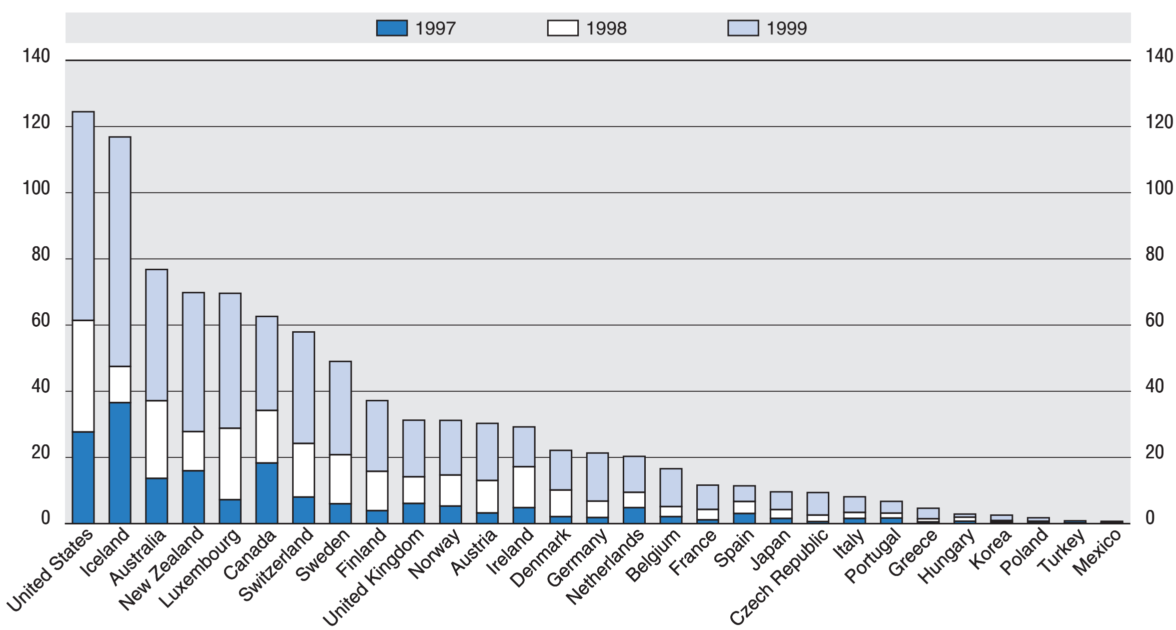
Table 2. **Estimated number of worldwide Web sites, 1997-99**

	1997	1998	1999
Unique public sites	800 000	1 457 000	2 229 000
Unique private sites	430 000	578 000	1 420 000
Total unique sites	1 230 000	2 035 000	3 649 000

Source: OCLC, <http://www.oclc.org/oclc/research/projects/webstats/statistics.htm>.

The Netcraft SSL Server survey provides one of the best available indicators of the growth of electronic commerce on the Internet. Whereas the leading search engines only cover http sites, Netcraft also undertakes a secure socket layer (SSL) survey. The SSL protocol was developed by Netscape for encrypted transmission over TCP/IP networks. It sets up a secure end-to-end link over which http or any other application protocol can operate. The most common application of SSL is https (*i.e.* SSL-encrypted http), a leading enabler for electronic commerce over the Internet (OECD, 1999*c*). Figure 3 presents data on secure Web servers in OECD countries for the period 1997-99; it indicates that the number of secure servers per inhabitant has greatly increased in the last two years. Of the more than 48 000 secure servers identified worldwide in August 1999, the OECD area accounted for more than 95%, and the United States for almost 70%.

Figure 3. **Number of secure Web servers per million inhabitants**



Source: OECD data and Netcraft <http://www.netcraft.com>.

Access technologies

As deregulation continues and competition increases, prices continue to fall for consumers who are being offered a wider choice of technologies. Table 3 gives the transmission speeds, market shares and platforms of various narrowband (dial-up, ISDN) and broadband (xDSL, wireless, cable, satellite) technologies.

Table 3. **Access technologies**

	Transmission speed[1]		Worldwide market share in % (households)		Platform
	Downstream	Upstream	1998	2002[2]	
Dial-up modem	Up to 56 Kbps	Up to 56 Kbps	90.8	66.8	Normal phone lines
ISDN	56-128 Kbps	56-128 Kbps	8.0	20.4	Supplied by PTT
xDSL	1.5-9 Mbps	16-500 Kbps	0.1	4.4	Normal phone lines
Cable modem	0.5-30 Mbps	0.1-1 Mbps	0.9	7.7	CATV networks
Wireless[3]	9.6 Kbps	9.6 Kbps	0.2	0.6	Wireless path
Satellite	0.4 Mbps	0.1 Mbps			Wireless path

1. Downstream refers to data transmission towards the user; upstream refers to transmission back to the service provider.
2. Forecast.
3. Market share includes satellite.

Source: EITO in Morgan Stanley Dean Witter (1999) and PricewaterhouseCoopers (1999).

The strong growth in demand is being driven by a combination of faster access speeds, pervasive use in workplaces and declining access costs. Dial-up access continues to be the preferred access mode for households and small businesses, while more advanced technologies such as ISDN are progressively more widely used in some countries where prices are relatively low (*e.g.* Germany). Access technologies such as xDSL, which allow higher speed connections, are increasingly deployed. xDSL makes possible a compromise between inexpensive (but slow) dial-up and expensive (but fast) leased lines. Internet access through cable lines is increasingly used in countries where cable access is widespread (*e.g.* Benelux, Switzerland).

Cellular mobile telephony penetration continues to grow rapidly: the number of subscribers in the OECD area reached almost one-quarter of the total population in 1998 (see Appendix Table 1). Penetration is very high in European countries (partly due to the adoption of the GSM standard), particularly in Nordic countries

Box 1. **Wireless access technologies**

Wireless and satellite systems are becoming increasingly important as means of accessing the Internet. With the development of applications with enhanced capacity and performance (in particular, high speed and multimedia capacity) as well as increased portability, the "wireless Internet" is becoming more of a reality. The growing integration and interoperability of fixed and mobile environments is allowing wireless technologies to be deployed both in the last mile area and in global networks (OECD, 1999d). The new third-generation wireless wideband systems (Universal Mobile Telecommunications System, or UMTS, in Europe) will offer both real-time (*e.g.* for speech) and non-real-time (*e.g.* for e-mail) modes using common mechanisms capable of providing reliable transport for message, file and stream-type data.

WAP

The Wireless Application Protocol (WAP) is an open, global specification developed by an industry consortium comprising over 200 members, including Ericsson, Motorola and Nokia. This protocol defines the Wireless Markup Language (WML), an XML application which allows mobile users to access specially tailored Web pages (*i.e.* XML or HTML pages are "filtered" into WML). WAP can be built on a variety of operating systems currently used by hand-held devices, such as PalmOS, Epoc (developed by the Symbian alliance), Windows CE, Java O/S, etc. By the end of 1999, several large telecommunications operators in Europe were already offering various Internet-based services using WAP.

Source: EITO (1999), Messerschmitt (1999) and WAP Forum, <http://www.wapforum.com>.

where it exceeds one-third of the population. The emergence of new standards and applications such as WAP (wireless application protocol), which allow different cellular protocols to merge for mobile Internet access will contribute to sustained demand for cellular mobile as an alternative mode of access (see Box 1).

Pricing

Consumers most commonly use dial-up connections via modems and telephone lines to access the Internet. OECD data on Internet access show that access costs vary widely across countries and that, in some, the PSTN charge accounts for most of the cost (OECD, 1999c). Nonetheless, price is not the only relevant factor: countries such as Italy and Spain have relatively low access costs but still have low penetration in terms of Internet hosts per inhabitant (see Chapter 1). Development will depend not only on low prices but, increasingly, on improved service, ease of use, speed and reliability.

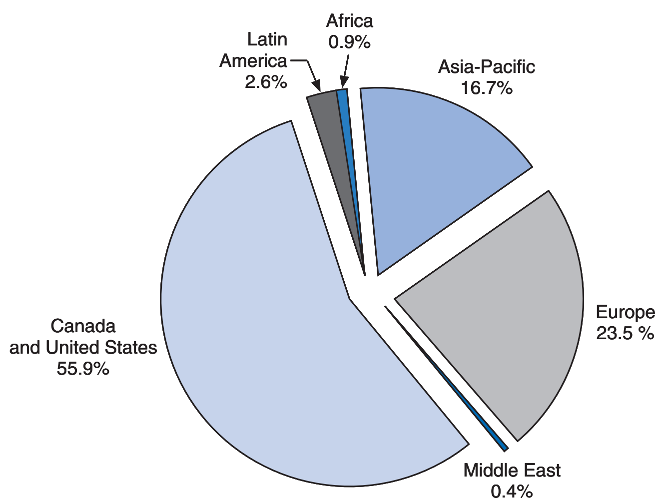
The appearance of new pricing schemes, such as free ISPs in Europe where local calls are metered, is altering the market. Data from the United Kingdom and France show that most customers of these providers are first-time users and that the main sources of revenue are advertising and commissions on transactions made through them (content aggregation).

In the case of leased lines, which are the main building blocks for business-to-business e-commerce, pricing practices are changing as competition among infrastructure providers increases (OECD, 1999*e*).

Installed base/diffusion

Data on the number of Internet users are often not comparable. For example, some exclude children, while others include "regular" users only. Nonetheless, it is clear that the number of people with access to the Internet is increasing rapidly. NUA estimates that by September 1999 there were more than 201 million users worldwide, or around 4.8% of the total population (Figure 4). If current growth rates continue, the number of users worldwide will reach 300 million before the end of 2000. However, there are strong disparities across regions. While the United States accounts for more than half of all users, Europe and, to a lesser extent, the Asia-Pacific region are growing at faster rates.

Figure 4. **Breakdown of worldwide Internet users[1] by region, September 1999**



Total number of users: 201 million

1. Users refers to adults and children having accessed the Internet at least once in the previous three months.
Source: Nua Internet Surveys <http://www.nua.ie>.

Data from private sources on usage by country also show disparities among OECD countries: the Nordic and English-speaking countries have the highest share of Internet users (more than one person in six), while other European countries tend to lag behind: around 12% on average for Europe, compared to around one in three for the United States (Morgan Stanley Dean Witter, 1999). Appendix Table 2 presents somewhat outdated figures which show that certain non-member economies such as Singapore, Hong Kong (China) and Israel have higher penetration rates than many OECD countries.

Households

The statistical profiles (Annex 1) provide a great deal of detail on the diffusion of various ICTs in homes and business. Table 4 presents a compilation of recent data from official sources on households' access to PCs and the Internet.

Table 4. **Diffusion of PCs and the Internet in households in selected OECD countries**

Percentage of households (or population) with access

	Access to PCs			Access to Internet		
	Percentage	Share of	Date	Percentage	Share of	Date
Australia	45.9	HH	Aug. 1998	40.0	P 18+ (W H)	May 1999
Canada	36.0	HH	1997	13.0	HH	1997
Denmark	52.0	HH	Early 1999	31.0	HH	Early 1999
Finland	42.0	HH	Mar. 1999	22.0	HH	Mar. 1999
France	19.0	HH	June 1998	10.0	P 15+	Apr. 1999
Italy	17.5	HH	1997	2.3	HH	1997
Japan	25.8	HH	1999	14.9		
Norway	50.0	P (H)	1997	13.0	P (H)	1997
Sweden	68.0	P	1997			
United Kingdom	58.0	P 15+	1998	28.0	P 15+	1998
United States	42.1	HH	1998	26.2	HH	1998

Key: HH = Households.
P = Population.
(H) = At home.
(W) = At work.
15+ = age 15 or older
18+ = age 18 or older

Source: National statistical offices.

As Figure 5 shows, other sources estimate even higher penetration in households, with PCs available in more than half of all households in seven OECD countries.

Businesses

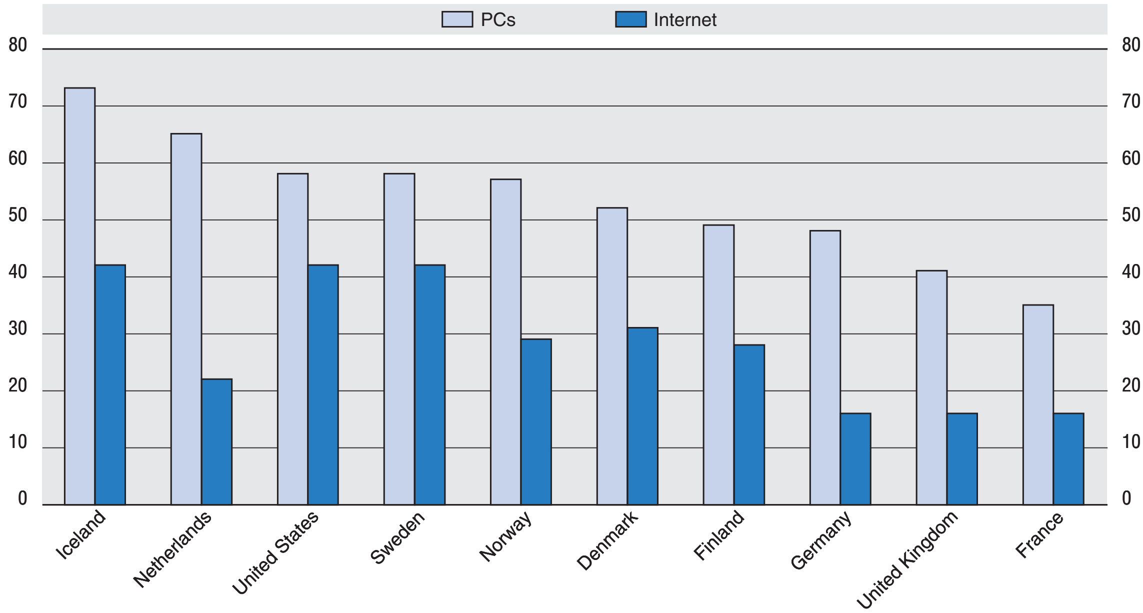
Although all reports agree that electronic commerce is expanding rapidly, the lack of common definitions makes comparisons difficult. The International Data Corporation (IDC) estimates that electronic commerce reached USD 111 billion worldwide in 1999 and will increase to USD 1.3 trillion within four years (USIC, 1999).[3]

The share of the business-to-business segment of e-commerce is the largest, with 70-85% of total revenues. Adoption of e-commerce models and technologies differs among countries as well as sectors, and North American companies continue to be the main users. In Europe, the United Kingdom, Germany and France are also investing heavily in Internet-based business-to-business software and applications (OECD, 1999*f*). Figure 6 presents the results of a recent survey which shows that, even among G7 countries, there is wide variation: more than six out of ten employees in US firms used one of these technologies, compared to one in three for Italy.

Payments

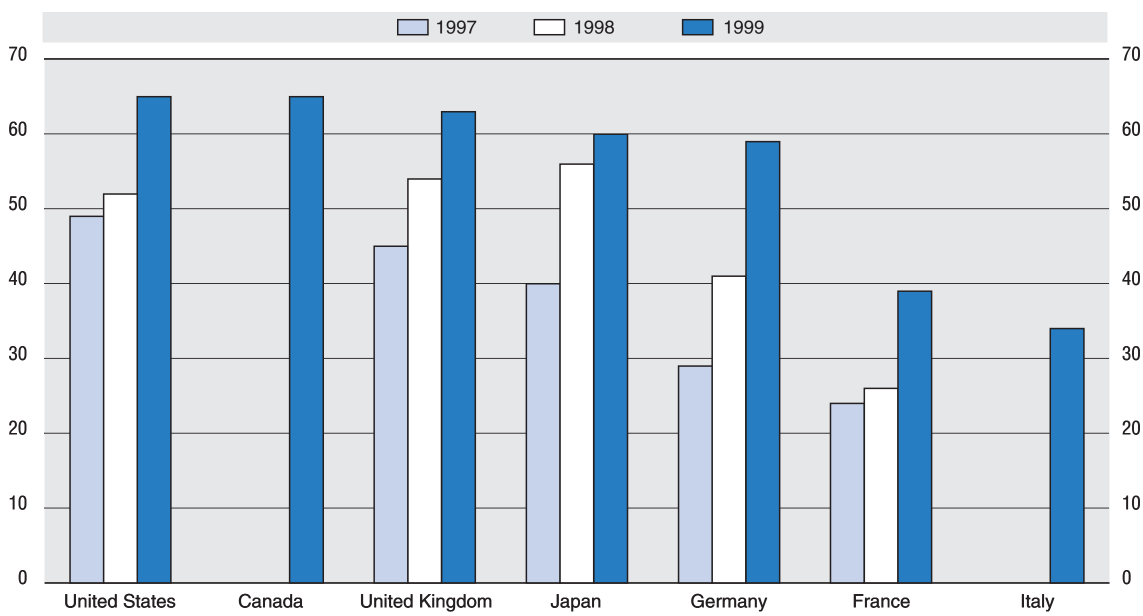
Table 5, which provides some background data on the use of electronic means of payment in various OECD countries, shows that although these technologies are being used more, the propensity of individuals

Figure 5. **Access to PCs and Internet in households, early 1999**
Percentage of households



Source: Gallup A/S, 1999, in Danish Ministry of Research and IT (1999).

Figure 6. **Percentage of employees using e-commerce-enabling technologies**[1]



1. E-commerce enabling technologies are Web site, frequently used EDI, or external e-mail.

Source: Spectrum Benchmarking Study – 1999, in UK Cabinet Office (1999).

Table 5. **Use of cashless payment instruments in selected OECD countries, 1993 and 1997**

Percentage of total volume of cashless transactions

	1993			1997		
	Cards	Credit transfers	Direct debits	Cards	Credit transfers	Direct debits
Belgium	17.1	60.0	8.9	23.4	58.0	9.8
Canada	31.1	5.2	5.0	48.8	8.4	6.7
France	15.7	15.4	10.6	19.5	15.7	12.1
Germany	2.6	45.6	43.7	4.1	48.2	42.0
Italy	4.1	44.6	4.4	11.2	41.6	8.6
Netherlands	3.1	61.3	24.4	18.2	51.7	27.1
Sweden	9.8	84.5	5.7	18.9	72.1	7.1
Switzerland	13.8	80.1	2.8	22.8	72.3	3.6
United Kingdom	21.0	20.4	15.6	31.1	19.6	18.7
United States	17.5	1.9	1.0	23.0	2.5	1.3

Source: BIS (1998).

and firms to use them varies widely.[4] Nonetheless, cards (credit, debit and charge) are used more and more frequently as a means of payment in all countries: in France, Switzerland and Italy, notes and coins accounted in 1997 for less than one-sixth of narrow money (M1) (BIS, 1998).

Online banking has been growing very rapidly: in the United States, it is estimated that in 1998 3.7 million households used online services such as banking and stock trading. This figure is expected to reach 7.2 million by 2000 and 22 million by 2003 (Forrester Research in USIC, 1999).

A "*digital divide*"?

As computers and ICTs continue to penetrate households, there has been concern in many countries not only that access is unequal but that the gap may be widening (NTIA, 1999). This section examines data from various OECD countries on access to PCs/Internet, broken down by four socio-economic variables (income, education, age, household type) which have a strong influence on uptake.

Income

Income continues to be a strong determining factor in the presence of PCs in homes. Figure 7 gives recent data for France, Japan and the United States which show wide disparity in PC penetration rates for different levels of income. Data from several OECD countries show that workplaces and (increasingly) homes are the most frequent locations for accessing the Internet, but that for lower income groups (and for the unemployed), schools and libraries also serve as important connection points (Statistics Canada, 1999; NTIA, 1999).

Education

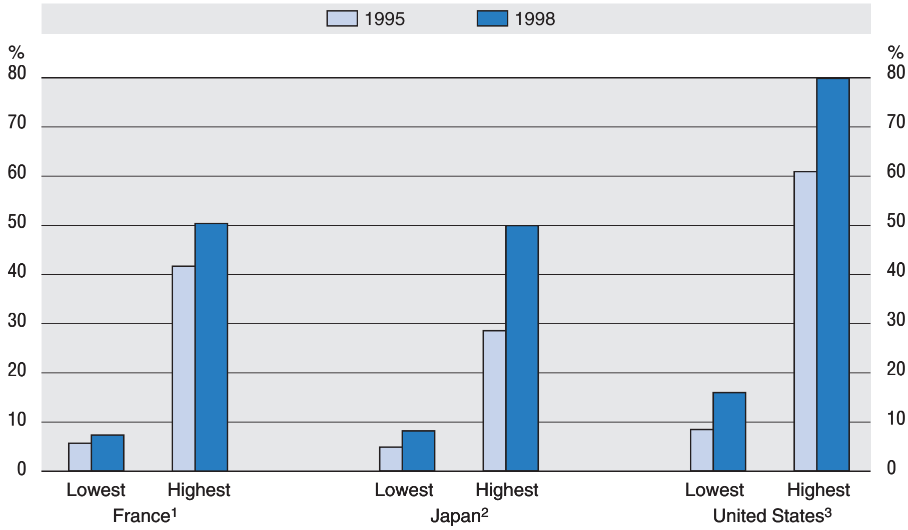
Through its effect on income, education continues to be a strong differentiating factor. Figure 8 presents data for Canada which show that, in 1998, households where the head completed a university degree are twice as likely to use a PC as those where the head only completed a high school/college degree, and more than seven times as likely than those where the head was without a high school diploma. Nonetheless, as with other income-correlated variables, the continuing drop in prices has contributed to narrowing the gap.

Age

As expected, older people tend to use PCs and the Internet less frequently than younger people. Figure 9 shows use of the Internet by various age groups in Australia in 1998 and 1999. Usage is growing at a faster pace among the youngest age group (18-24).

Figure 7. **PC penetration by household income in selected OECD countries, 1995 and 1998**

Percentage of households with a PC

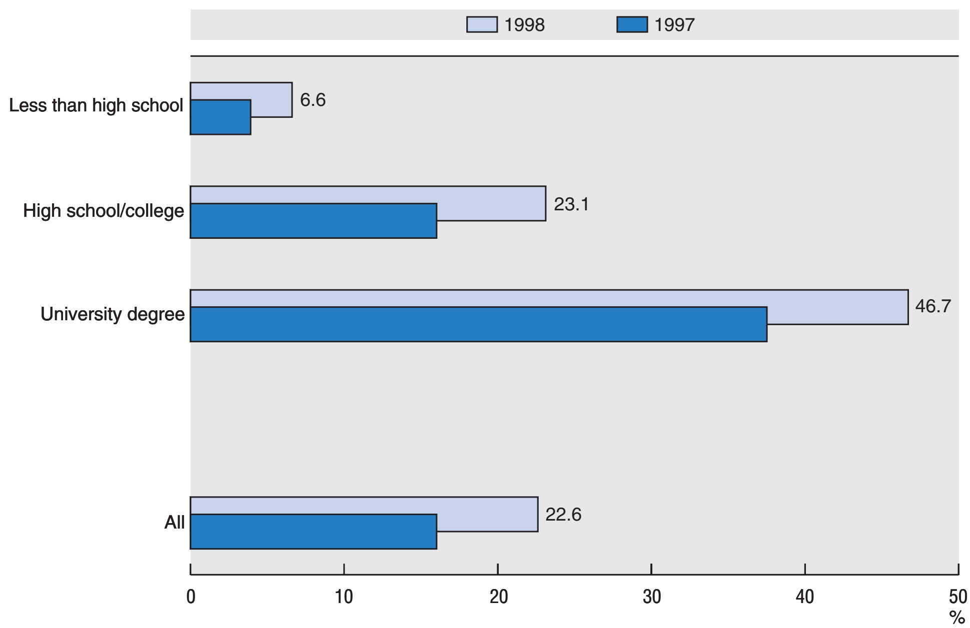


1. Lowest income bracket: less than USD 4 600; highest: more than USD 70 000. Income data were converted to USD using PPPs.
2. Lowest income bracket: less than USD 9 100; highest: more than USD 73 500. Income data were converted to USD using PPPs.
3. Lowest income bracket: less than USD 2 500; highest: more than USD 75 000. Income data were converted to USD using PPPs.

Source: OECD, based on data from INSEE (France), EPA (Japan), and US Department of Commerce.

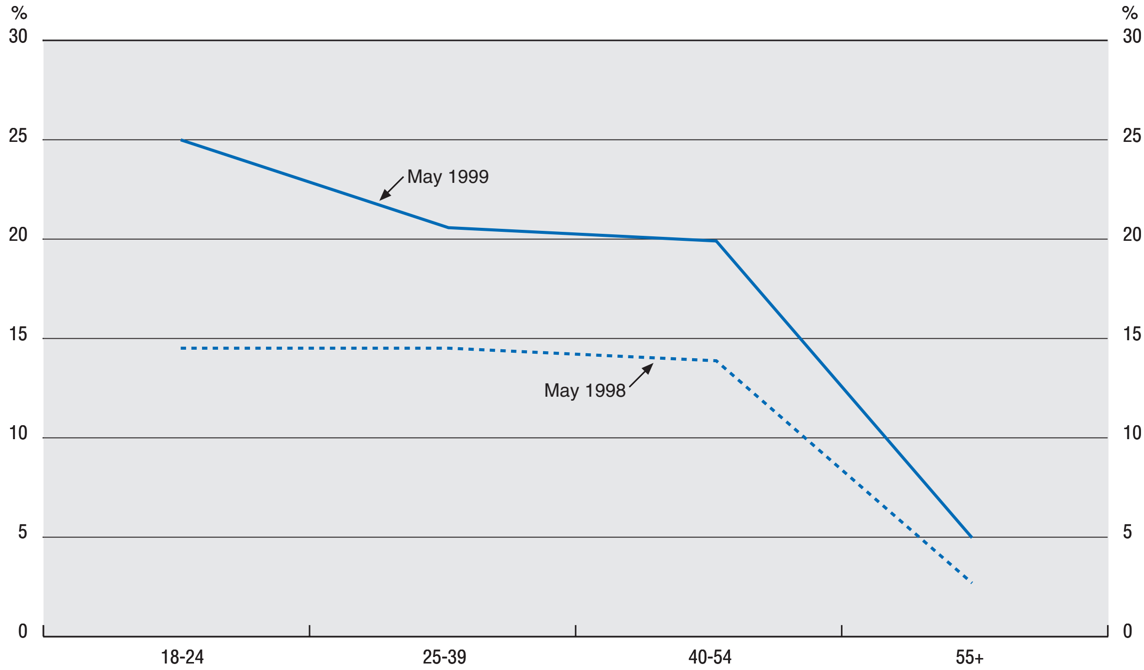
Figure 8. **Canadian households regularly using a computer by educational level of the head of household, 1997 and 1998**

Percentage of households



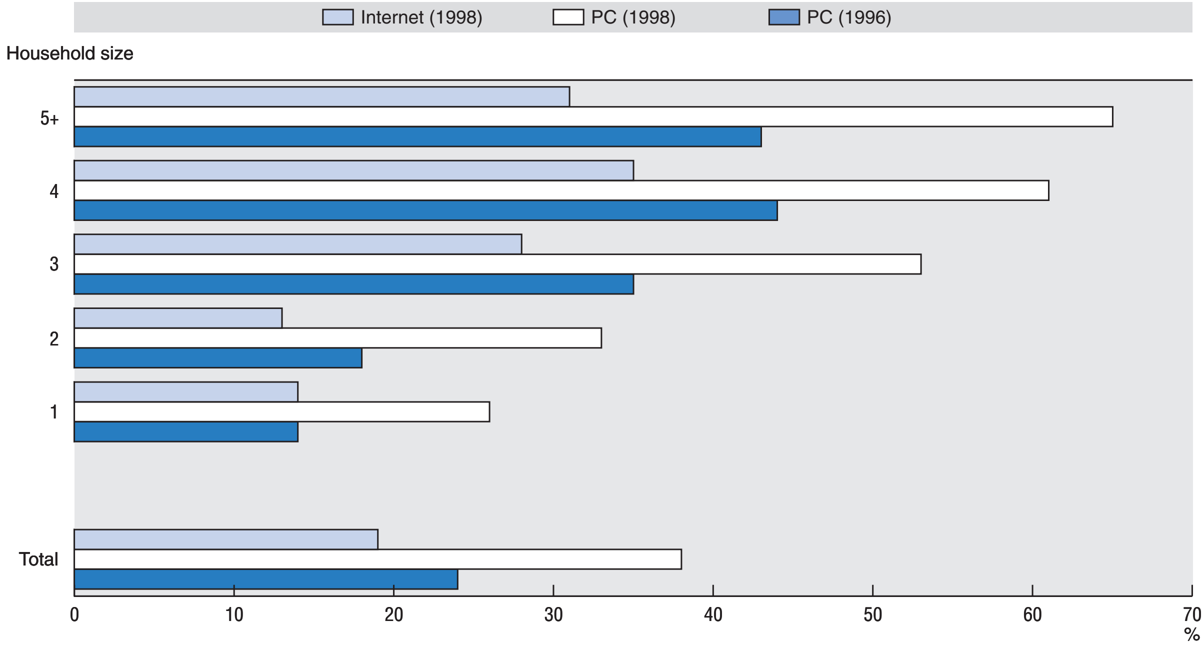
Source: Statistics Canada (1999).

Figure 9. **Adults[1] accessing the Internet in Australia by age, 1998 and 1999**



1. Refers to people having accessed the Internet in the previous 12 months.
Source: ABS (1999).

Figure 10. **Percentage of households in Finland with access to PCs and the Internet according to household size, 1996 and 1998**



Source: Statistics Finland, Consumer Surveys.

Household type

Households with children tend to have higher penetration rates than those with one or two members. Figure 10 shows that in 1998 in Finland, one-quarter of single-person households had a PC, compared to more than half of households with three persons, and almost two-thirds of those with five persons or more. There is less difference for Internet access, but it is still significant, varying between 13% for two-person households, and 35% for those with four persons.

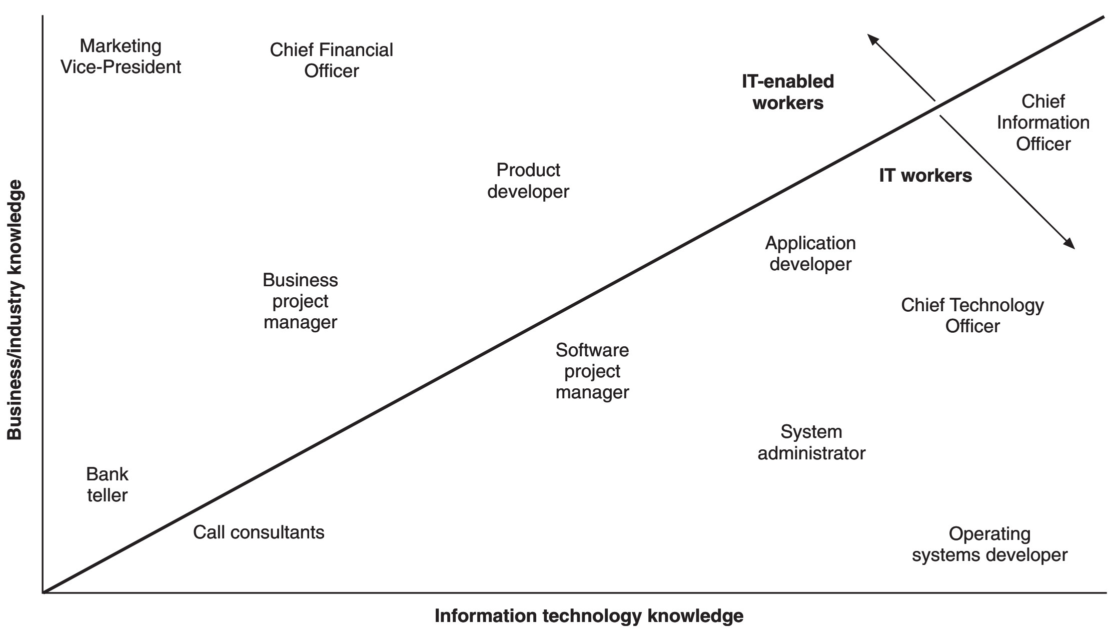
These data suggest that since some social groups (low income households, the unemployed) cannot afford PCs and Internet access, public access points will contribute to narrowing the "information gap".

Human resources

In addition to available infrastructure and access technologies, individuals must have the skills necessary to participate in the Information Society. Two related sets of issues will affect the adoption of e-commerce: *i)* the supply and the potential shortage of IT workers; and *ii)* the need for IT skills – "IT-enabled" workers – in various occupations throughout the economy (Figure 11). This section looks at three types of data relating to the shortage issue: unemployment rates, wages and graduates. It also highlights the need for governments to focus on developing skills for the new economy.

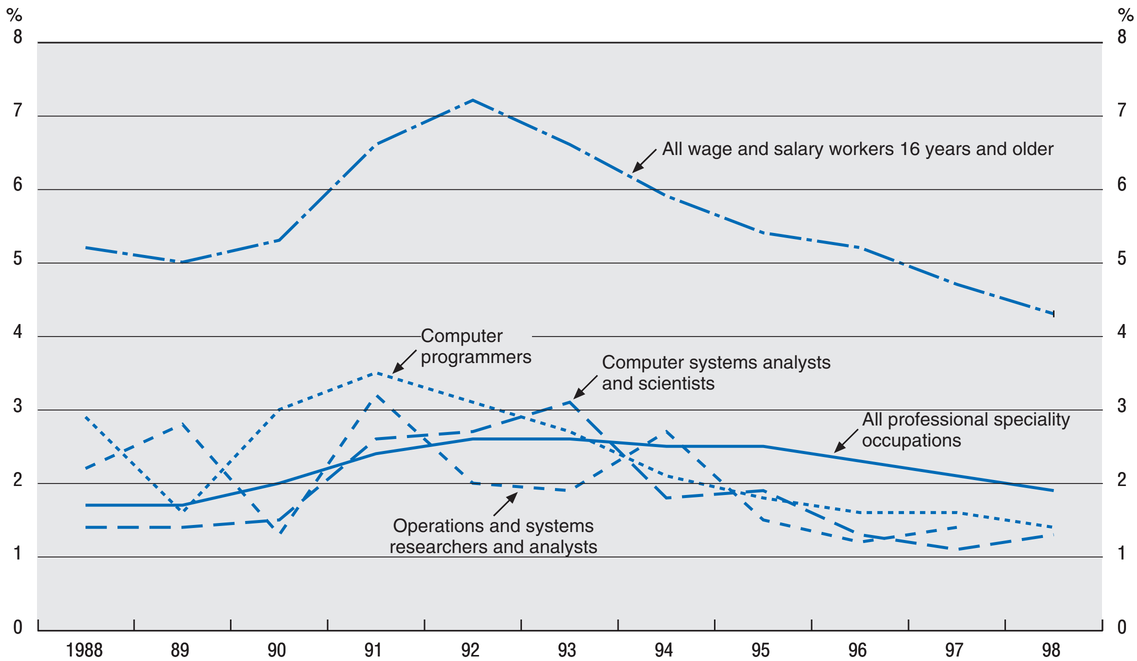
In various OECD countries, particularly the United States, there is concern that the supply of IT professionals is insufficient to meet current and future demand. Various studies by public and private sources explore the reported difficulties in recruiting IT workers, particularly in core IT occupations such as computer science, electrical engineering, software design and systems analysis. Although the analysis below largely focuses on the United States, there is concern about possible labour shortages in countries such as France, Canada, the United Kingdom and Ireland as well.[5]

Figure 11. **IT workers and IT-enabled workers**



Source: Computer Research Association, in Freeman and Aspray (1999).

Figure 12. **Unemployment rates for IT and other workers in the United States, 1988-98**



Source: Freeman and Aspray (1999); US Bureau of Labor Statistics, 1999.

In the past several years, many US employers have reported difficulties in recruiting and retaining highly skilled IT workers. There have been a number of studies exploring these reported difficulties (ITAA, 1998; OTP, 1997; GAO, 1998; Lerman, 1998; Freeman and Aspray, 1999). Many ideas have been put forth to increase the pool of IT workers using a variety of means such as creating public/private partnerships, reforming education and training programmes, and increasing temporary immigration. IT skills represent an important issue for policy makers and better data are needed to understand the dynamics of this portion of the labour market.

US data on unemployment show that while unemployment rates are significantly lower for IT workers than for many other occupations (three to four times lower during the 1990s), this is not a new trend. These rates are generally in line with rates for other professionals (Figure 12). The results suggest a tight IT labour market (similar to the overall market for highly skilled workers) but do not support the hypothesis of a severe (and increasing) shortage.

US data on wages are also inconclusive. Earnings of IT workers have grown at a rapid pace in the last ten years (Table 6) but not significantly faster than those of other professionals. Although these results

Table 6. **Salary growth for IT and other occupations in the United States, 1988-97**

Occupation	Percentage change in salary 1988-97
Computer systems analysts and scientists	36.2
Operations researchers/systems analysts	28.4
Computer programmers	42.9
All professional occupations	35.1
All workers with four or more years of college	33.2
All workers 16 years old and older	30.6

Source: Freeman and Aspray (1999).

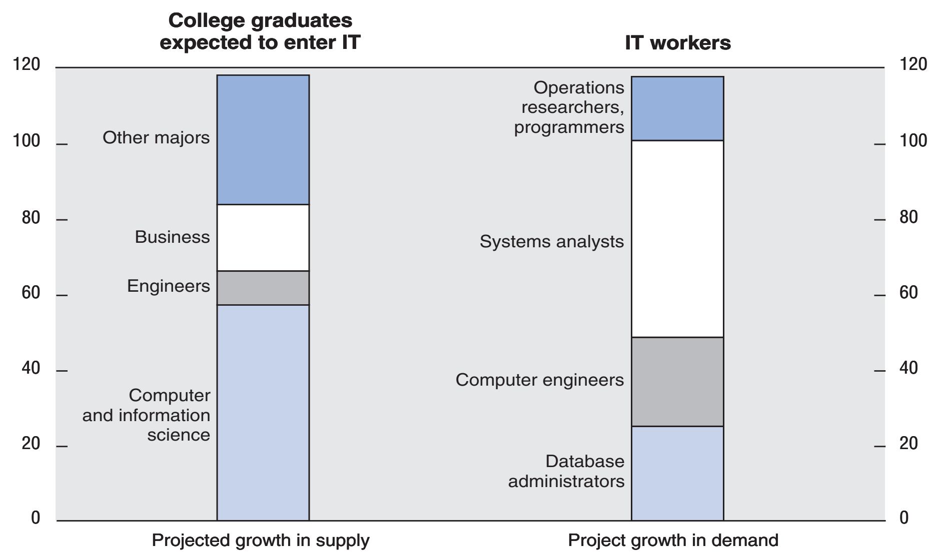
might undermine the argument for a skills shortage, these data are also subject to certain shortcomings. For example, they are derived from wage data and do not take into account the stock options and signing and other bonuses which are increasingly used to attract highly skilled workers. In addition, they may hide wide variations within occupations due to differences in work experience; during periods of rapid growth and insufficient labour supply companies may hire workers with lower levels of qualification (and/ or less experience), thereby slowing average wage growth. Surveys from private sources do suggest strong wage inflation in IT occupations, particularly those in highest demand, *i.e.* those related to new growth areas such as the Internet or information security specialists.

Data on the supply of graduates in IT fields also paints a mixed picture. It is estimated that among the 1992-93 cohort of college graduates, only one-third of those with jobs in computer science or programming had undergraduate degrees in computer or information science (Lerman, 1998). Fully 28% had business degrees, and almost 20% had engineering or science degrees (excluding social sciences). It is true that the number of graduates in IT fields has declined in recent years and that a growing number of computer science graduates are moving towards non-IT fields (mainly finance and other services). However, many observers feel that the supply of graduates should be sufficient to fill IT positions if salaries are attractive enough. In the past three years, bachelor-level enrolment in leading US computer science and computer engineering programmes more than doubled. Figure 13 presents a set of projections showing that a large gap between expected supply and demand is unlikely.

A growing body of evidence thus seems to suggest that despite a tight labour market, there may be no real shortage or at least it may be smaller than sometimes described. These results also highlight the need to develop better definitions of what constitutes an IT worker and how to measure IT skills. Given the rapidly changing environment, many IT jobs require specific skill sets, specialised knowledge and professional experience which many prospective job seekers might not possess. It is therefore difficult to draw conclusions about shortages without better understanding of skill mismatches.

Figure 13. **Expected annual demand for IT workers and sources of supply in the United States**

Annual growth in thousands, 1996-2006



Note: These data depict net demand for workers resulting from new job growth in each occupation and do not include replacements for workers leaving. The BLS estimates that around 245 000 such workers will be needed (over the 10-year period) for these occupations (excluding operations researchers).

Source: Lerman (1998).

Nonetheless, certain policy actions, such as the initiatives recently launched in several OECD countries, might usefully address the tightness of the current labour market and the problem of the supply of potential IT workers. For example, industry-university collaborative programmes encourage students to choose IT fields when they graduate. Internships and apprenticeships can also be used to inform students about the possibilities offered by jobs in IT fields. High school and university curricula can be re-examined to take into account the multi-disciplinary skills (including science and business) required for today's (and tomorrow's) jobs. Better information about the labour market could also encourage students to choose science and technology fields (OTP, 1999).

In addition, there is the issue of training and the need for IT workers to maintain up-to-date skills to meet the industry's needs. Schemes such as company training programmes, private training centres, traditional academic institutions and certification supplied by vendors are being implemented. The high salaries paid to IT specialists, which lead in many cases to rapid employee turnover, may discourage firms from investing in lifelong learning and other incentives for their workers. Nonetheless, many firms have developed strong programmes which yield positive results: for example, Lockheed Martin Corp., working with local colleges and universities, has been running a two-year programme involving 500 engineers, (OTP, 1999).

Many OECD countries are addressing the IT skills issue through broad nation-wide initiatives. In 1999, following recommendations from the Expert Group on Future Skills, Ireland's government committed IEP 95 million to addressing problems related to skills shortages (Forfás, 1999). The United Kingdom has recently announced a series of initiatives to foster better IT skills in the workforce (UK Cabinet Office, 1999). The Danish Ministry of Education has launched several initiatives to foster the development of IT skills in schools and other learning centres (Danish Ministry of IT and Research, 1999). Various programmes aimed at different segments of the IT skills spectrum are being implemented in the United States (US DOC, 1999).

Conclusion

The readiness of OECD economies to reap the benefits of the e-commerce revolution can help determine their future growth patterns. Given the current the lack of common definitions for surveys, the measurement of e-commerce poses serious problems; however, governments are looking closely at the readiness of individuals and firms to participate in the "digital economy". The combination of rapid infrastructure development, improved performance, lower prices and new applications is fuelling the growth of electronic commerce applications in businesses and households. Although uptake has been very rapid in many countries, access and usage are not equally distributed. Income and education remain strong differentiating factors, but their importance may be declining in some countries as prices continue to drop. With regard to human resources, the tight labour market for IT professionals has been an issue of concern in some OECD countries, but a severe shortage appears unlikely. Nonetheless, governments need to continue focusing on longer-term solutions for raising their citizens' overall IT skills so that they will be able to participate in the Internet economy.

NOTES

1. An Internet host is a domain name that has an IP address (A) record associated with it. It would be any system connected to the Internet (via full or part-time direct or dial-up connection) (Internet Software Consortium, <http://www.isc.org>). A Web page is an individual file, while a Web site is made up of various pages. For additional information, see the Web Characterization Terminology and Definitions Sheet of the World Wide Web Consortium (W3C): <http://www.w3.org/1999/05/WCA-terms/>.
2. Nonetheless, some caveats should be observed when using this indicator. Since it measures hosts, it should only be considered as a lower bound estimate on the "size" of the public Internet. In addition, generic Top Level Domains (gTLDs) such as .com or .org have been redistributed according to registration data which may be imprecise. The adjusted data provide a better estimate of the number of hosts per country than do country code TLDs (such as .ca for Canada or .fr for France).
3. A study conducted by the University of Texas and sponsored by Cisco estimates that e-commerce revenues for US-based firms reached almost USD 102 billion in 1998 and USD 170 billion for 1999 (Internet Economy Indicators, 1999). The use of a broader definition of e-commerce (which includes the "intermediary layer") raises the 1999 estimate to USD 250 billion.
4. Chapter 4 examines in greater detail the issue of electronic financial transactions.
5. For Canada, see, for example, the Information Technology Association of Canada (ITAC) (1999) estimate of a shortage of up to 30 000 positions. In the United Kingdom, a 1999 report quotes a forecast from a private sector source of 80 000 vacancies by 2002 (UK Cabinet Office, 1999). Anecdotal evidence on shortages of IT workers has also been presented in France: currently, there would be about 10 000-25 000 vacancies, with the total increasing to 61 000 by 2005 (Pierre Audoin Conseil, 1999). OECD (1999a) summarises available estimates for various other countries along with anecdotal evidence on possible shortages (see Annex 4.5).

Appendix

Table 1. **Cellular mobile subscribers per 100 inhabitants, 1997-98**

	1997	1998
Finland	45.6	57.8
Norway	38.4	48.4
Sweden	35.8	46.4
Iceland	24.0	38.3
Japan	30.4	37.6
Italy	20.5	35.8
Denmark	27.5	33.5
Australia	26.0	31.8
Portugal	15.4	31.4
Korea	15.1	30.3
Austria	14.3	27.3
Ireland	14.4	26.5
United Kingdom	14.3	25.5
United States	20.4	25.3
Switzerland	14.4	22.8
OECD	**15.6**	**22.4**
Luxembourg	16.1	22.3
Netherlands	10.8	21.3
Greece	8.6	19.5
New Zealand	13.1	19.3
France	9.8	19.1
Spain	10.9	17.7
Canada	14.1	17.6
Belgium	9.6	17.1
Germany	9.9	16.9
Hungary	7.1	10.8
Czech Republic	5.1	9.4
Turkey	2.6	5.5
Poland	2.1	5.0
Mexico	1.9	3.4

Source: OECD Telecommunications Database.

Table 2. **Internet users as a percentage of the total population in selected OECD countries and non-member economies, 1998**

	Percentage
Iceland	32.0
Finland	30.5
Norway	30.4
Sweden	29.0
United States	28.3
Australia	23.4
Canada	21.2
New Zealand	18.0
Denmark	17.9
Singapore	14.0
Switzerland	13.8
United Kingdom	13.7
Netherlands	12.5
Hong Kong, China	9.9
Israel	9.6
Germany	8.6
Belgium	7.7
Ireland	7.2
Austria	6.6
Spain	5.0
France	4.7
Italy	3.7
Portugal	2.5
Greece	2.2

Source: Computer Industry Almanach, <http://www.c-i-a.com>.

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P*art* II

IT POLICY SPECIAL FOCUS – ELECTRONIC FINANCIAL TRANSACTIONS

Chapter 4

OVERVIEW OF ISSUES IN ELECTRONIC SETTLEMENT OF PAYMENTS

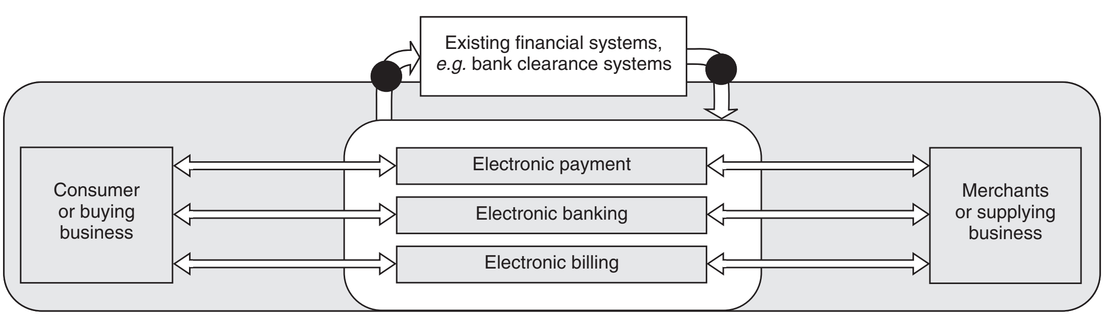
If electronic commerce is to flourish, there must be a secure, reliable and user-friendly infrastructure that allows settlement of online transactions. Currently, there is some uncertainty and confusion regarding payment methods for such transactions. This comes, in part, from the fact that it is difficult for average consumers to understand how safe these methods are, in terms of technological reliability as well as protection of privacy and personal data and consumer protection.

This chapter provides an overview of the technological and policy issues surrounding electronic settlement of payments as defined below, including potential barriers to their development, as a basis for the analysis in the following chapter, which outlines various government IT policies to promote electronic settlement of payments.

Three modes of payment are considered: electronic payment, electronic banking and electronic billing. While the boundaries separating these three modalities are increasingly blurred, they can be described as follows. Electronic payment consists of payments made through use of credit cards over the network and through various forms of electronic money and electronic cheques. Electronic banking consists of telephone banking, online banking (use of dedicated software to access banks' computer servers) as well as the emerging Internet banking. Finally, electronic billing refers to presentment and payment of bills over the Internet. In addition to the above, the chapter will also look at electronic money being used for transactions at physical stores, as this has great potential for use in online transactions as well.

This chapter is limited to the shaded area indicated in Figure 1, essentially to the settlement interface between the merchant (supplying business) and the purchaser (consumer, or business in the case of business-to-business electronic commerce). The link between the providers of various modes of electronic payment (e-payment, e-banking and e-billing) and the existing financial networks is not

Figure 1. **Scope of the analysis**



Source: OECD.

addressed, unless it forms an integral part of the e-payment/e-banking/e-billing services, as in the case of electronic cheques, where automatic clearinghouses (ACH) play an important role. It is assumed that this aspect of the transaction remains more or less the same as in traditional payment modalities and does not add any issues that are specific to online payment. Also, value-added services such as electronic trading of stocks (often referred to as electronic trading), financial information services or electronic sales of insurance policies are excluded, as they are viewed as services sold rather than enablers.

The following sections attempt first to identify the criteria for analysing various types of electronic financial transactions. Next, an overview is provided of the current state of electronic settlement of payments, including available technologies and their current use. A final section offers insight into the technological and policy issues that may emerge in the future.

Issues pertaining to electronic settlement of payments

Many factors influence the current development of electronic payment and raise potential barriers to its further use. It is therefore difficult to provide a comprehensive analysis. This issue has been extensively studied from a technological point of view. This chapter addresses the following issues: *i*) where and how payment takes place; *ii*) when payment is made; *iii*) who provides the settlement service; *iv*) between what parties the settlement takes place; and finally *v*) whether the transaction can be traced.

Where and how: real world versus virtual world

Whether a settlement system is available for use only in the virtual world or in both the real and virtual worlds may affect the extent to which that system develops. Systems may also face different regulatory regimes, an issue closely related to how settlement service is provided, *i.e.* whether there is a portable physical medium (such as a smart card) or whether the system relies solely on the exchange of data (which could be stored, for instance, on the user's computer hard disk). Differences in the medium also raise technology-related trust issues, such as the security of the hardware and software employed.

Currently, a number of electronic payment schemes exist, mainly for real-world transactions. The presence of a physical, portable medium characterises this type of settlement mode. While they are now largely used for physical transactions, there is ample potential for such systems to be used for online transactions. For a card, the issuer may connect the card's payment function with existing functions such as pre-paid function-specific cards (telephone cards, mass-transit cards) or credit cards.

Such "real-world only" applications can be transposed to the online realm by attaching specialised hardware, such as smart card readers, to personal computers on which businesses and consumers conduct transactions. The issue is not only the availability of the medium (the card) but also the need to ensure a level of security as high as that offered by terminals located at a physical merchant's location. There are other methods which are available both in real-world and virtual-world transactions, such as credit cards, banking and billing services.

Virtual-only systems circulate over the network data which are recognised by the recipient's system as having monetary value (electronic money) or contain payment instructions (such as electronic cheques). Both electronic money and electronic cheques exist only in the virtual world until they are sent to the service provider or a financial institution for redemption. In the case of electronic money, liquidity becomes an issue, so that the issuer of electronic money needs to hold enough physical money in reserve as a back-up. Virtual-only systems also allow for methods without an equivalent in the real world, such as micro-payments, which enable payment of a small fraction of a currency's denomination. These are primarily used in sales of individual pieces of information or services such as electronic journal articles, or for Internet games.

When: timing of payment

In the physical world, the timing of payment differs. Cash payments or transactions using debit cards are instantaneous (strictly speaking; debit cards that debit money only once a month should ideally be called charge cards), whereas the use of personal cheques or credit/charge cards imply a payment delay.

In some prepaid arrangements, where the provider of the good/service is the same as the issuer of the payment modality (such as for single-function cards), the provider of the good/service receives payment prior to the transaction. In other cases (such as travellers' cheques), the provider needs to redeem payment from the issuer of the mode of payment. Various regulations are in place to ensure that merchants can indeed receive payment and that consumers can be certain that the payment method is acceptable to the merchant or service provider.

In the online world, instead, for cash-like payment systems, the payment usually occurs prior to the transaction, as most of these systems are based on some type of prepaid arrangement using electronic purses which store monetary value that has been loaded onto a medium (card, hard disk). Consumers and merchants need to be certain that their pre-payment will be honoured, while providers need to be sure that multiple spending can be prevented.

In all electronic modalities based on online use of credit cards, payment takes place after the transaction. Here merchants bear the larger share of the risk. Risk increases in rapid network transactions, especially when the good or service can be provided online in digital form.

Payment at the time of transaction in a strict sense (corresponding to cash or debit-card transactions in the physical world) is more difficult online, except when using a debit card or some form of electronic billing that is more or less instantaneous.

Who provides: traditional players versus new entrants

Who provides, or who is allowed to provide, the payment service is an important question. In many countries, financial institutions, especially banks, are more tightly regulated than many other sectors. On the other hand, the recent move towards deregulation in the financial sector has allowed non-traditional players to enter this market. This leads to questions about competition between the more heavily regulated financial institutions and some newcomers such as information and communication technology (ICT) firms, whose technological know-how makes them well-placed to enter this market. Competition between incumbents and new entrants is fierce. International differences in financial regulations – the availability of universal banking, who can issue credits/loans – could also be a crucial issue.

Banks and other financial institutions are working hard to survive, as provision of services such as electronic billing by ICT firms begins to erode their market. While they have the know-how for providing financial services, they may not be at the forefront from the point of view of technology. An additional burden is the persistence of old IT systems, often based on mainframes and proprietary systems, for communicating with the outside world and among themselves. For instance, banks that operate on batch-transfer of data are finding it difficult to move into client-server systems that can provide real-time data to customers.

ICT firms are increasingly involved in "service content", including providing electronic payment/billing. As noted above, they have a technological advantage as well as, in some cases, a regulatory advantage in terms of their involvement in electronic financial transactions. While not directly related to the emergence of electronic financial transactions, specific services such as loan issuance are increasingly carried out by players such as auto manufacturers (*e.g.* General Motors), a sign of the erosion of the financial services market.

There are many cases of cross-sectoral co-operation between ICT firms and traditional players in the financial sector. Yahoo! Inc. recently established a partnership with BancOne and First Data Corp. to provide online payment services to merchants operating electronic commerce sites on Yahoo! Such cross-sectoral co-operation is further blurring the distinctions between sectors.

Between whom: business-to-business versus business-to-consumer

In terms of electronic financial transactions, the issues can be quite different for business-to-consumer or business-to-business electronic commerce. Businesses have specific, long-established methods for settling their financial transactions, electronic or otherwise. Also, unlike business-to-consumer transactions, a large part of business-to-business transactions is conducted between known parties, so pre-established trust removes some of the trust-related issues associated with business-to-consumer transactions.

A large share of business-to-business payments are conducted through existing financial institutions. This is also the case when they take electronic form. Many of these transactions are carried out using tools such as electronic banking or electronic billing. For transactions between trusted parties, financial electronic data interchange (EDI) is increasingly used. However, it is still unclear whether this method, when and if it moves to open networks (by using for example TCP/IP – transmission control protocol/Internet protocol), will be used for transactions with previously unknown parties.

In business-to-consumer electronic financial transactions, trust-related issues are most important. Currently, these transactions are mainly conducted using credit cards (either by transmitting card details directly using encryption or via telephone or fax once the order is placed, or a combination of the two). Electronic money and other forms of e-payment, such as those based on electronic cheques or electronic money, are emerging, but they remain relatively limited compared to the use of credit cards, in terms both of volume and of value. Electronic banking and electronic billing are starting to be used by consumers as well, but not yet for settling electronic commerce payments.

Tracing transactions: traceable versus anonymous transactions

For business-to-consumer electronic commerce, an important aspect of privacy and consumer protection issues is whether the transaction remains anonymous or a trace is kept in such a way that information concerning the parties and the amount and the nature of the transaction can be identified.

From the consumer's perspective, a balance needs to be struck between insuring the anonymity of the transaction and guaranteeing the security/integrity of the system. Consumers may want payments to be traceable when they require proof that payment has actually been effected but, under some circumstances, anonymity might be preferred.

This issue is of great importance to fiscal authorities as well. Unaccounted (untraceable/anonymous) payment systems could pose problems for tax authorities' task of identifying tax revenue sources. The "taxation framework conditions" welcomed by Ministers at the OECD Ottawa Ministerial Conference on Electronic Commerce singled out electronic payment as an area which tax authorities will monitor in connection with fiscal policies.

Current landscape of electronic financial settlements

This section first discusses the evolution of non-cash payments in selected OECD countries. An examination of existing non-cash payment systems provides an indication of the kind of mechanisms favoured by consumers and by regulators. It is assumed that the factors that may be influencing the pattern of non-cash payments would also have an impact on the evolution of electronic payment modalities. The analysis relies on data from the Bank for International Settlements (BIS). Finally, a discussion of the current state of electronic payment, relying primarily on private sources, describes various technological solutions and their use.

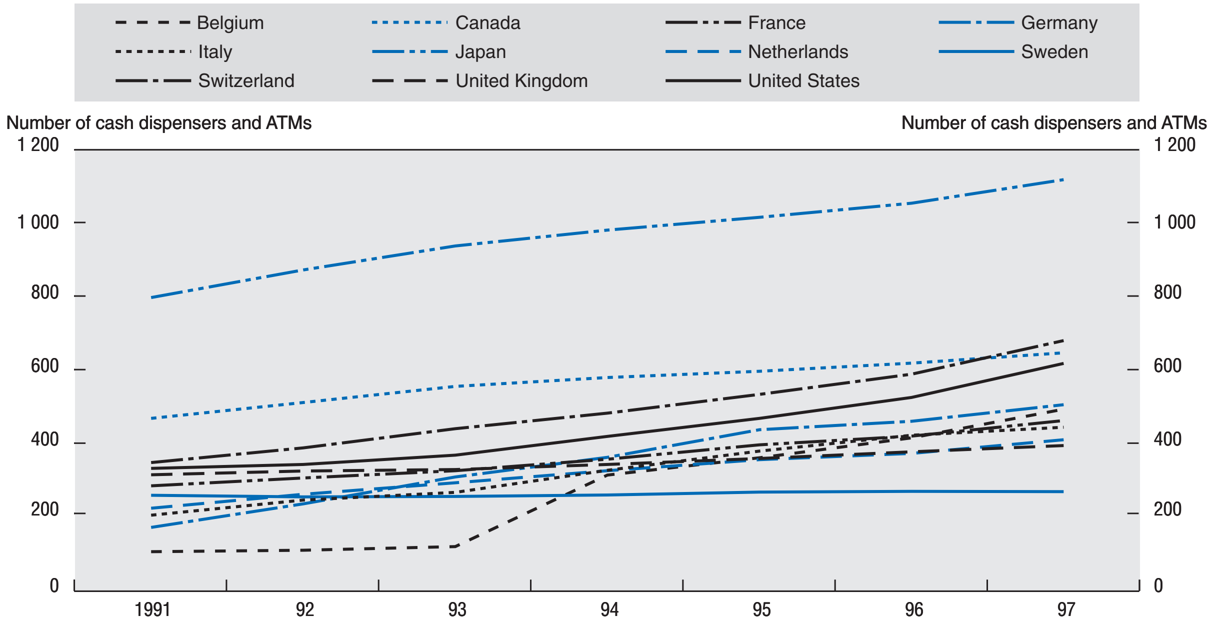
Evolution of non-cash settlements

Cash dispensers and automatic teller machines

While the penetration and use of automatic teller machines (ATMs) does not constitute an indicator of non-cash payments, Figures 2 and 3, which show time-series data on ATM penetration and use, give an indication of consumers' "use" of cash. For all countries, ATM penetration and use is rising. However, average value per transaction is either remaining constant or decreasing. In terms of frequency, the English-speaking countries, Sweden, and Netherlands have higher ATM use than other countries, but the average value of transactions is lower. On the other hand, in countries with very low frequency (Japan, Italy and Switzerland, with ten or fewer transactions a year) transactions have a higher average value. This cannot be explained by ATM penetration alone: while Canada and the United States have a higher than average

Figure 2. **Penetration of cash dispensers**

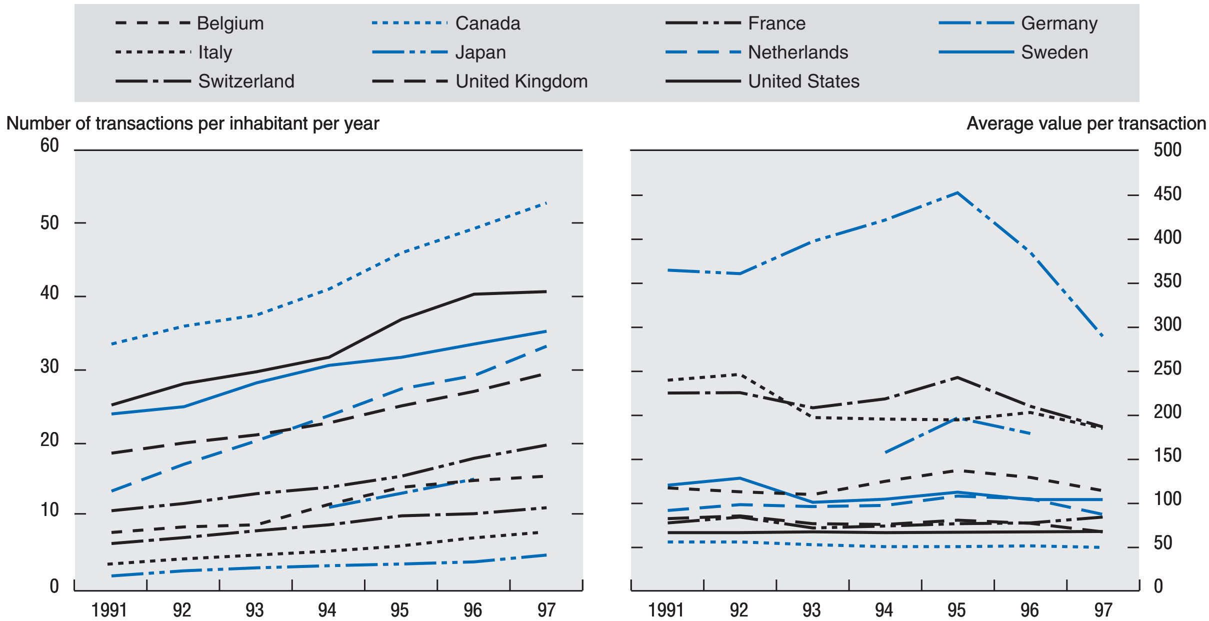
Number of cash dispensers per million inhabitants



Source : BIS, Statistics on payment systems in the Group of Ten countries.

Figure 3. **ATM usage**

Number of transactions per inhabitant per year and average value of transactions (USD)



Source: BIS, Statistics on payment systems in the Group of Ten countries.

penetration rate, Sweden has the lowest; Japan has the highest penetration rate with the lowest frequency of use. A possible explanation is that higher frequency of use means more convenience (lower usage charge, longer ATM operating hours, etc.) and more adequate alternative settlement mechanisms. The complex national patterns of penetration, frequency and value of transactions suggest that electronic payment will also have varying patterns of uptake and use across countries.

Credit cards

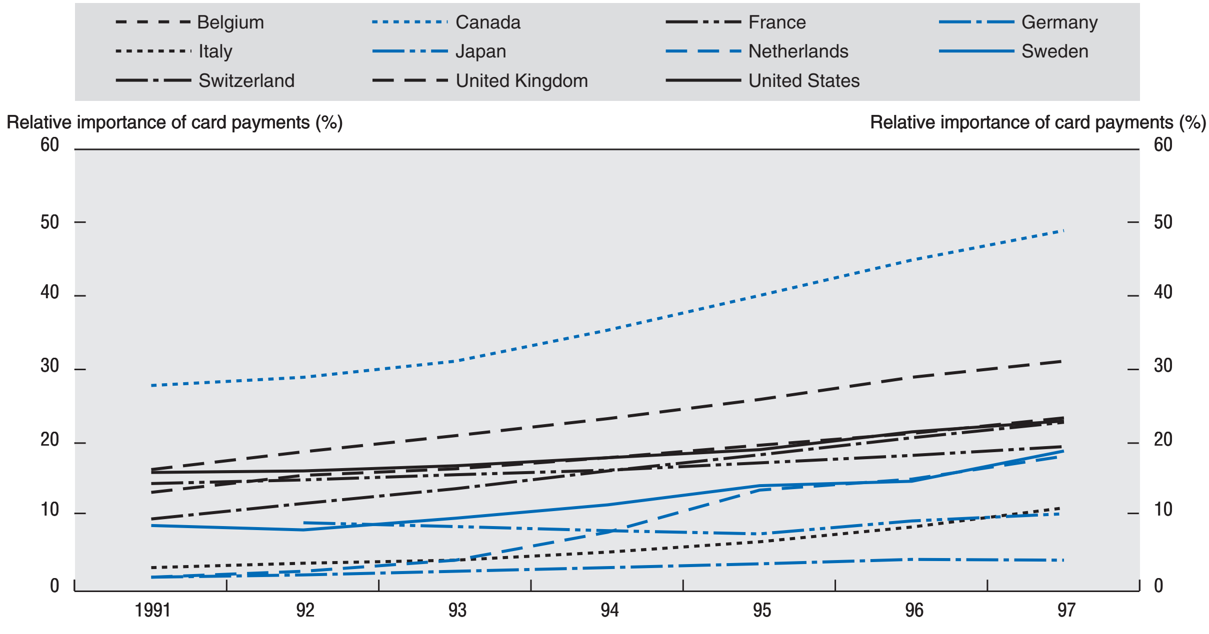
Figures 4 and 5 show the relative importance of non-cash payments (percentage of total non-cash transactions) by volume. When considering that electronic financial transactions are also a subset of non-cash transactions, current use of various non-cash transactions could give insight into the prospects for electronic financial transactions.

Figure 4 shows usage of card payments (including credit cards, debit cards and charge cards[1]). Canada, the United States, the United Kingdom and Belgium have card payment ratios of over 20%, while in Japan, Italy and Germany, 10% or less of non-cash transactions are carried out through cards. The difference in credit card usage pattern is likely to be reflected in online use of credit cards as well.

Cheques

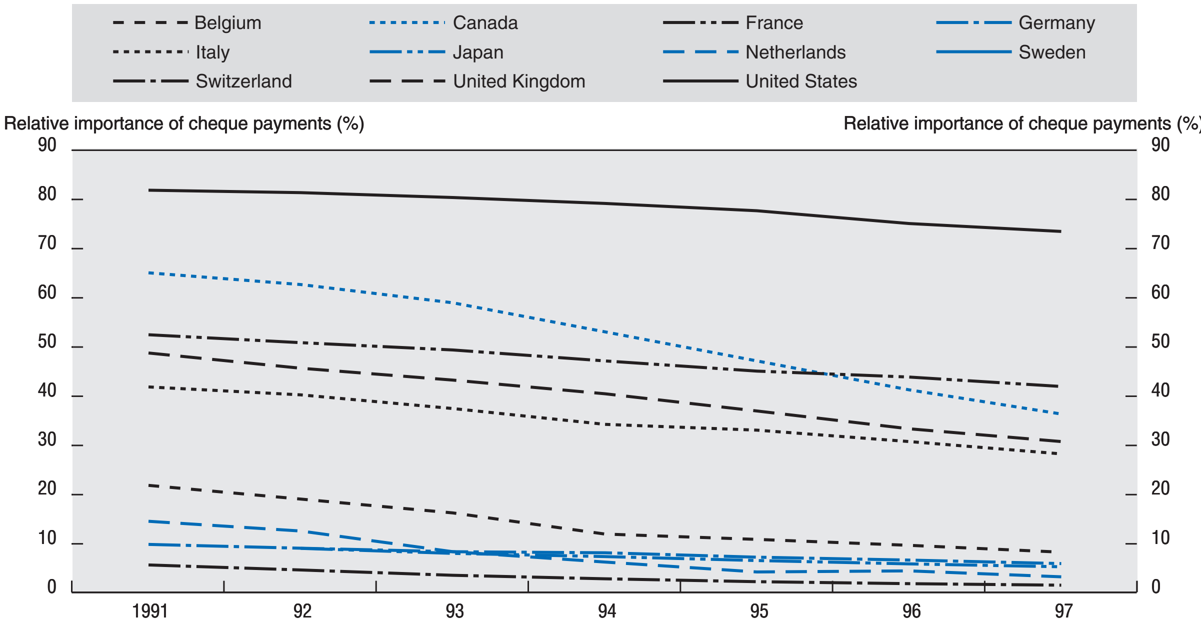
Figure 5 shows that the use of cheques is decreasing in all countries. The United States has a very high proportion of cheque usage (73.2%), France, Canada, the United Kingdom and Italy have a moderate usage of cheques (around 30-40%), while in the remaining countries less than 10% of non-cash payments are made by cheque.

Figure 4. **Share of card payments in total non-cash transactions**
By number of transactions



1. For Japan, OECD estimates are based on BIS figures. The 1992 figure is adjusted using an increase in the number of households.
Source: BIS, Statistics on payment systems in the Group of Ten countries.

Figure 5. **Share of cheque payments in total non-cash transactions**
By number of transactions



1. For Japan, OECD estimates are based on BIS figures. The 1992 figure is adjusted using an increase in the number of households.
Source: BIS, Statistics on payment systems in the Group of Ten countries.

Bank transfers

Bank transfers here include both credit transfers (each transaction is initiated by a user) and direct debits (the payee withdraws money directly from the payer's account). In general, a substitution between bank transfers and cheque usage can be observed. The countries with the lowest use of cheques (Belgium, Germany, Japan, Sweden and Switzerland) have the highest combined use of credit transfers and direct debits (between 67.8% for Belgium and 90.2% for Germany in 1997). In the United States, the country with the highest rate of cheque usage, only 3.8% of cash-less transactions are carried out through bank transfers.

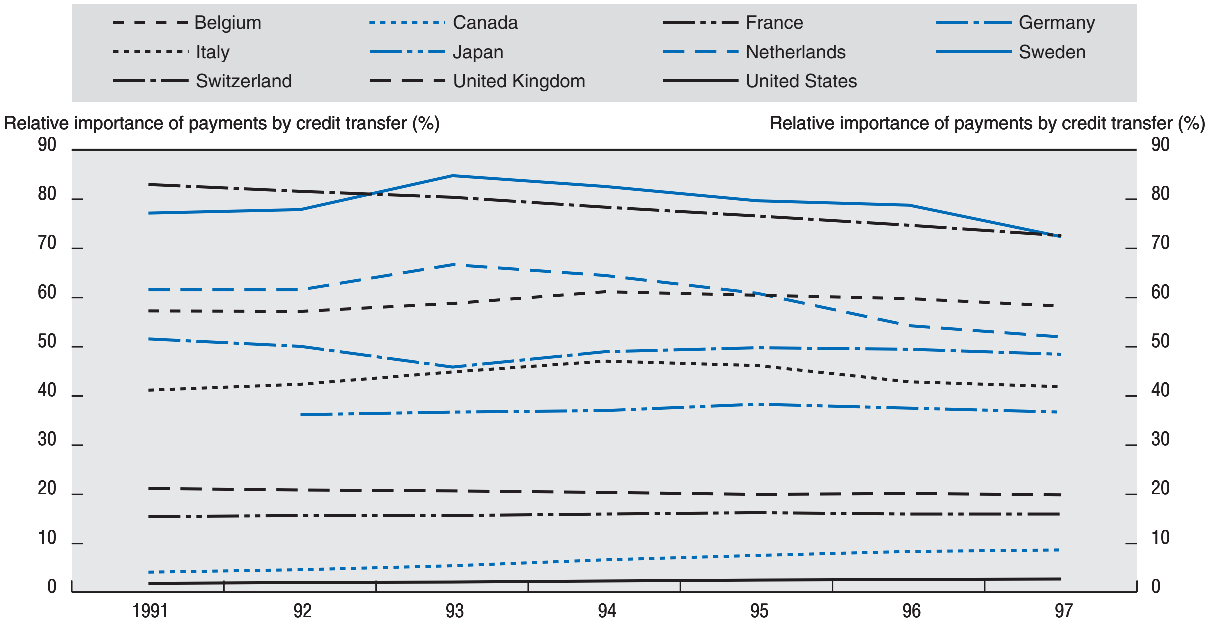
Figure 6 shows the share of credit transfers. It is highest in Sweden and Switzerland (above 70% in 1997). It is lowest in the United States, Canada, the United Kingdom and France (less than 20%). In other countries it is in the 30 to 60% range.

Figure 7 shows the use of direct debits. Most countries have 10% or less direct debit usage. This may be due to the fact that direct debits are mainly used for regular payments, such as utility bills or media (TV, newspapers, and magazines). Nonetheless, in Japan and Germany, over 40% of non-cash payments are conducted using direct debit. Changes over the years in the use of bank transfers among countries are less marked than for credit card use (increasing) and cheque use (decreasing). The level of usage has remained more or less constant or slightly decreased for credit transfers, while increasing slightly for direct debits.

Implications for electronic settlement of payments

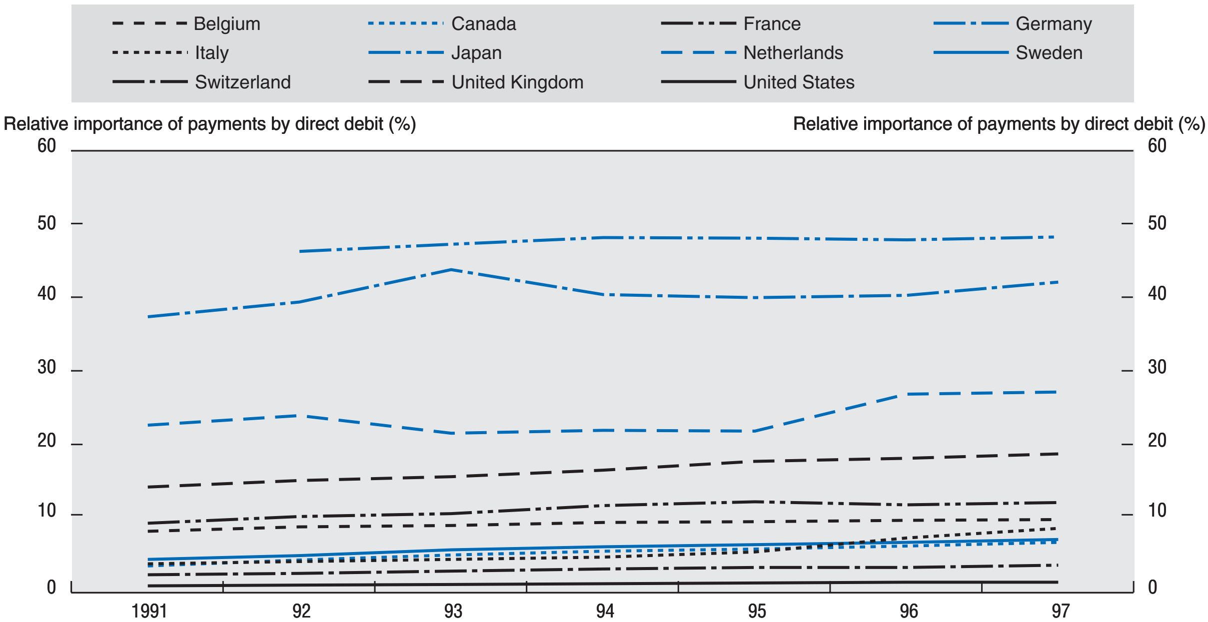
One can extrapolate actual as well as potential use of credit cards for electronic commerce from the share of credit card payments. Their increasing use in all the countries examined shows that credit cards

Figure 6. **Share of credit transfers in total non-cash transactions**
By number of transactions



1. For Japan, OECD estimates are based on BIS figures. The 1992 figure is adjusted using an increase in the number of households.
Source: BIS, Statistics on payment systems in the Group of Ten countries.

Figure 7. **Share of direct debits in total non-cash transactions**
By number of transactions



1. For Japan, OECD estimates are based on BIS figures. The 1992 figure is adjusted using an increase in the number of households.
Source: BIS, Statistics on payment systems in the Group of Ten countries.

may be the primary method used for retail online transactions, pending the development of alternative solutions. Countries with a high percentage of credit transfers may experience high use of electronic banking solutions when the proper infrastructure is in place. Instead of going to banks or post offices, consumers may be able to conduct these operations from their homes. Finally, cheque and direct debit usage may find a parallel in the emerging electronic billing. Therefore, countries with high levels of direct debit may switch more easily to electronic billing.

Some technical solutions and their prospects

Electronic money – electronic purse

In this system, a monetary value is stored on an electronic medium, be it a card (usually a smart card containing an IC chip) or a computer's hard drive. Because money is "stored", the system is often referred to as an electronic purse (or wallet), as opposed to electronic money, which refers to the software algorithm of the actual unit of monetary value. The terms "electronic money" and "electronic purse" are often used interchangeably, but an electronic purse can be understood as the medium in which electronic money is stored. If electronic money is installed on a portable medium such as a card, it can potentially be used in both the real and virtual worlds, but when stored on a hard drive, it can only be used for virtual transactions.

At international level, there are currently three main initiatives, led by the private sector: Mondex (United States, MasterCard), VisaCash (United States, Visa) and Proton (Banksys, Belgium). In addition, many experiments are being conducted at the national level, some of which use one of the above technologies, while others rely on technologies developed nationally, such as NTT's Supercash. In this area, a great deal of market consolidation is taking place. For example, Proton has a co-operation agreement with Visa. Box 1 shows some pioneering initiatives that have failed.

Box 1. **Failures of electronic money/purse schemes**

Together with the emergence of business-to-consumer electronic commerce, electronic money has attracted much attention as a method of payment, especially for transactions for which the use of a credit card might not be economical. Despite high initial expectations, many early entrants have either gone out of business or have changed their business model and are now providing payment services using credit cards.

DigiCash, based in the Netherlands and the United States, which developed *eCash*, completely anonymous and yet secure electronic money, filed for bankruptcy in the United States in November 1998. The system involved a technology that provided complete privacy while maintaining security of the system.

CyberCash which operated its electronic money *CyberCoin* to support Internet purchases of small amounts, has stopped supporting this platform since May 1999.

Several test-bed electronic purse experiments have also proven to be less successful than expected. VisaCash's experiment during the Atlanta Olympic Games and the VisaCash/Mondex Experiment in New York City proved relatively unsuccessful because of the low level of use. Analysts point out as main problems the lack of network effects (limited geographical scope) and the slowness of the system.

It would appear that an electronic money/purse scheme is not a prerequisite for electronic commerce. Currently, an overwhelming proportion of business-to-consumer electronic commerce uses credit card payment. At present, the driver for the development of e-money/purse schemes seems to be its use in small face-to-face transactions. Nonetheless, such a system might be favoured in sales of services for which a credit card transaction is not economical, or when consumers prefer the transaction to retain some anonymity.

Aside from the Proton system, implemented at full scale in Belgium in June 1999, e-money/purse is still at a stage where many pilot projects are being carried out.

Table 1. **Some numbers on electronic money/purse schemes**

Name of service	Numbers
Mondex	Pilot projects in more than 50 countries. Total of 1.5 million cards issued as of year-end 1998.
VisaCash	70 pilot projects in 31 countries in conjunction with financial institutions. Total of 22 million cards printed to date.
Proton	30 million cards and 200 000 terminals in countries with a Proton licence. In Belgium, 5 500 000 cards and 45 000 points of sale (POS) (December 1998). In June 1999, Proton was integrated into Belgium's Bank Card system (Bancontact/Mister Cash).

Source: Respective firms/organisations.

So-called "micro-payments" are one subset of electronic money. Millicent, developed by Digital (later purchased by Compaq) allows purchases of small-value items, such as a single article from a magazine. It is seen as a possible alternative to advertisement or subscription-based business models, but its penetration is still limited in scope.

Electronic money is not widely used in the United States. One possible cause is the low adoption of smart cards as compared to magnetic stripe cards for credit card transactions. In the United States, because of low telecommunication costs, credit card purchases can be cleared on the spot through an online connection with credit companies. Smart cards, on the other hand, store information on the chip which assists in clearing transactions that do not require establishing an online connection. Another reason for the slow adoption of smart cards in the United States is the fact that they can reduce by up to 80% the transaction fees that card-issuing banks collect.[2] In Europe, the higher cost of telecommunications has been a barrier to accessing the central server for every transaction; the need to develop a secure mechanism in the card led to the propagation of smart cards which are safer than magnetic stripe cards.

Credit cards

Credit cards are the preferred mode for settling business-to-consumer electronic commerce transactions. Security is the major issue arising from the use of credit cards to settle online payments. It can be addressed in two ways: *i)* through the use of SSL (secure socket layer), an encryption mechanism that is incorporated into Web browsers to encrypt credit card details; and *ii)* by replacing encryption or complementing its use with other mechanisms such as authentication (SET – Secure Electronic Transaction).

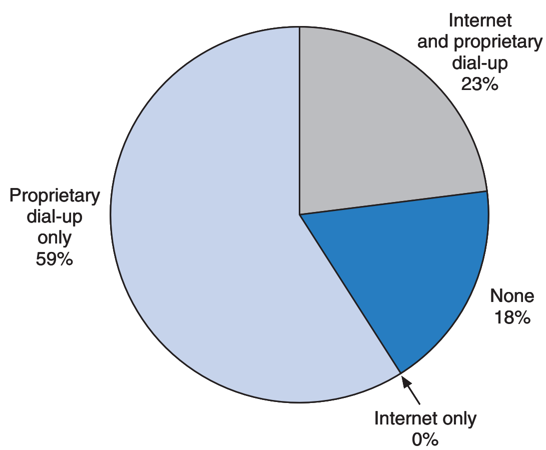
Use of SSL is equivalent to sending credit card details by phone or fax. Encryption technologies ensure that details cannot be stolen as they are being transmitted over the Internet. This is the method most widely used today for business-to-consumer electronic commerce. While straightforward and easy for consumers to understand (because of its similarity to transactions via phone/fax) and thus encouraging trust, its disadvantage is that the details have to be entered every time a transaction takes place. There is also an element of unreliability related to the weakness of encryption algorithms used in browsers as computing equipment is becoming more capable of deciphering them, an added element of trust is brought in by merchants that protect consumers against fraudulent use.

SET provides an alternative to SSL. The system was initially developed by Visa and MasterCard in collaboration with technology firms and subsequently supported by other credit card companies. Despite the initial excitement, the industry view is that SET has not really taken off. There are a number of barriers on both the merchant's and the consumer's side. For the former, the fact that the system authenticates at the level of the merchant and not the server, thus making it a more complex system, is a major drawback. For the latter, the problem is similar in that individual consumers need to install the SET software from a CD-ROM onto the Web browser software, create a key and obtain a certificate. The system's complexity also slows the speed of transactions. In addition, there is no clear incentive on the part of consumers to adopt SET, as secure transactions are already available through SSL.

Electronic banking

Electronic banking can be a tool for paying electronic commerce transactions. Credit transfers may be used for transactions with merchants who do not accept credit cards or for amounts that are too large for credit card transactions. For the latter in particular, electronic banking could be particularly well adapted to business-to-business transactions when adapted for commercial banking use.

Figure 8. **Breakdown of US banks' electronic banking services**



Source: Mainspring.com (1998).

Electronic banking includes the following: telephone banking (banking over the French Minitel could be included in this category); online banking (using proprietary software which differs from bank to bank and is usually compatible with personal finance software packages such as Intuit's Quicken or Microsoft's Money); and Internet banking (access via the Web, no proprietary software needed). The take-up of Internet banking is still slow in the United States, with only 23% of banks offering Internet access in 1998, compared to 82% using proprietary dial-up services.

Table 2. **Penetration of electronic banking in selected countries**

Country	Indicators
France	29% of 180 top financial institutions had a site in 1998 (12% in 1997) 100 000 users of online banking (5% of Internet population) CCF: 60-70% of clients use online banking, all categories combined[1]
United States	3 million Internet banking users for an Internet population of 52 million (6%)[1] Forrester Research: 21 million users by 2003 [1]
Belgium	Telephone banking: 11.7 million transactions by individuals and 69.7 million by enterprises and organisations in 1996 (compared to 56.3 million ATM withdrawals and 14.5 million ATM credit transfers)[2]

1. *Stratégie Internet*, "Les vitrines des banques deviennent des guichets", October 1998.
2. Result of survey conducted by the Association belge des banques, from "Vade mecum statistique du secteur bancaire 1997", June 1998.

The biggest advantage of electronic banking is reduced costs for banks. In the United States, the cost of banking (per transaction) is estimated as follows: in person, USD 1.07; by telephone, USD 0.52; ATM, USD 0.27; by Internet USD 0.01.[3] In the United Kingdom, the chief executive of Prudential (which runs Egg, a direct banking arm), estimates that costs are four times less for Internet banking than for telephone transactions and ten times less than for in-person transactions.

Business use of electronic banking has great potential. According to mainspring.com, 43% of US small businesses have access to the Internet but only 8% engage in online banking (including PC banking and Internet banking).[4] Of those 8%, most rely on dial-up services using proprietary software.

Box 2. **Telephone banking in Belgium and the Nordic countries**

While not a driver for electronic commerce, telephone banking has proved quite popular in certain countries.

In Belgium, telephone banking is possible for sums below a certain limit and for any sum if one calls from a pre-registered phone number (the server calls back to confirm). Security is ensured by using a personal identification number (PIN).

The most recent and interesting trend is telephone banking using mobile telephony (sometimes referred to as mobile banking) which is increasingly prevalent in Nordic countries and emerging in other countries.

In late 1999, Vodafone and the Commonwealth Bank intended to launch Australia's first mobile-phone-based banking service. In the United States, mobile banking has yet to take off. It will be interesting to observe to what extent mobile banking develops, in the light of the development of Internet access through mobile telephones and other mobile terminals.

Electronic billing

Electronic billing, or electronic bill presentment and payment (EBPP) is a way of conducting electronic financial transactions that is attracting increased attention. While the principle is very similar to that of cheques, it requires special and separate attention because, if this service is provided by non-banks, it could be a threat to banks, as it could erode their revenues from processing traditional payment methods such as cheques and from cash management.

As Table 3 shows, a major advantage of electronic billing is its low processing cost.[5] Other estimates also show electronic bill payment processing costs of 23 cents (US) as opposed to 83 cents for processing paper cheques.[6] Overall, EBPP could save billers, customers and other players involved in the billing process some USD 2 billion annually by 2002 in the United States by removing the paper medium.

For consumers, an added advantage of electronic billing is the possibility of bill consolidation, which would allow bill payers to visit a single site that would handle all of their bill-payment needs.[7] McKinsey

Table 3. **Cost comparison of paper-based and online transactions**

	Paper-based	Online	Savings (%)
Cost to bill issuer	USD 1.65-USD 2.70	USD 0.60-USD 1.00	40%-80 %
Cost to customer	USD 0.42	USD 0.00	–
Cost to bank	USD 0.15-USD 0.20	USD 0.05-USD 0.10	30%-75%
Total transaction	USD 2.22-USD 3.32	USD 0.65-USD 1.10	50%-80%

Source: UK Department of Trade and Industry.

identifies three types of consolidator models: *i*) closed-system model; *ii*) sherpa model; and *iii*) standard model. For the time being, Checkfree (closed-system model) has the largest share of the market (80% in 1997[8]), but many projects are emerging in the other two models: TransPoint by Microsoft and First Data Corporation (sherpa model); and OFX and Gold (standard model).

Currently, more than half of so-called online payments still involve paper cheques.[9] However, according to Killen & Associates, 12% of all credit card, energy and other consumer bills will be paid through an Internet-based EBPP system by the year 2000.[10]

New intermediaries

An interesting phenomenon in the world of electronic financial transactions is the entry of non-traditional players (in the sense that they did not previously process financial settlements) into the market. This is partly due to the technological intensity of this sector, which requires high levels of know-how, especially with regard to security issues. At the same time, traditional financial actors (banks) are entering new markets to provide authentication and certification services. For the sake of convenience, three types of new intermediary functions can be described: payment facilitator, payment as part of the entire electronic commerce chain, and payment and authentication.

- Payment facilitator

Handling payments could be one of the biggest problems for online merchants. Several companies have looked at this, and have started to provide payment services as an integral part of other services. For example, in March 1999, Yahoo! Inc. teamed up with two financial service firms, Banc One Payment Services and First Data Merchant Services Corp. to provide Yahoo!Store with credit card payment capabilities. Along the same lines, Sun Microsystems and AOL (with its subsidiary Netscape) are also developing a payment system. It is not clear yet which type of business models these new intermediary functions will use (such as charge per transaction, or added features to attract more merchants).

Integrion, a consortium consisting of IBM and 18 leading banks, is another type of new intermediary which facilitates the task of banks that have to provide support for different interfaces (ATM, Internet banking, PC banking, telephone banking) and provides the backbone systems of the banks. Its proprietary network provides a level of security and reliability that is not available through the Internet.[11]

- Payment and authentication

SET, which allows for secure transactions using credit cards over the Internet, can be considered a new intermediary. In order to increase security, SET relies heavily on an authentication mechanism: both users and merchants are individually authenticated by the system.

Microsoft is developing an electronic wallet scheme, Passport, which has more the character of an intermediary. The electronic wallet can either be stored on the user's computer or on a server. The user's information will also be stored on a Microsoft server, which could include, in addition to payment information, information such as zip code, age, gender, e-mail address. Here the service's characteristics are closer to those of an information aggregator than to those of a simple payment service provider.

- Payment as part of a larger e-commerce chain

In October 1998, the Internet Engineering Task Force (IETF) submitted version 1.0 of the Internet Open Trading Protocol. It defines certain electronic commerce components, such as identification of parties to the transaction, description of the order, payment, delivery and signature, all described as XML documents. The payment component includes information such as currency, amount and payment method (SET, Mondex, etc.) which are incorporated into the protocol as plug-ins.

Emerging issues

The most important issue surrounding electronic payment, as with physical payment modes is the question of trust. Users of electronic settlement need to trust the modalities they use. Trust can be attained through measurable characteristics such as reliability, safety and predictability, but also through the more subjective notions of usability, familiarity and acceptance by others. Finally, trust comes at a cost. Finding the right level of trust is a task that is left to developers and marketers of settlement modalities as well as policy makers.

Technological issues

Bandwidth: Many electronic payment modalities require some level of encryption, and this requires extra bandwidth. Adequate bandwidth is needed: *i)* to ensure proper security of the payment application; and *ii)* to ensure rapid operation. Both of these objectives must be met to ensure successful payment solutions. Increasing bandwidth is a market solution. Other bandwidth-hungry applications such as multimedia are likely to increase the demand for more bandwidth.

Physical security: Some methods, such as those employing smart cards, raise issues of hardware security. The move from magnetic strips to IC chips on card-based platforms increases the level of security. However, some cards can be tampered with by heating the chip. At a personal level, security around terminals poses an additional problem.

Logical security: Passwords, encryption, biometrics and combinations of these are means to ensure the logical security of a system. While PINs, used in many card transactions including bank cards and credit cards, are far from totally secure, they continue to be used for important financial transactions. On the other hand, many consider that weak encryption is harmful to the development of electronic transactions, even though the "weak" 40-bit encryption codes on browsers are eight characters in length, as compared to the four or five characters for PINs. Lack of familiarity with the technology may contribute to lack of confidence in it.

Policy issues

Certification and authentication/encryption/privacy: Some payment mechanisms rely on certification and authentication. The policy aspect of this issue involves who will issue certification and authentication applications (public entities, financial institutions, technology firms, etc.). As encryption is used in these applications, export restrictions on encryption algorithms have continued to be an issue. Whether public entities can obtain the encryption keys (key escrow) is a related issue, and there are further important privacy issues related to the levels of encryption used and authentication required.[12]

Liability and consumer protection: The liability of providers of electronic financial settlement modes needs to be clarified in order to gain the trust of both service users and suppliers. In developing a liability policy, a balance needs to be struck between provider liability and protection of consumers and merchants using the payment modality.

Financial regulation: There has to be an appropriate legal and regulatory framework governing electronic settlement modalities, as they involve sets of tools which are vulnerable to misuse, whether directly through the technology (forging electronic money) or through use for illicit purposes (money laundering, tax fraud/evasion).

Market issues: Electronic settlement of payments, in addition to being an enabler of electronic commerce, is also a form of financial service, and is likely to develop its own market, which may consolidate into a few viable technologies. If and when this happens, the market power of the technology holder will increase and might allow it to enter adjacent markets. Regulating exclusive licensing practices for the technology and ensuring interoperability are among possible ways to limit market dominance.

NOTES

1. In a strict sense, "credit card" means that reimbursement of the payment can be put off for a period of time during which the credit card company charges interest; "debit card" means that the amount drawn on the card is withdrawn from the user's bank account at the time of transaction, and "charge card" means the amount is charged at a later time (*e.g.* end of the month) with no interest charge.
2. Mainspring.com, "Smart Cards for Security, Not Shopping", <http://www.mainspring.com>, 9 July 1998.
3. Department of Trade and Industry, "Converging Technologies: Consequences for the New Knowledge-Driven Economy", September 1998.
4. Mainspring.com, "Small Business Banking Struggles to Go Online", <http://www.mainspring.com/FreeAll/PrrofPoint/0,1632,16null,00.html>, 7 July 1998.
5. Department of Trade and Industry, *op. cit.*
6. Mainspring.com, "The Slow March to Online Bill Payment", 7 July 1998.
7. Ouren, Singer, Stephenson, Weinberg, "Current Research: Electronic Bill Payment and Presentment", *The McKinsey Quarterly*, 1998, No. 4, <http://mckinseyquarterly.com/home.htm>.
8. McKinsey, *op. cit.*
9. Mainspring.com, "The Slow March to Online Bill Payment", 7 July 1998.
10. *Internet Week*, 3 August 1998, Issue 726 (from the Web)
11. Integrion, <http://www.integrion.com>.
12. See also OECD work on privacy, including the "Guidelines Governing the Protection of Privacy and Transborder Flows of Personal Data" of 1980 <http://www.oecd.org/dsti/sti/it/secur/prod/privacyguide.htm> and the "Declaration on the Protection of Privacy on Global Networks" of 1998 <http://www.oecd.org/dsti/sti/it/secur/act/privnote.htm>.

Chapter 5

POLICIES TO PROMOTE ELECTRONIC FINANCIAL TRANSACTIONS

Policies that promote electronic financial transactions (which include electronic payments – see Chapter 4 – but may also include activities such as interbank transfers not necessarily associated with settlements) are an area of IT policy with wide impact. As payment issues are involved, electronic financial transactions touch many aspects of the economy and will be an essential component of the emerging digital economy, especially in relation to electronic commerce. While the technologies themselves are often led by the private sector, their use has public policy implications.

IT policies in this area reflect the overall evolution of IT policies. The technologies that make electronic financial transactions possible are led primarily by the private sector, as is the case in many IT areas, and government's role is shifting from technology development to technology diffusion in many areas, including use by government itself. This trend is particularly visible for technology applications such as electronic financial transactions, which use software technologies such as encryption as well as hardware technologies, for example in the form of smart cards.

This chapter summarises the policies followed by OECD Member countries to promote the development of electronic financial transactions. Its goal is to examine, through examples of IT policies for electronic financial transactions, how governments can contribute to the diffusion of a particular technology (or set of technologies) aimed at new and more efficient ways of organising commercial transactions. In addition to contributing to the diffusion of these technologies, use by governments is increasingly driven by efficiency and accessibility considerations: governments have reported significant internal cost savings by moving to these technologies while at the same time ensuring broader access by citizens.

Chapter 4 identified trust as the primordial requirement for online payments and noted that individuals perceive trust in various ways. Government policies in this area are thus centred on trying to respond to users' need for trust. To this end, governments seek to demonstrate that the technology works, for example through government involvement in technology development or testing of pilot projects. Building a critical mass of users also helps to gain trust. While pilot projects may have a similar although limited impact, governments can contribute by using electronic financial transactions and encouraging mass use to build familiarity and hence trust. Finally, users need assurance that there is an adequate legal framework, developed by trusted parties, for these new modes of financial transactions. As the medium "money" has been regulated by public entities, establishment of the ground rules by a public body may be a way of ensuring this trust.

General country approach

This section briefly gives some examples of different policy approaches to electronic financial transactions. It provides insight into how three countries with different economic and institutional structures approach these issues. To some extent, Japan has adapted to electronic financial transaction development its long tradition of promoting co-operative projects in the private sector to foster late-stage development, diffusion and innovation in new technology areas. Norway has focused on providing a stable, forward-looking framework for complex, rapidly changing payment systems and avoiding detailed regulations which could constrain development and the ability to adapt to changes in technology and market conditions. Spain has sought to promote the Information Society and e-commerce in enterprises, paying particular attention to security and electronic signature issues to encourage electronic financial transactions.

Japan

In Japan, various ministries oversee and regulate segments of economic activities in very specific ways and create what can be characterised as industry-government co-regulation of various sectors of the economy. Electronic commerce is overseen mainly by the Ministry of Post and Telecommunications (MPT) and the Ministry of International Trade and Industry (MITI). Co-regulation exists in this area as well, as both ministries have established industry associations, which implement concrete projects to promote the development of electronic commerce in general and electronic financial transactions in particular. The Ministry of Finance is primarily responsible for setting the regulatory and legal framework for electronic financial transactions.

In July 1995, the MPT launched its Cyber Business Association (CBA) and in January 1996, MITI established the Electronic Commerce Promotion Council of Japan (ECOM).[1] Both of these associations have a number of leading information technology firms as well as non-IT firms (such as financial services, advertising and think-tanks) as members. Membership in these industry associations is not mutually exclusive.

ECOM co-ordinates 19 concrete e-commerce technology test-bed projects and formulates industry-led guidelines on issues related to electronic commerce, including electronic payments, authentication and model contracts. It also conducts about ten CALS (commerce at light speed) projects and 16 electronic data interchange (EDI) projects ranging from satellite building to stationary relay systems.

Like ECOM, CBA conducts electronic commerce test beds. Its main technology development projects are the Internet Cash project (see below) and its international interconnection experiment. At the same time, CBA members also address specific policy-related issues that hinder the development of electronic commerce and have produced *Guidelines for Protecting Personal Information in Cyber Business* and the *Content Protection Working Group Report*.

Norway

In 1996, the Banking Law Commission, created by the government in 1990, submitted a report including a draft act on payment systems. In that report, the Commission referred to the increased use of electronic processing and transfer of data in payment systems, resulting in a wide range of new types of payment services. It also referred to growing public awareness of the risks attached to payment systems. The draft act includes common rules for the clearing, settlement and transfer of payments between banks (interbank systems). It also covers types of payment services which institutions offer customers based on payment cards, numeric codes or other forms of independent user-identification. The draft act covers such services as banks' EFTPOS service, automated teller machines (ATMs), registration of telephone orders and use of the Internet.

Norway currently has no separate statutory regulation of payment systems. These are primarily regulated by agreements among participants. The two bankers' associations (the Norwegian Bankers' Association and the Savings Banks Association in Norway) have played a leading role in the development of existing payment systems and the establishment of the agreements. The purpose of the Commission's draft act is not to replace but rather to supplement the existing self-regulation. The draft act gives the authorities more control and a legal basis for issuing instructions. However, payment systems are a complex, rapidly changing area and detailed regulations could constrain their development. Furthermore, detailed regulations might restrict participants' ability to adapt to changes in technology and market conditions. The Commission has therefore assumed that, in the application of the act, emphasis will be placed on avoiding such consequences where this is compatible with the purpose of the act.

In 1998, the Commission submitted a report with a draft act on financial undertakings, which proposes rules for establishment, licensing, organisation, etc. In this report, the Commission also discusses prepaid electronic cards, especially in terms of receiving deposits. It considers that although, as a general principle, banks alone should have the right to accept deposits, non-banks should be able to establish and operate prepaid electronic cards to a limited extent.

Spain

Among government initiatives to promote electronic financial transactions, the most relevant is the creation within the Ministry of Industry and Energy of a directorate to deal with the development of the information society. This directorate is preparing new initiatives, among them the promotion of e-commerce in enterprises. The main policy concerns regard electronic financial transactions and are security of transactions and electronic signatures. An advisory body to the Ministry of Industry and Energy, the Information Society Forum, provides industry's point of view in the preparation of policies to develop the Information Society in Spain. The Forum currently has five working groups dealing with e-commerce, education and training, public administration and public services, language and culture, and content and technology innovation.

Development/demonstration/testing of technologies

This section deals mainly with applied technologies such as smart cards but does not delve into the underlying technologies, such as encryption or further miniaturisation of embedded chips, which enable these technologies and might fall under the category of basic R&D.

Most of the projects are government-led demonstration-type projects that use various private sector technologies. In some cases, the technologies are adapted to the specific characteristics of the projects. In these settings, government projects act as test beds to identify the best technology available. As there are many competing technologies, especially in the area of electronic money, these types of undertakings have high utility, as testing conducted purely by the private sector (for example in a single corporate setting) will not have the same impact as, for example, tests conducted in a wider city or regional setting. There are also important cost considerations, as corporate users may be unable to justify carrying out large-scale experiments.

The following sections describe projects conducted in relation to electronic money, online use of credit cards and electronic banking/billing.

Electronic money/purse and related financial transactions

Europe

Within the European Union, most R&D programmes related to electronic financial transactions are carried out within the framework of the European Commission DG III (Industry, now Enterprise). CAFE (Conditional Access for Europe) was carried out under the European Commission's ESPRIT3 programme. It was launched in July 1994, the first experiment began in April 1995 and the project was completed in February 1996. The project developed an electronic wallet based on smart cards entirely based on public-key cryptography. The wallet supports multiple issuers of electronic value, multiple currencies, anonymous payments and recovery of lost/damaged/stolen cards. The project was conducted with the collaboration of private sector firms including DigiCash, which provided software and hardware solutions, as well as Gemplus Card International of France for the smart card. The project continued as the OPERA project (ESPRIT4) through mid-1997 and involved an unattended card-loading station at which users could load money onto their cards, either through their bank account or from cash. For the final product, the project brought together various technologies developed by different providers. It involved integrating technology rather than developing new technology.

In other cases, electronic payment solutions are adopted in the context of a larger technology development project. One example is the SEMPER (Secure Electronic Marketplace for Europe, Commission service – DGXIII) project which is part of the EC's ACTS (Advanced Communications Technologies and Services, Fourth Framework Programme). Other examples include the MILLION (Multimedia Interactive Leading Life-giving Initiative on Net, ESPRIT4) project which was a system for managing tourist traffic in cities using a personal digital assistant (incorporating payment solutions for booking hotels and transportation) and IMPRIMATUR (Intellectual Multimedia Property Rights Model and Terminology for Universal Reference, ESPRIT4), a project in which the payment solutions demonstrate how intellectual property can be purchased over the Internet.

The European Commission's ISIS project, aimed at developing a secure payment method, entered a more concrete phase in 1999 through the FINREAD programme, the goal of which is to finalise the technology and encourage implementation. A French initiative, CyberComm, created in December 1998 as a fusion of two separate industry-led initiatives, C-SET and E-Comm, is a contender for the technology.

In Belgium, PROTON, a system based on smart cards, has been in use since the mid-1990s for payments for which credit card payments are too costly. This system was developed by Banksys, a private bank association in Belgium, which is also overseeing the bankcard system; it is also being used in the Netherlands as part of its national smart card projects. In Sweden, Nordbanken and Sparbanken are also using PROTON. SE-banken entered the project, named CASH, during spring 1997. For these combined bankcards and cash cards, loading terminals are placed in homes with teleconnections to banks.

Japan

- InternetCash and other MPT undertakings

In September 1998, the Cyber-Business Association (MPT) launched the first stage of its *Internet Cash* project. In this project, electronic cash is stored on a smart card and allows for anonymous payments over the Internet using a personal computer and a card reader. It aims: to *i*) verify whether electronic money is a suitable method of clearance for commerce of goods and services deliverable over a network (*e.g.* software and content); *ii*) identify the advantages and disadvantages of electronic money for consumers; *iii*) accumulate know-how; and *iv*) establish a secure transmission technology for electronic money over the Internet. The technological framework is based on the NTT-Bank of Japan Scheme. The second phase of this project (STEP2) started in April 1999, in which iCash was issued to 10 000 test users.

In October 1999, CBA started a new phase of the iCash project by adopting online payment by dollar-denominated iCash for international electronic commerce.

The MPT started collaboration with Visa International[2] on their respective e-money pilot projects, with a view to establishing an electronic money standard. Currently in Japan, three major electronic money technologies are being piloted: NTT's Supercash (on which iCash is based), VisaCash and that based on the Mondex technology.

In April 1999, MITI and MPT, together with private sector participants, agreed to standardise the e-payment methodology. In the same month, MPT, private financial institutions and participating firms in Internet mall operations formed the Japan Internet Payment Promotion Association to harmonise payment methods by the year 2000. This body hopes that harmonising the settlement system will lead to the development of electronic commerce in Japan.

- ECOM's undertakings

ECOM is not developing its own proprietary electronic money scheme but is concentrating on the hardware [integrated circuit (IC) cards] that might become the platform for electronic cash. Among its 19 test-bed projects, a multi-function IC card is being developed in a project entitled Electronic Market Place. This multi-function card is meant to handle both credit and debit functions. VisaCash-type electronic money was used in another test-bed project, Smart Commerce Japan. Another project, Contactless IC Card, aims at developing a contactless IC card that could become a foundation technology for electronic payment.

Korea

In 1996, the Bank of Korea and the Financial Clearing Agency provided a standard for electronic cash to promote its rapid development, and in 1997, established a plan for a system involving the common use of an IC card to increase security and broaden usage.[3] In February 1997, efforts to set a standard for electronic cash without excessive investment led to an international electronic cash standard, EMV (Europay, Master, Visa), for all commercial banks. The chip operating system (COS), an operating system for IC chips, was finalised in December 1997.

A single IC card that replaces credit and debit cards is used off-line at all participating shops. The development of electronic cash is still in its infancy, however, and the medium is not yet appropriate for use over the Internet. To overcome this limitation, the Electronic Cash Working Group, under the Korea Information and Communication Promotion Association, is currently trying to develop a new type of electronic cash, so called "e-cash", which can easily be transferred over networks, including the Internet.

United States

- Government-sponsored smart card pilot projects

The US Department of Treasury carries out government-led pilot projects in the area of smart cards in defence-related departments (Departments of Defense and of Veterans Affairs). These departments may have been chosen as partners because of the mass of potential participants and the controlled environment. The following pilot projects involving smart cards were conducted:

– Payroll payments to soldiers, involving a total of 100 000 cards worth approximately USD 25 million at three separate locations. At one of the test sites, biometric sensors are used at terminals to verify identification. The VisaCash technology is used.

– Payment collection using smart cards at the Veteran Affairs Medical Centers in two locations. Cards were distributed to patients, physicians, visitors, volunteers and employees who use the cards at the cafeterias and retail stores operated by the Veterans Canteen Services. The pilot project involves 46 000 reloadable and disposable cards. The VisaCash technology is used.

In September 1997, American Express started to use a smart card system for US marines based on Belgium's PROTON technology. The card is used not only for electronic payment but also for the management of firearms distributed to the marines.

- Department of Commerce – Advanced Research Program

While large-scale pilot projects are carried out mainly by the Department of Treasury, the Department of Commerce provides assistance, through the Advanced Research Program of the National Institute of Standards and Technology,[4] to R&D on basic technologies related to electronic commerce in general, some of which is applicable to electronic financial transactions. For example, the programme Interoperable Infrastructures for Distributed Electronic Commerce identifies technologies that may be developed to remove barriers to the development of Internet-based markets. One potential technology idea is an innovative solution for a trusted technical and organisational infrastructure to provide interoperability and security related to services such as multi-application smart cards.

Credit card based systems

Secure Electronic Transaction (SET) and its derivatives

- Europe

In Europe, the European Commission's DG Enterprise carries out the Interoperable C-SET (Chip Secure Electronic Transaction) project with the collaboration of many private sector players, including financial services and technology firms. The Groupement des Cartes Bancaires of France and Banksys of Belgium, which are responsible for the operation of bank cards in their respective countries, have both signed a co-operation agreement in the framework of this project. In Sweden, some banks are starting pilot projects using SET, with each bank acting as the certification authority.

• Japan

In Japan, ECOM carries out many projects that aim either to develop distinct payment solutions that incorporate SET (for example, by developing a Secure Electronic Commerce Environment – SECE) or to include SET as an option in an overall Internet mall experiment. Table 1 summarises the projects.

Table 1. **Summary of ECOM projects involving SET**

Type	Name of project	Payment technologies
Principal objective to develop/test credit-card settlements	Smart Collar Club	Virtual credit card settlements[1] based on SET
	CyberNet Club	Use of credit card using a SET compatible protocol
	Smart Commerce Japan	Pure SET but also using IC cards based on VisaCash
	Cardless Card System Platform	SET-based system with a physical card[1]
	SECE Common Platform	Development of secure electronic commerce environment (SECE) derived from SET
Use of credit card settlements in an Internet mall	Cyber Commerce City	SET-based credit card transactions
	Media Port Nagoya	Use of SECE
	Virtual City	SET-based credit card transactions

1. Based on the fact that payment to credit card companies is based on automatic debits from bank accounts.
Source: Electronic Commerce Promotion Council of Japan, <http://www.ecom.or.jp>.

E-Debit-based system

In Japan, e-Debit is another very popular payment system and e-Debit-based electronic commerce systems are expected to be used in the future. In this context, the Telecom Service Association of Japan (TELESA; <http://www.mm.telesa.or.jp/index_eng.html>), under the sponsorship of MPT, is carrying out an e-Debit-based project for international interconnection of EC test beds. This project is called INGECEP (Integrated Next Generation Electronic Commerce Environment Project), and has been under way since July 1998 between Japan and Singapore.

In this project, TELESA plays the role of a clearinghouse, debiting the amount of the payment for the item purchased from the account of a test user, and crediting the bank account of the mall in Singapore once the item has been delivered to the purchaser. By adopting this process, test users can purchase items securely from the foreign mall using e-Debit.

The INGECEP, by adopting the e-Debit system, aims to promote consumer protection in international electronic commerce, including adopting a clearinghouse system, privacy protection policies, tracking systems, etc. This project is registered as an official APEC project and the partnership was to be expanded to include Korea by the end of November 1999.

Non-SET related credit card use

In Japan, ECOM also carries out pilot projects in which credit cards are used for payment using tools other than SET. The JapanNet project combines certification and authentication mechanisms with the use of credit cards. The Electronic Market Place developed its own credit card transaction protocol called iKP (acronym in Japanese for Internet Settlement Information Transfer Protocol).

Electronic banking and electronic billing

In November 1998, Canada Post rolled out an electronic system that lets users pay bills to various companies on line. The Austrian Ministry of Finance and the Chamber of Trustees has developed a system called FinanzOnline, which was launched in March 1998. Further details are provided below.

As shown in the section on the evolution of non-cash settlements in Chapter 4, Japan has a high percentage of direct debits, and this leads to the development of similar online systems. Several of ECOM's test-bed projects involve extensive use of the existing banking infrastructure. Smart Collar Club has adopted (in addition to SET-based credit card transactions) a system called virtual banking settlement in which customers open an account with a virtual bank on the Internet. The bank issues SmartChecks, which are used for payment. The virtual bank maintains a connection with the customer's physical bank account. In another project, Virtual City, direct debit from the users' bank account, which the users register with the provider, is a payment option.

Creating demand for electronic financial transactions

Governments can resort to what can be characterised as demand-pull or demand-creation policies to promote new technologies. For electronic financial transactions, governments can use new information technologies not only to promote the technology but, more justifiably, to save public money. If governments adopt electronic financial transactions, the parties transacting with them will have to adopt the technology as well. Governments also need to establish an adequate legal and regulatory framework to convince users that these transactions are as safe and trustworthy as other financial transaction modes, many of which are regulated by government bodies.

Government use of electronic financial transactions

Governments use electronic financial transactions mainly for government procurement, tax collection and benefit payments. Use on a pilot basis, such as the use of smart cards by the US military, promoted by the US Department of Treasury, is described above.

Australia

For procurement, the Commonwealth Procurement Online by 2000 (CPO 2000) programme <http://www.ogit.gov.au/ecommerce/ecindex.htm>, carried out by the Office for Government Online, aims to develop an implementation strategy for electronic procurement (purchasing and payment) for the Commonwealth government to replace electronic commerce services established by Telstra Transigo. The electronic payment component of the CPO 2000 project will develop a framework for the entire government to meet its own needs and those of its suppliers and to promote electronic payments in both the public and private sectors.

Europe

- United Kingdom

The United Kingdom announced in 1998 that by 2002, 25% of all government dealings with the public would be electronic. The statement was met with some criticism in that, as the definition of electronic means includes telephones, the 25% mark had almost already been met. In March 1999, the announcement was followed by a pledge that 100% of public services will be delivered electronically by 2008. In areas involving electronic financial transactions, submission of self-assessment tax forms, VAT registration and return filing, payment for supply of goods and services to governments are to be conducted online by 2002.

• Belgium

A European Commission DG XIII programme called MIRTO (Multimedia Interaction with Regional and Transnational Organisations) is being carried out in Brussels. The programme aims at developing new electronic ways for public administrations to provide services to citizens. Some parts of the project will necessarily involve payment mechanisms, and three propositions are being considered, namely credit card, debit card (MisterCash) and PROTON (the electronic purse), owing to the financial (ability to accept small payments) and technical (issues of terminal) specifications required.

A number of projects are also run by local governments. The Edison Project is administered by the Flemish Administration of Education; it is an electronic system for automated payment to schools of their operating subsidies and teachers' salaries.

• Austria FinanzOnline – the federal electronic tax return and data exchange system

After a two-year development and testing period, a new electronic data transfer system was launched in March 1998. The system is called "FinanzOnline" and was developed by the Ministry for Finance and the Chamber of Trustees. It is an electronic data transfer procedure of the Austrian Financial Administration based on Internet/Web technology. This "electronic tax file" is targeted at professional tax consultants and economic advisors who may need to access tax information for clients (and personal use) via the Internet. FinanzOnline allows online queries, updates and transfer of tax data. In addition, data may be transmitted offline via a newly developed databox. Technical implementation and operation are carried out in co-operation with the Federal Computing Centre (BRZ) as the technical network infrastructure and the formerly state-owned company Datakom Austria as the billing authority. Further development of the system will make it possible to transfer tax declarations, annual financial statements and balance sheets and will offer the opportunity to file applications by the end of 1999. In return, the revenue authority will electronically transfer tax assessment notices, which can be queried at any time. By that time also, the validity of personal identity numbers of turnover tax within the EU market should be accessible electronically.

FinanzOnline offers the following services for querying financial administration data:

– Client billing data: account balance, posting of entries, arrears of accounts, information on advance payment/tax assessment, information on status of repayments.
– Payroll information.
– Required tax returns for clients and those already available at the tax office.
– Status of authorisation of the consulting office (if known to financial administration).
– Status of authorisation of employees (granting access to FinanzOnline).
– General information pertaining to the financial administration.
– Electronic data transfer (of selected documents) to the financial administration.

• Finland

The development of information networks and information technology has led to new solutions, especially for data collection. This involves the possibility of forwarding information to authorities using machine aids or with the help of an operator. To this end, the Finnish Ministry of Trade and Industry asked that the following measures proposed by the Working Group on Reducing Administrative Procedures should be taken:

– The present separate reports by a business to the National Board of Patents and Registration and to the tax administration are to be replaced by one notification of starting up a business (at the same time, company registers and registers of places of business will be compiled for the Central Statistical Office).
– The National Board of Patents and Registration, the National Board of Taxation and the Central Statistical Office are to prepare to introduce an obligatory system for filing final accounts reports.

– These same bodies are to offer firms the opportunity to switch to a system which allows them to use machine aids to transfer data on their final accounts and other obligatory information to these authorities. The same applies to general data, *i.e.* all information produced for the authorities. The authorities are to be prepared to offer enterprises an opportunity to send data using electronic equipment either directly or with the help of an operator.

– Regarding the transfer of data in computer language, the working group recommends a model which enables the transfer of data with the help of operators.

The Ministry of Trade and Industry has stated that the Advisory Committee for Small and Medium-sized Enterprises is to analyse the following proposal for actions to be taken to promote collective use of company information:

For the needs of specific information on companies, the authorities are to be entitled to use data collected by another authority. A specific act to this effect is to be issued. The right of an authority to obtain information about an enterprise from another authority shall be limited to such information as the authority is entitled to obtain directly from the enterprise concerned.

• Netherlands

Income tax processing has been extensively automated. Since 1996, it has been possible to make electronic income tax returns. In 1996, 400 000 citizens took advantage of this facility and currently over 1.2 million do so. As a result, the time required to process returns has been shortened by five months. Recently, an experiment was started to allow firms to send turnover and wage tax returns via the Internet. The Dutch government is also to complete a pilot project on electronic tendering by early 2000.

United States

In the United States, use of electronic financial transactions by government entities is widespread.

• Electronic Fund Transfer 99 (EFT99)

This refers to the Debt Collection Improvement Act of 1996, which was signed into law in April 1996. It requires the use of electronic fund transfer (EFT) for most federal payments, with the exception of tax refunds, effective January 1999.[5] Following comments received by concerned parties from federal payment recipients, consumers, financial and non-financial institutions, the Treasury issued a final ruling in September 1998. It specifies the conditions for waivers, defines the requirements for accounts to which Federal payments can be made by EFT, provides that any individual who receives federal benefits, wages, salary or retirement payments can set up a low-cost Treasury-designated electronic transfer account (ETA) at financial institutions, and defines the responsibilities of federal agencies and recipients.

The provision of ETAs enables individuals who would otherwise not maintain an account at a financial institution to open an account to receive federal payments at reasonable cost and with the same level of protection that is provided to other account holders at the same financial institution. It can be considered that setting up ETAs is a measure that facilitates the implementation of the goals of EFT.

EFT 99 has generated an increase in the number of providers of electronic cheque services. Bank Boston and Nations Bank, with a system designed by IBM and Sun Microsystems, Citibank, Chase Manhattan and Bank America may participate in similar experiments.

• Tax payments

According to the US Internal Revenue Service (IRS), tax reporting over the Internet is expected to increase ten-fold in 1999, from 940 000 in 1998.[6] The IRS has allowed electronic tax filing since 1994. As of tax year 1998, however, it has eliminated the requirement that a signed physical document be submitted in addition to the electronic filing. In addition, the IRS now allows the use of credit and debit cards for payment. This has led to an increase in the use of the electronic tax-filing system. Contributing to this trend is the increased provision of electronic tax-filing services by companies such as Yahoo! and Intuit or traditional tax-filing services such as H&R Block. Forrester Research predicts that by 2003, most tax filings will take place over the Internet.

The IRS expects that 23% of returns will be filed online this year and that the rate will increase to 50% by 2005. Tax refunds are increasingly handled electronically by direct deposit to taxpayers' bank accounts, and about one-third of all refunds are to treated in this way.

- Customs

The United States Customs processes 94% of all customs declarations and collects 60% of all duties electronically. The use of EDI for its operations has reduced error rates from 17% to 1.7% and saves an estimated USD 500 million in processing costs each year.

Setting up an adequate legal framework

This section reviews various countries' attempts to provide a legal/regulatory framework that would encourage both users and providers of electronic financial settlement services to adopt the new types of services made possible by information technologies. The intent is not to provide a detailed analysis of the content of the various policies and regulations but to show the means by which various governments are trying to increase the trust of users and providers and to encourage the development of electronic financial settlement technologies and services.

Europe – European Union

- EC Recommendation concerning transactions by electronic payment instruments

In July 1997, the European Commission issued a Recommendation [COM(97)353] concerning transactions by electronic payment instruments and in particular the relationship between issuer and holder.[7] It updates and modernises an earlier Recommendation (1988) on payment cards. It covers "bank-account-access" products, *i.e.* instruments that provide for remote access to accounts held at financial institutions, including electronic banking and payment cards, and "electronic money" products, *i.e.* instruments on which electronic value is stored (cards, computer memories), including loading and unloading value. The recommendation clarifies the obligations and liabilities of the parties to a contract (holder and issuer of electronic payment instrument) and aims to boost trust in electronic payment systems by ensuring that:

– Customers have clear information available to them, both before and after a transaction.

– There is a fair apportionment of responsibilities between issuer and holder of an electronic payment instrument, so as to place the burden on the party closest to resolving the problem.

– Customers have access to simple and effective means of redress.

In connection with the above Recommendation, in February 1998, the European Parliament asked the Commission to submit a proposal for a directive on electronic payment instruments and on financial transactions carried out over the Internet, after inquiring into the degree of implementation of the recommendation of July 1997 and taking account of the need to differentiate the rules on credit cards, payment cards, cash cards and payment systems. The parliament stated its preference for self-regulatory mechanisms for ensuring consumer protection and security, given the introduction of rules to ensure consumer awareness about potential liabilities associated with electronic payment instruments.

The European Commission also supports the Memorandum of Understanding on Open Access to Electronic Commerce for SMEs, signed by industry representatives from the banking, telecommunications, retail and technology sectors, as well as consumer representatives and SME organisations. The European Commission took the initiative in this process. In the area of electronic payments, the Memorandum of Understanding advocates the development of compatible standards for payment, specifically for smart cards and stresses the importance of separating the card itself (hardware) and the software or data stored on the chip, so as to foster interoperable solutions. In March 1999, it published a final report.[8]

In the area of payment systems, the report calls for stimulation of multi-functional smart cards, creation of electronic payment systems in which the service providers bear the risk in order to increase trust, standardisation of electronic purses in an industry-voluntary manner, and advancement of electronic processing of existing purchase order and invoice payment procedures used by SMEs.

- Norway

The work of the government-appointed Banking Law Commission to create a harmonised legal framework for financial institutions (organisation and business activity), protect consumer interests and assess the need for regulation of payment transactions is described in the general section above.

- Japan

ECOM's Electronic Settlements Working Group seeks to contribute to creating a proper environment for the promotion of electronic settlement systems. Its three working groups deal with issues related to settlements involving business-to-consumer transactions, business-to-business transactions and design of terminals for IC and magnetic cards. The group recently produced model contracts for four payment modes envisaged for electronic commerce:

– Settlement by credit cards (for electronic commerce over the Internet).

– Settlement after the transaction (cheque-type, for electronic commerce over the Internet).

– Settlement at the time of transaction (debit-type, for electronic commerce over the Internet).

– Settlement prior to transaction (electronic money, prepaid arrangement for a transaction in the physical world).

The Ministry of Finance (MOF) is also involved in the electronic money aspect of electronic commerce. Following the work of the Informal Group on Electronic Money and Electronic Payment in 1996 and the Informal Group on the Establishment of the Environment for Electronic Money and Electronic Payment in 1997, the Ministry issued a final report in June 1998. The report gives insight into issues that need to be dealt with in an eventual legal framework for electronic money and electronic payments, including transparent information and fair transaction rules. As of early 1999, MOF is envisaging the enactment of a law on electronic money, which is to be submitted to the regular parliament session. The law is to:

– Minimise barriers to entry by admitting non-financial institutions, not imposing a limitation on activity on issuers and ensuring that issuer entities meet registration obligations with the Financial Supervisory Agency.

– Meet the need for legal frameworks to provide stability in the payment system and consumer protection by ensuring corresponding physical monetary reserve to issued electronic money, managing the reserve fund (as trust fund) separately from other funds, and returning this separately managed fund to users of electronic money on a priority basis in case of failure.

– Grant inspection and audit authority to the Financial Supervisory Agency.

The Centre for Financial Industry Information Systems (FISC),[9] an MOF-affiliated organisation, also studies issues related to electronic payments. Its Study Group on Electronic Settlements issued its second report in 1997. The report addresses issues of technology/security, business, contract/legal aspects and the public interest from the perspective of the current situation in the financial and financial information services sectors. It also incorporates the idea of financial institutions taking responsibility for authentication and certification, as well as a model contract for electronic money.

United States

- General policies

In July 1998, the Federal Financial Institutions Examination Council (FFIEC) issued its Guidance on Electronic Financial Services and Consumer Compliance.[10] Under this document, which includes sections on "Compliance Regulatory Environment" and "The Role of Consumer Compliance in Developing and

Implementing Electronic Services", electronic financial services include, but are not limited to, online financial services, electronic fund transfers and other electronic payment systems (such as stored value card systems and electronic money). The first of these sections summarises relevant sections of existing federal consumer protection laws and regulations that address electronic financial services and gives an indication of interim policy compliance guidance to service providers. The second discusses the need for involvement of compliance officers in the design, development, implementation and monitoring of electronic banking operations.

- Electronic banking

With the widening use of electronic banking in the United States (see Chapter 4), more questions are being raised by providers of electronic banking services and by an increasing number of users. While no official statistics are available, there is increasing risk of fraudulent banking services, as indicated by the issuance, by the Federal Deposit Insurance Corp. (FDIC) on its Web site, of a warning on suspicious Internet banking sites.[11]

In April 1997, the Office of Thrift Supervision (OTS) published an advance notice of proposed rulemaking with the aim of seeking comments on OTS electronic banking regulations. The concern was whether OTS's regulations are sufficiently flexible to allow federal savings associations to engage in appropriate electronic banking activities and consistent with regulations such as the Truth in Lending Act, Regulation E and other relevant statutes and regulations. The action was prompted by inquiries from federal savings associations as to whether they may provide banking services over the Internet (including opening accounts for depositors living abroad).[12]

In November 1998, the OTS issued a final ruling on the above proposition.[13] It allows federal savings associations to innovate by using, or participating with others in using, electronic means to facilitate its operations or provide any product or service as part of their authorised activities. The rule also requires savings associations to report 30 days prior to establishing a transactional Web site.

Policy lessons

What is government's role in developing and diffusing applications of information technology in an area such as electronic financial transactions? Information technology development is basically led by the private sector. Governments no longer seek to develop national champions in areas such as supercomputers and semiconductors because of the rapid pace and international nature of technological development. Nevertheless, governments can play an important role in the diffusion of technologies.

For electronic financial transactions, the most important issue is user trust. For electronic payment modalities, it is important to determine what constitutes an adequate level of trust. A technical solution providing maximum safety might be possible from a purely technological point of view, but it may entail higher cost and perhaps lessen user friendliness. Furthermore, the adequate level of trust, as well as the means to ensure that trust, is likely to differ from country to country owing to national experience and institutions and the diffusion of different electronic transaction systems based on prior established systems.

The issue is how to reconcile efficient diffusion of rapidly developing technologies with the interests of users (consumers as well as companies), and how to ensure that a balance is struck between rapid diffusion and potential monopoly and technology lock-in. Leaving diffusion entirely to the market could lead to a "winner" likely to control most of the market (*e.g.* Microsoft in the PC operating system market). This would avoid confusion among users about which technology to adopt, and initial technology diffusion could be rapid. However, there is the risk that the "winner" would act as a monopolist and have great impact on adjacent markets. The counter-argument is that the IT sector is developing so rapidly that no one firm can develop an enduring monopoly.

Technology push

Competition

Co-operation with the private sector firms developing the technologies is an essential component of technology-push policies. However, the private sector develops competing, and often incompatible, technologies, such as electronic money schemes and safe mechanisms for using credit cards for online transactions. The market does not judge on the quality of the technology alone. Other factors, such as the market power of companies developing these technologies, come into play, and could affect financial transaction information technology. While the best technology may not provide the best overall solution, the public interest requires that market failure should not result simply from monopolistic activities.

Through test-bed projects, governments can provide a continuing and neutral test marketplace for technology competition. For example, some of the pilot projects in Japan suggest a movement towards convergence; the process has been based on testing a range of competing technologies, rather than on government or single firms choosing and promoting one option exclusively.

International interoperability

Electronic financial transactions are an enabler of global electronic commerce. Electronic financial settlements, and especially electronic payment modes, need to be interoperable. The panoply of technological solutions currently available at national and international level suggests that it may be difficult to ensure technological convergence among all of them. Furthermore, because conditions for trust and transaction and payment systems differ from country to country, rapid adoption of a single international standard is unlikely. If this is the case, interoperability will be essential.

Governments have an interest in ensuring that various systems are interoperable. If there is a set of different technologies for electronic financial transactions, there is a clear market incentive to make them interoperable. Under such circumstances, the task of governments is to encourage the trend towards international technological interoperability.

Demand creation

Government can encourage diffusion, familiarity and trust through the use of electronic financial transactions not only by central government but also by local authorities that are closer to the daily lives of individual citizens. The ability to transact and pay for local government services which individuals are likely to use regularly, will have a strong impact on acceptance of electronic financial transactions. The selection of the technology employed by government will affect the eventual shape of the technology widely adopted, and the selection process needs to provide a mix of technological competition that encourages innovation, while providing stability and continuity for clients. Finally, legal and regulatory frameworks surrounding electronic financial transactions need to be technology-neutral and provide a stable, forward-looking framework for payment systems, avoiding detailed regulations which constrain development.

NOTES

1. Other industry associations set up under MITI leadership, with their mission identified by MITI as the development of electronic commerce, include: Japan Electronic Data Interchange Council (JEDIC), CALS Industry Forum (CIF), Nippon CALS Research Partnership (NCALS) disbanded in May 1998, Research Institute for Advanced Information Technology (AITEC), Japan Information Processing Development Center (JIPDEC), and Japan Computer Emergency Response Team Co-ordination Center (JPCERT/CC).
2. Visa International started a large-scale electronic money experiment using VisaCash in Tokyo; 100 000 IC cards were issued by credit card companies and banks, and around 2 000 merchants participated.
3. Based on the standard, Samsung, Hyundai, and LG together have developed an e-cash IC card embedded with prepaid value under KRW 100 000 for small transactions.
4. <http://www.atp.nist.gov/>.
5. <http://www.fms.treas.gov/eft/index.html>.
6. *Nihon Keizai Shimbun*, 23 February 1999.
7. European Commission, [97/489/EC] *Official Journal* No. L208, 02/08/1997 P.0052-0058.
8. *Open Access to Electronic Commerce for European SMEs*, March 1999.
9. The Center for Financial Industry Information Systems (FISC), <http://www.fisc.or.jp/> (Japanese only).
10. <http://www.ots.treas.gov/ebanking.html> or <http://www.ffiec.gov>.
11. <http://www.fdic.gov/>.
12. *Federal Register*, 2 April 1997 (Vol. 62, No. 63).
13. <http://www.ots.treas.gov/docs/73058.html>.

P*art* III

CURRENT ISSUES AND DEVELOPMENTS

Chapter 6

SOFTWARE DEVELOPMENT IN NON-MEMBER ECONOMIES: THE INDIAN CASE*

The rapid growth of India's software industry[1] testifies to the increasing outsourcing of software development. In 1995, IDC estimated the global market for computer services at over USD 220 billion. A substantial fraction involved outsourcing of some software development and maintenance: custom software development was estimated at nearly USD 16 billion, systems integration at USD 32 billion, IT consulting at USD 11 billion and business service outsourcing at USD 9 billion.

Against a backdrop of perceived shortages of skilled professionals in the developed countries, a growing portion of this outsourcing crosses national boundaries to reach large pools of trained professionals in India, China, the Philippines, Eastern Europe and Russia. A recent study based on responses to a telephone survey of 532 IT and non-IT companies with more than 100 employees found that there were some 346 000 IT positions currently vacant in the United States in three core IT occupational clusters (programmers, systems analysts, computer scientists and engineers). In addition, there were 240 000 vacancies in areas such as technical writing, training and sales (ITAA, 1998). An earlier study estimated a shortfall of nearly 1 million software professionals in Japan. Even if these figures are high, most observers agree that, in developed countries, demand for skilled software professionals has grown rapidly and may exceed supply (for a more detailed discussion of labour markets for IT workers, particularly in the United States, see Chapter 3).[2]

The Indian software industry has attracted a disproportionate amount of interest in the popular media, as revenues, at close to USD 3 billion in 1997, were a tiny fraction of the estimated world software market of USD 300-500 billion.[3] Moreover, no Indian software firm has yet introduced a significant software product. There are compelling reasons, nonetheless, for looking at India, as its software industry has captured a significant portion of the world trade in software services. It has been estimated that India has 16% of the global market in customised software, and that more than 100 of the Fortune 500 firms had outsourced to India (Dataquest, 31 July 1996, pp. 43-44). Perhaps most of impressive of all, the industry has grown rapidly, at over 50% a year over the last five or six years. If current trends persist, software exports may account for a quarter of Indian exports within the next five years. Tables 1 and 2 show the software industry's growth in revenue and employment.

Table 1. **The Indian software industry: exports, domestic and total revenue**

Millions of USD

	Exports	Domestic revenue	Total revenue
1993-94	330	228	558
1994-95	485	341	826
1995-96	734	515	1 249
1996-97	1 085	681	1 766
1997-98	1 800	900	2 700
1998-99	2 600	1 223	3 823
1999-2000 (est.)			6 000

Source: NASSCOM.

* This chapter was prepared by Prof. Ashish Arora, Heinz School, Carnegie Mellon University, Pittsburgh.

Table 2. **The Indian software industry: employment and revenue/employee**

	Employment	Revenue per employee (USD)
1993-94	90 000	6 199
1994-95	118 000	6 998
1995-96	140 000	8 924
1996-97	160 000	11 036
1997-98 (est.)	180 000	15 000

Source: NASSCOM.

For 1998-2002, NASSCOM's survey indicates that the industry will continue to grow by more than 50% a year. During 1998-99, the software industry in India is expected to have a turnover greater than USD 3.8 billion. Of this, sales in the domestic market are expected to be about USD 1.2 billion, the rest being exports. Currently, software exports represent 4.5% of India's total exports. The industry association also indicated a target of 23% of the customised software market and 5% of the products and packages market in the world IT economy by 2003. NASSCOM also projects that software exports will constitute about 25% of India's total exports by 2003.

These projections are likely to be excessively rosy (Arora *et al.*, 1999; D'Costa, 1998).[4] India's software industry faces a number of challenges, as its labour cost advantages diminish and competition from other countries with supplies of educated and under-utilised workers increases. However, even if the projected goals are only partially achieved, the Indian software industry will still have earned a substantial place in the world software industry, especially for customised software and software services. If the projected trends in demand for skilled workers hold, demographics alone should continue to ensure the survival and growth, perhaps at a reduced rate, of India's software services industry.

India's success has, for the most part, been due to a combination of resource endowments, favourable government policies (such as substantial investments in higher education), and good timing. By the late 1980s, India was graduating a large number of English-speaking engineers and science graduates, but demand for their services was limited. In addition, India had begun to liberalise its economy. At around this time, the information technology revolution in the developed world had started to take root and shortages of skilled programmers and IT professionals were beginning to be felt. There were Indians working in virtually all large US firms, some of whom played an important role in bridging the gap and matching US buyers with Indian suppliers. In response, a number of Indian firms were quickly formed. The government considerably simplified the process of obtaining the many clearances and permits typically required of firms in India's organised sector. There were also incentives, but the most important factors in entrepreneurs' ability to seize the opportunity were government's lack of interference and the low level of initial investment required to launch a software services company.

Although India has characteristics that make it well-suited to fill this role, countries in South Asia, East Asia (such as the Philippines) and eastern Europe should also be able to take advantage of the reported shortage of skilled IT professionals. Although firms in the United States and Europe are comfortable with outsourcing software development to firms offshore, they will not outsource anything more than very simple coding unless they believe that the supplier has the required managerial and technological capabilities. Acquiring these capabilities and gaining the trust of clients takes time. Domestic market experience is typically not a good substitute for exporting experience.

Background and evolution of Indian software firms

The Indian software industry consists of a large and growing number of firms. Using NASSCOM membership as a measure, the number of Indian software firms has grown from around 430 in 1996-97 to over 620 in 1997-98. Many of these firms entered the industry during or just before the economic liberalisation of 1991. Given the large increases in demand, few if any firms have exited the industry. Table 3 shows that the industry is dominated by a few big companies, with a large fringe of small and medium-sized

Table 3. **Market share by revenue and number of employees, 1997**

Companies ranked by revenue	Number	% of total revenues	% of total employees
Top 5%	16	56	47
Top 10%	32	72	62
Top 20%	65	87	78
Top 30%	97	93	86
Top 40%	130	96	91
Top 50%	162	98	94
Top 60%	194	99	96

Source: Carnegie-Mellon University Software Dataset.

companies. According to NASSCOM figures, the top 25 companies accounted for a 58.7% share of software exports revenue in 1997-98. Nearly a quarter of the companies have turnover of less than INR 10 million (about USD 250 000).

For the most part, the market leaders in Indian software firms are relatively new. With a few exceptions, notably Wipro and Satyam, these firms specialise in software, in marked contrast to the early entrants. The early history of India's software industry is closely tied to that of computer hardware. The Tata Institute for Fundamental Research built India's first computer in the early 1950s, soon after the ENIAC was built in the United States. Although computers were later purchased from commercial vendors like IBM and DEC, the Indian nuclear and space research establishment continued to invest in hardware development capability. For commercial users, multinational corporations (MNCs) such as IBM and ICL provided hardware bundled with software well into the 1960s. During the 1970s, although users continued to supplement such software with internally written software, some leading scientific and defence research labs began to outsource some software development to local firms. Commercial users also began to outsource software development. In an interesting parallel with the current situation, this outsourcing often involved little more than software programmers coming to the labs to write and develop software alongside in-house software developers. Probably one of the biggest contributions that the public sector research establishment made to the Indian software industry was to provide a nucleus of highly skilled engineers and scientists.

Heeks (1996, p. 69) notes that in 1974 Tata Consultancy Services (TCS) was the first firm to agree to export software in return for being able to import hardware. TCS entered into a collaboration with Burroughs, and by 1978, the joint venture was spun off as a separate firm (called Tata Burroughs Limited and later, Tata Unisys Limited). TCS continued to grow in size and competence: it currently has some 9 000 employees and has successfully carried out several large, complex export projects.

Other companies followed. One of the earliest was Patni Computer Systems (PCS), a privately held firm started in 1972 with a data conversion project for commercial databases. The Indian affiliate was formed in 1976 and currently has three divisions. In addition to software exports, the company also has a hardware division (mainframe products, PCs) and a copper laminating division. At the time, India was seen as a cheap source of supply, but steep duties on imports of computer equipment (including keyboards, CRT screens), as well as union regulations, caused much data conversion work to be shifted to China and Chinese Taipei.

PCS formed an alliance with Data General, a mainframe computer firm; PCS marketed its equipment and provided it with programming services. The link to hardware firms is typical of older software firms (TCS-Burroughs, TUL-Unisys, Hinditron-DEC, Datamatics-Wang). In addition to firms that focused on software exports, others served domestic users, such as Computer Maintenance Corporation (CMC). Responsible for maintaining computer systems after IBM left India, CMC has over 2 000 employees and can develop and implement large and complex projects, especially for infrastructure systems.

Once software exports took off, many firms entered the industry. Entry barriers were low because firms could start with a small initial investment and little more than office space and communication facilities. With the growing need for maintenance services, many firms began by providing these services, often by sending software programmers to the client on a temporary basis. Firms became profitable quite rapidly and used their profits, coupled with bank loans (and, somewhat later, equity infusions), to finance their expansion. Economic liberalisation and the establishment of software technology parks where firms could get office space and communication facilities helped as well.

Entrants were of two types. One was existing firms diversifying into software. These included computer hardware firms, such as HCL and Wipro, as well as firms with large in-house data processing and system integration capabilities such as Larsen & Tubro (LTIL). Others, such as BFL, Sonata, Satyam and Birla Horizons, were part of large and medium-sized industrial groups. The second type was start-ups, such as PCS, Datamatics, Infosys and Silverline. TCS, PCS, Datamatics, CMC and Wipro are pioneer software export firms. Managers at many software firms worked in these companies early in their career.

Entry strategies varied, and not all firms entered to provide software export services. Some entered to develop packaged products, products for specific industries or enterprise resource planning (ERP) products. In the early to mid-1990s, software service exports increased in importance. Some product-focused firms went into services in order to finance product development and services, especially through exports, which provide steady earnings. On the whole, however, most firms that began with other operations have moved to software services as their core business, developing customised software both on and off site.

The result has been a great deal of turnover among the leading software firms (Table 4). Signs of maturity are now appearing. Larger firms tend to earn more per employee, and the number has increased over time, albeit slowly. Although entry is still strong, there are indications that the market leaders are identifying niches and areas of specialisation in terms of technology or functions, as well as vertical domains (industrial sector). Two firms, BFL and IIS Infotech, have recently been acquired by a Dutch bank and a British software service company, respectively; nonetheless a major consolidation still appears to be some time away, mainly because demand is still growing rapidly and economies of scale are relatively unimportant, particularly for low-level coding and maintenance.

Contrary to popular belief, the industry is not concentrated in Bangalore, although it is certainly an important location. Locations such as Bombay (Mumbai), Pune, Madras (Chennai) and Hyderabad are important as well (Table 5). However, except for the region around Delhi, there are no noticeable clusters in the northern or eastern regions.

For the most part, the western and southern states have provided better infrastructure and environment for business and have more public sector research establishments. Bombay has TIFR (Tata Institute for Fundamental Research), with the country's earliest computer division, BARC (Bhabha Atomic Research Centre), the AEC (Atomic Energy Commission) and two premier educational institutions in IIT Bombay and Bombay University. In addition, Bombay is widely acknowledged as the commercial capital and is home to the technologically progressive Tata group, of which Tata Consultancy Services is a part. Bangalore also has, in addition to two well-known engineering colleges, the Indian Institute of Science and a number of public sector establishments involved in space research (ISRO), aeronautics (HAL), and computers and electronics (ECIL, BEL). More recently, the software industry has spread to Calcutta and

Table 4. **Top eight Indian IT exporting firms**

Rank	1980-81	1985-86	1989-90	1994-95	1997-98
1	TCS	TCS	TCS	TCS	TCS
2	TUL	TUL	TUL	TUL	Wipro
3	Computronics	PCS	COSL	Wipro	HCL Consulting Ltd.
4	Shaw Wallace	Hindistron	Datamatics	Pentafour	Pentafour
5	Hinditron	Infosys	Texas Instruments (TI)	Infosys	NIIT Ltd.
6	Indicos Systems	Datamatics	Digital (DEIL)	Silverline	Infosys
7	ORG	DCM DP	PCS	Fujitsu	Satyam
8	System	COSL	Mahindra-BT	Digital (DEIL)	Tata Infotech Ltd.

Source: Heeks (1996) and Carnegie-Mellon University Software Dataset.

Table 5. **Revenue of the 405 NASSCOM member firms by geographic region, 1997**

Region	Revenue (millions of USD)	Number
Mumbai-Pune	597.5	107
Delhi Region	285.8	95
Bangalore	323.6	84
Chennai	130.9	34
Hyderabad	62.0	21
Others	57.6	64

Source: Carnegie-Mellon University Software Dataset.

Bhuvaneshwar in the east and central parts of India. Firms in these locations are less export-oriented than those in Bombay or Bangalore.

Characteristics of the Indian software industry

Domestic demand

For its domestic clients, the Indian software industry provides a wide range of services as well as a few products for business applications. Table 6 shows the composition of domestic demand. Domestic firms have begun to invest in information technology, particularly MRP (manufacturing resource planning) and ERP systems.

With some exceptions, domestic demand is the more challenging. It involves large, complex projects such as the screen-based trading system for the Bombay Stock Exchange, or the reservation system for railways, both by CMC. It also involves products such as ERP systems and products for the banking and insurance industry. Work for the domestic sector differs in that most firms make products and packages rather than simply providing support services. Domestic clients call in some of the larger software firms such as TCS, CMC, Wipro or Infosys to develop software systems from scratch, which range from analysis of requirements to post-production support. A number of medium-sized firms make products for the Indian and Middle Eastern markets which are very specific to the business culture. In the area of ERP packages, some firms are trying to compete in the domestic market with global giants like SAP, BAAN and PeopleSoft.

Many companies started targeting the domestic market in the late 1980s, some producing packaged software products such as word processing packages for Indian languages (*e.g.* Sonata) or accounting packages and products for the banking sector. Another leading firm, Mastek, provided custom software development services for large clients. For the most part, these efforts were less remunerative than the export market, and most companies that began with a domestic focus have turned to exports as well. Firms which focused on executing large complex domestic projects or products for the domestic market have also moved into software services in a substantial way. This clearly suggests that the export of software services is the most profitable business and even product-focused firms have added software services and consulting to fund product development (Udell, 1993).

Table 6. **Domestic Indian software industry by type of project, 1997-98**

Segment	Percentage
Turnkey projects	47.9
Products & packages	38.2
Consultancy	8.1
Data processing	5.6
Other	0.2

Source: NASSCOM.

Given the simpler and more routine tasks involved in current software exports, these firms' sophisticated capabilities and expertise have not been of great value to them in the export market. There are a few exceptions, possibly the most noteworthy one a subsidiary of Citicorp that has successfully exported its banking products to a large number of developing countries. Other firms have also targeted other developing countries as outlets for specialised products for the financial, banking and hospitality industry.

Many MNCs have set up liaison offices and subsidiaries (Table 7) and a number have sought domestic partners. Initially, the partnerships were to sell the MNC's products (hardware and software packages) in India. Increasingly, however, India is used for software development and some companies have established, or are establishing, software development centres in India and exporting packages or system components from India to other countries. The work done at development centres is fairly sophisticated. For instance, the operating system for the "network computer" introduced by Oracle is said to have been designed entirely in India. Similarly, the Texas Instrument's R&D centre is capable of fairly sophisticated work, including analog chip design. Other prominent MNCs present include Motorola, Siemens, Hughes Network, Computer Associates and Cadence.

Table 7. **Leading IT MNCs in India by revenue**

Company	Revenue (millions of USD)	Local partner
HP	37.2	HCL, HPISO
IBM	35.1	TISL, Lotus
Intel	21.9	Intel
Compaq	21.9	Compaq
Digital	19.6	DEIL (now Compaq)
Acer	16.1	Wipro-Acer
Sun	13.2	Sun
Microsoft	12.2	Microsoft
Redington	10.5	
Seagate	9.7	ACL
Siemens	9.4	SISL, SNI, SCS
Apple	5.3	
Citizen	5.4	TVSE
Liebert	4.9	Tata Liebert
Novell	4.9	Onward Novell
SGI	4.4	
AST	4.3	
Dell	4.3	
Oracle	4.3	
Motorola	4.2	Motorola ISG, MIEL

Source: *Financial Times*, 8 December 1997, Supplement.

In addition, a number of software service providers located in the United States have established large Indian operations. Firms such as Information Management Resources (IMR), Syntel, CBSL and Mastech use their India operations much as Indian software export firms do, to tap a large pool of relatively cheap and skilled workers. Virtually all of these firms are headed by people of Indian origin and as Indian software exporters establish overseas subsidiaries, the distinction between the two will disappear.

Exports

Insofar as exports are concerned, the industry is primarily service-oriented (Table 8). Whereas products account for nearly 40% of the domestic market, they account for a little over 10% of exports. Over 85% of exports are software services, including custom software development, consultancy and professional services. Most firms in India mainly undertake maintenance tasks for applications on legacy systems such as IBM mainframe computers, development of small applications and enhancements for existing systems, migration to client-server systems (often referred to as porting or re-engineering). The Year 2000 problem has also opened a broad market for firms that traditionally undertook mainframe-based

Table 8. **Composition of India's software exports, 1996-97**

Segment	Percentage
Professional services	47
Consultancy	28
Products and packages	11
Data processing	11
Other	3

Source: NASSCOM.

maintenance projects.[5] There is remarkable similarity across firms in this respect despite marked differences in origin and domestic market orientation, although the leading firms distinguish themselves in some respects.

Although competition from countries such as the Philippines and China is often mentioned by the media, competition from US-based service providers (often founded and staffed by Indian software professionals) is very significant. When asked, most software exporters indicate that their main competitors are located in the United States or in India (Arora *et al.*, 1999).

The United States accounts for over half of all export revenues (58% in 1997-98), compared with 21% for Europe and only 4% for Japan (Table 9). Southeast Asia and West Asia together account for 10% of software exports. Several Indian software companies are planning to use euro conversion projects as their entry vehicle into the European market. Owing to the language barrier, a smaller number have targeted the Japanese market. Most of the larger exporters have branch offices in the United States, and several have offices in countries such as the United Kingdom and the Netherlands. Branch offices are used for marketing and to serve the many professionals working on site.

Offshore development centres are popular among firms based in the United States and Europe that wish to take advantage of India's skilled workers and lower wages.[6] Under this system, the client negotiates a long-term agreement on prices for time and materials (usually standardised on a man-hour basis). When the client sends a project to the centre, the negotiations are largely restricted to the resources and time required. Some large US firms have three to four vendors in India and often ask them all to bid.

With very few exceptions, work outsourced does not involve the development of mission-critical applications, nor do projects involve very sophisticated technology. Often firms outsource work considered routine or uninteresting by their IT professionals. They also outsource such work to free up in-house staff to develop software or information systems they consider more specific to their business. Requirements analysis and high-level design are typically done either in house or by US-based consultants, although in some cases an Indian firm has been asked to do requirements analysis and the programming work is then given to a lower-cost supplier, in India or elsewhere.

A typical export project is small (less than ten man-years), has a value of less than USD 1 million, and involves maintenance, porting an existing application from a legacy platform to a client server platform or Y2K work (Arora *et al.*, 1999). Somewhere between one-third and two-thirds of the work is executed offshore (in India). However, since the rates for onsite work are roughly three times those for offshore work,

Table 9. **Destination of exports, 1997**

Destination	Percentage of export revenues
United States	58
Europe	21
Southeast Asia	8
Japan	4
Australia and New Zealand	2
West Asia	2
Rest of the world	5

Source: NASSCOM.

export earnings from onsite work are about twice those from offshore work. From a life-cycle perspective, systems requirements, high-level design, and installation and testing are typically not outsourced, while low-level design, coding, and post-installation maintenance (of older systems) are.[7]

Most Indian software firms have evolved from product maintenance to product testing and low-level design and coding of software components. Here, clients provide the outsourcing firm with the functional specifications of the applications to be developed. Apart from the coding of the requisite modules, the Indian firms also carry out most of the testing phases (except for acceptance testing, which is carried out by the client or the final customer).

The vendor (the Indian software firm) rarely works on the requirements specifications, a phase best done by those who have worked in the specific domain for many years, have a good knowledge of the market and understand the business well. Testing operations could include specialised testing that requires knowledge of the application and domain area.

Service exports are split roughly evenly at present between offshore and onsite, although the percentage varies across firms. Table 10 shows that the fraction of work done offshore is increasing, albeit slowly. Most industry observers agree that one man-year of offshore software development is billed at about USD 30 000 while one man-year of onsite (in the United States) development costs USD 90 000-100 000. In contrast, rates for domestic work are of the order USD 10 000 a year. Needless to say, the rates vary somewhat, depending on experience and type of specialisation. Onsite work is deemed necessary for communication, although it is about two to three times as expensive. The shift to offshore work requires substantial investment in physical infrastructure (including the security infrastructure demanded by some clients to protect their intellectual property). It also requires that the Indian firm be able to demonstrate the project management capabilities required to execute even small projects.

Table 10. **Percentage of offshore exports based on software development in India**

	Percentage offshore
1988	10
1989	25
1991	15-27
1992	34-36
1993	38
1996-97	41+

Source: NASSCOM.

Firm specialisation

Although many Indian software firms provide services for a broad range of industrial domains, including manufacturing, banking and insurance, retail and distribution, and transport (Table 11), some are now beginning to specialise in order to build specific competencies. Others are focusing on building generic competencies related not to industries but to technical areas within software development, such as networking, systems software, software tools and conversion and porting.

Most firms claim to provide services for most platforms. However, there has been a steady move from mainframe-based to open systems. Indian firms jumped on the open systems bandwagon early on, and in the past few years most have gained experience on Windows platforms (Tables 12 and 13). While a few only provide services for Windows and NT platforms, the larger firms have projects that span most platforms and provide services on IBM mainframes, Unix Workstations and Windows NT platforms. The expertise of Indian firms on UNIX and WinNT platforms is considered to be on a par with that of US firms. Since the advent of object-oriented languages and Java, most firms have invested in training developers in these areas. Although some firms have started projects in Java and have shown some expertise in the new

Table 11. **Industrial domain of final product market, 1997**

Sector	Percentage of firms
Banking	78
Retail and distribution	73
Manufacturing	72
Government	68
Transport	65
Communication	64
Insurance	57
Hotels	56
Others	46
Defence	25

Source: NASSCOM.

Table 12. **Hardware platform capability claimed by Indian software firms, 1997**

Platform	Percentage
PC	98
LAN/ Novell	92
UNIX	90
Mainframe	80
AS/400	72
HP	70
DEC	65
SUN	60
RS 6000	65
Unisys	52
Tandem	55
Others	40
SGI	35
Mac	25

Source: NASSCOM.

Table 13. **Development platform (OS) capability claimed by Indian software firms, 1997**

Platform	Percentage
PC (DOS, Win, Apple)	68
UNIX	55
Midrange	30
Mainframe	12

Source: NASSCOM.

platforms, US clients do not consider their Indian counterparts to be adequately familiar with cutting-edge technologies. Nonetheless, some Indian firms do write device drivers for UNIX- and PC-based systems, some of the larger firms like TCS and Wipro have research divisions and a number of professionals working at smaller organisations are conversant with the latest technologies.[8]

In efforts to move up the value chain, many Indian firms actively work towards obtaining internationally recognised quality certifications like the Software Engineering Institute's CMM (Paulk *et al.*, 1993), the international standard ISO 9000 and the United Kingdom's TickIT. Of the top 250 firms, more than one-third have already been certified and the vast majority of the rest are in the process of certification (Table 14). Virtually all of the larger firms, accounting for about 45% of total revenue, have quality certifications (Arora and Asundi, 1999).[9]

The evidence suggests that some established firms are growing in their ability to handle larger and more complex projects. As US and European firms have become more experienced in outsourcing to

Table 14. **Quality certification – top 250 firms**

	Number	Percentage
Already certified	89	35.6
In the process of certification	136	54.4
No plans at present	25	10

Source: NASSCOM.

India and better able to assess the capabilities of Indian firms, they have been willing to let a greater share of the work be performed offshore. This saves money and economises on scarce managerial resources.

In addition to the type and complexity of work done, the nature of payment terms is another indicator of the industry's maturity. Fixed-fee contracts involve greater risk for the vendor than cost plus or time and material contracts. With greater risk comes greater control over the organisation and management of work. Although systematic data are not available, the evidence suggests a steady increase in the fixed price component of work. Bannerjee and Duflo (1998) present data from 236 contracts (not including offshore development centre contracts) from 125 software companies. They find that 58% are fixed price contracts, while another 27% are "mixed". Only 15% of the contracts are pure time and material contracts. The dynamic nature of software development results in changes in requirements and specifications and thus in frequent time and cost over-runs, which are often shared between the Indian vendor and the overseas client.

Human resources

It is widely believed that the key to the success of Indian software exports is the supply of trained, low-cost software professionals. Wage costs in India are estimated at one-third to one-fifth of US levels for comparable work (Table 15). Other figures suggest that once all costs are factored in, the cost of software development is half of US levels. As a comparison, wage data for Ireland suggest that wages are about two-thirds the US level and two to three times the level in India.

Apart from costs, the other component is the size of the talent pool. In 1997, the total number of software professionals was estimated at about 160 000, with a median age of 28.4, compared with 140 000 in the previous year (NASSCOM, 1998). Virtually all of these professionals have either an engineering degree or a "Masters in Computer Applications". In addition, although there are a large number of students trained by private, for-profit firms such as NIIT and Aptech, the educational offerings of the private for-profit sector are not considered to be on a par with those of engineering colleges. Graduates of these institutions are usually hired by smaller and younger firms as well as by non-software firms to maintain

Table 15. **Salaries of software professionals in the United States and India,[1] 1997**

	United States (USD per annum)	India[2] (USD per annum)
Help-desk support technician	25 000 - 35 500	5 400-7 000
Programmer	32 500 - 39 000	2 200-2 900
Network administrator	36 000 - 55 000	15 700-19 200
Programmer analyst	39 000 - 50 000	5 400-7 000
Systems analyst	46 000 - 57 500	8 200-10 700
Software developer	49 000 - 67 500	15 700-19 200
Database administrator	54 000 - 67 500	15 700-19 200

1. Figures are starting salaries for large establishments employing more than 50 software professionals. They may be marginally lower for smaller firms. Salaries for a particular designation vary owing to factors such as educational and experience profile of the professional; platform of operation; nature of the assignment (contract/full-time); location of the employer; and additional technical/professional certification.
2. Converted at exchange rate of INR 41.50/USD.

Source: INFAC, Bombay (1998).

existing software or develop customised software. As a result of this indirect demand, firms like NIIT and Aptech are very profitable and growing rapidly.

Despite the relatively non-technical nature of the bulk of the work, the Indian software industry tends to recruit engineering graduates. India graduates over 60 000 engineers a year and a large fraction are now finding employment in the software industry. Most of the leading firms recruit either engineers or students with a first degree in mathematics or science. Many also have in-house testing and training programmes. Although expensive, the leading software firms see quality of staff as a key competitive element and as a way to signal their ability to handle large projects offshore.

However, although they pay substantially above standard wages, firms find it difficult to recruit and retain talented professionals, many of whom can find highly paid jobs in the United States. Development centres and subsidiaries of foreign multinationals are also adding to the demand. Software professionals with 3-6 years of experience are especially mobile and attractive to foreign employers. Manpower shortages are reflected in the 20% increase in wage costs and industry attrition rates are said to be nearly 20-25%.[10] Moreover, the large number of firms still being established makes it difficult for firms to retain skilled personnel (Nidumolu and Goodman, 1993). The problem appears to be that students trained by for-profit training institutes are not judged appropriate for export services, although exports do not require an engineering background. On the contrary, many domestic projects are far more complex and technically demanding.

Since only a small fraction of the students trained by the existing private training institutes are seen as suitable by the software industry, a number of public sector and industry initiatives address the shortage of software professionals. The government has recently announced the establishment of the Indian Institutes of Information Technology, along the lines of the well-known Indian Institutes of Technology. A number of for-profit training institutes are also appearing. Institutes have been set up by Silverline and Mahindra-BT is a joint venture between the Mahindra Group and British Telecom. The latter is an ambitious effort which aims to teach methodologies and techniques for software development.

Firms are responding to the problem of employee attrition in a number of ways (Arora *et al.*, 1999). One is to provide employees with opportunities for career development and personal growth. Many stress their ability to provide a career path that allows employees to become managers, something apparently valued by Indian professionals. A number of firms are actively considering stock options for employees now that this has become possible. Interestingly, few firms felt that they paid above-market wages.

Finance

Software services, especially for export, are very profitable, with good cash flow and limited up-front investment. Therefore, finance is not a major problem for software service firms, unless they wish to expand rapidly or overseas. However, obtaining finance is a major concern for firms developing software products. A substantial share of such firms rely on equity financing as the primary external source of capital, although loans from banks and term-lending institutions are also important. Some firms rely upon financing from their parent firm or from business groups with which they are affiliated. In some cases, payments from clients provide good cash flow and banks are willing to lend against contracts. Some domestic and foreign venture capital funds operate in India. However, venture capital funds associated with a well-known Silicon Valley venture capital firm, Draper International, have only been able to allocate 60% of the available funds.

The problem appears to be as much on the demand as on the supply side. In addition to the usual problems involved in setting up businesses in India, venture capitalists are primarily interested in products developed for large markets and that therefore can succeed in the United States. As developing products for the US market in India is widely thought to be very difficult, many firms that develop products also provide software services to generate cash and to enter the market relatively easily and gain experience. In addition, for tax reasons, it is better to make equity investments in a US firm than in an Indian firm but then to have a wholly owned subsidiary which makes its financial report in India and is granted tax exemptions. Some start-ups from India have moved to the United States, whereas others from the United States have moved part of their operations to India. In the meantime, while NASSCOM has emphasised the need for venture capital, it looks to the future when it hopes that more local firms will develop new products.

Infrastructure

A modern and accessible communication infrastructure is considered vital for the continued growth of the industry. This is most obviously the case for software service exports, especially for offshore software development. Overall, India's data communication infrastructure is expensive and limited. The problem has a significant institutional component, as government agencies such as the Department of Telecommunication and VSNL, until recently India's sole Internet service provider, are unwilling to give up their hold on telecommunications.

Some clients do find network speed and general problems with the communication infrastructure a major irritant.[11] However, as with finance, most firms consider the communication infrastructure problem less important than finding and retaining qualified software professionals and the physical infrastructure (*e.g.* roads, power). Two quite different inferences are possible: either the communication infrastructure is adequate and firms have found ways around the high price and low availability constraint; or the offshore component of the tasks carried out in most Indian firms requires only limited communication so that the existing bandwidth is adequate. Consistent with the latter interpretation is the fact that export projects are simple, small and reasonably easy to specify in detail in advance.[12] Moreover, as the poor communication infrastructure has impacted the diffusion of the Internet domestically, growth of new firms that could provide software services for and via the Internet has been discouraged.

Global business strategies

Existing software service providers face two closely related major challenges: *i*) finding and retaining talented software professionals; and *ii*) developing beyond competition based on low cost in an environment with rapidly rising labour costs (Arora *et al.*, 1999). The leading firms have responded to this challenge either by trying to move to higher-value-added consulting (by developing domain expertise) or by developing new software tools that can lower the cost of providing the service (thus offsetting higher wage costs).

Some firms are moving up the value chain by accumulating knowledge about the industry segments for which they currently develop software (Arora *et al.*, 1999). They hope that, by better understanding the business needs of their clients, they can anticipate these needs and provide solutions. The first step in this respect is to perform the "requirements analysis and design" in addition to the coding that is currently the staple work. This requires being able to understand what the client wants and to translate that into a design for a software system. This calls for both greater technical capability and better knowledge of the client's business processes. Most of the larger firms believe that they have the experience, methodological maturity and managerial capability to make the transition, but feel that they need to add to their domain expertise and marketing ability. The high turnover in employees makes the accumulation of such expertise a particular challenge, because the loss of an employee implies the loss of that employee's experience and expertise.

Firms are therefore trying to embody some of their knowledge in products or tools. In most cases, these are not "shrink-wrap" software products to be sold off the shelf. Rather, they are software tools a firm can use to provide better service to its clients, or software code that has to be customised to meet the client's specific requirements. For instance, some firms have developed specialised tools that help them search more efficiently for Y2K-related bugs. Others are developing suites of tools that help them standardise and partially automate tasks such as porting.

Both strategies have promise, and many firms are trying to combine them. Both require technological sophistication and capability. However, the biggest challenge is that successful implementation of these strategies will require a great deal of commitment from management. Firms will have to invest a great deal in hiring, training and retaining employees, expanding overseas and establishing subsidiaries in countries such as the United States and in western Europe, as well as in acquiring the required technological and business expertise. Furthermore, such investments will have to be made over long periods, possibly well in advance of any return on investment. As noted above, Indian firms have so far been able to enjoy high profits without having to expose themselves to such risk. Thus, although most of the established firms have such strategies, relatively few are implementing them with any determination. For instance, only a few firms have taken concrete steps to retain their key executives. There is little evidence of attempts to reduce dependence on employees by building a database of customers and prospective clients or one that captures experience gained during export projects.

In the absence of such efforts, the firm will face increasing wage costs and relatively static billing rates. This will inhibit its ability to hire and retain talented professionals, reducing its attractiveness to overseas clients. Although many, perhaps even most, of the established firms may fail to move up the value chain, the few that succeed are likely to become much larger and more prominent. They will be able to execute large, complex projects with little or no supervision from their US clients. In time, they may even be able to anticipate the business needs of their clients and offer them solutions. Such firms could then acquire other Indian software firms (or their assets) or employ them as subcontractors.

Thus, while not all (or even most) of the established firms need to succeed for the Indian industry to move successfully to the next stage, at least a few established firms must do so or give ground to lower-cost competitors from other countries. In this case, there would be a real danger that the industry would shrink. Many clients outsource with a view to discovering their suppliers' capabilities so as to increase progressively the number and complexity of projects outsourced. If a supplier fails to meet expectations, even the simpler projects may be taken away and given to other suppliers, which may be in other countries.

Perspectives of overseas clients

Although low labour costs are an obvious advantage, both Indian firms and their overseas clients point to a related factor – the availability of skilled manpower – as being at least as important. Many of the larger US firms are knowledgeable about outsourcing software development and about the strengths and weaknesses of Indian software services firms. The most frequently cited reasons for outsourcing are the shortage of skilled professionals and their high cost in the United States. In addition, firms outsource in order not to invest in in-house capability in areas outside their core competence or which are not considered central to their mission. Other reasons include the need to accelerate product development in the face of ever shorter product life cycles.

Perceived strengths of Indian software firms

Clients see excellent programming and coding skills as one of the biggest strengths of Indian firms. Many also consider them good and willing learners and receptive to new ideas; Indian firms are also generally quite flexible in terms of the software and hardware platforms for which they provide services. Probably the single most important reason for choosing Indian firms over others is the large pool of software professionals. In some cases, clients outsource to Indian firms to get access to more specialised engineering talent, particularly in the area of telecommunications.

In essence, the major strengths are the strong technical skills of Indian programmers, the large numbers available, lower wages, and the eagerness of Indian firms to accommodate clients. For the most part, the domestic experience of the Indian vendors is judged to be of very limited value. This reflects the limited range of services that Indian firms provide to clients in the United States. On the whole, however, clients are satisfied with their outsourcing decision.

Perceived weaknesses of Indian software firms

Most clients believe that their Indian vendors could not work on high-level specifications or definition stages of a project although, for the most part, this belief is not born of experience. It is based largely on two perceived weaknesses of Indian firms: weak management systems and poor domain knowledge (Arora *et al.*, 1999). For instance, a leading US developer of software products considered that its Indian vendors had a weak understanding of product development for the US market. Even a highly rated Indian subsidiary of a leading electronics and communication firm was rated as being four to five years behind the latest technologies. There is also some scepticism about Indian programmers' productivity and creativity.[13]

Regarding management skills, many clients are critical of the Indian system of promoting software programmers to managers on the basis of seniority rather than proven managerial ability, as this weakens project management. Indian firms, on the other hand, cite this practice as a way of providing a career path and a major element of their attempt to hold down employee attrition. Most clients also view employee attrition as a problem that their Indian suppliers should tackle quickly. Some recounted experiences where virtually the entire project team left after six months, causing substantial delays (Arora *et al.*, 1999).

Clients perceive a number of (cultural and political) issues as irritants or barriers. One is the apparent unwillingness of Indian software professionals to point out potential problems up front, and a general unwillingness to say no to clients for fear of offending them. Another related weakness is a lack of familiarity of both firms and professionals with Western work culture and work norms, especially in the United States. Other difficulties include resistance within the United States to foreign programmers, poor telecommunication infrastructure and delays in obtaining the required work visas for onsite Indian programmers.[14]

An international comparison of performance

In terms of revenue and exports, the Indian software industry is comparable to Ireland's and Israel's and larger than that of South Korea. However, earnings per software professional appear to be well below those in Israel and Ireland. All three – India, Ireland and Israel – have common characteristics, including an abundant, highly educated and relatively inexpensive, English-speaking workforce. All three also have special characteristics that have enabled them to emerge as significant players in the world software markets, albeit in different types of activities and domains.

Israel

Israel has emerged as source of entrepreneurial firms developing software products in areas such as security and anti-virus technology. Table 16 shows the growth in exports and total revenue for the Israeli software industry.

Israel has about 300 software houses employing nearly 20 000, with total revenue of over USD 1.5 billion. Many of these firms receive US venture capital financing and some are listed on NASDAQ. A large share are engaged in developing, often technically highly sophisticated, software packages for export markets. Many of the world's largest computer companies, including Microsoft, IBM, Intel, Hewlett Packard, National Semiconductor and Motorola, have set up software development centres in Israel. IBM employs 300 scientists and engineers at its design facility in Haifa, where Microsoft has also set up its first R&D facilities outside the United States. Motorola and National Semiconductor have major

Table 16. **The software industry in Israel: exports and total revenue**

Millions of USD

	Exports	Revenue
1989	65	380
1990	89	450
1991	110	540
1992	135	600
1993	175	700
1994	220	800
1995	300	950
1996	400	1 100
1997	540	1 300
1998 (est.)	700	1 500

Source: Israeli Association of Software Houses.

design centres, and Intel is currently investing in its largest R&D centre worldwide there. Israel has a large number of technically skilled workers with high entrepreneurial drive. Reportedly, about 20% of Israel's population has arrived in the last five years. These immigrants have doubled the number of technicians, engineers and scientists. Israel now has 135 engineers and technicians for every 10 000 population, compared with only 18 for the United States (*The Economist*, 1999). And venture capital has flowed to Israel. Over 50 venture capital funds are said to be operating there and more than USD 4 billion was invested in high-technology start-ups in Israel in 1998.

Ireland

In 1998, the Irish software industry employed over 21 000 persons, and had revenues of over USD 7.4 billion. It comprises some 760 companies, of which about one-sixth are foreign. The relatively high degree of foreign ownership, particularly among larger establishments, is consistent with Ireland's emergence as a favoured location for multinational firms. Apart from a relatively large, relatively inexpensive, English-speaking workforce, Ireland's attractions include low corporate tax rates and other investment incentives, as well as EU membership (a convenience for exports to other EU countries). Nearly 70% of Irish exports are to the European Union, of which more than half to the United Kingdom. Technology-based sectors, notably electronics and software, and chemicals account for 43% and 25% of Irish exports, respectively. The indigenous Irish software industry develops software products and provides a variety of software development and support services. A few Irish software firms are listed on NASDAQ and almost all ancillary/support companies are accredited at the highest international standards, such as ISO 9000.

Conclusion

The picture of the Indian software services industry is a mixed one. On the one hand, there is a great deal of excitement, owing to its rapid growth and export success. On the other hand, the work performed is fairly mundane, with only limited potential for sustained growth. The last couple of years have brought some evidence that established Indian firms are maturing and growing in their ability to execute larger and more complex projects, as well as higher-value-added parts of such projects (such as requirements specification and high-level design). The domestic market provides far more challenging projects, but the links between it and exports is, at present, tenuous. There is little evidence that experience with complex domestic projects has a high pay-off in the export market or that the "learning to walk on two legs entry strategy" (Schware, 1992) is being practised by Indian firms. Indeed, many firms that began with a domestic market focus seem to have moved towards less challenging but more lucrative export tasks. The sustained growth of the Indian economy over the last four to five years may increase the attraction of the domestic market but exports seem likely to continue to account for two-thirds of the industry revenue.

Nevertheless, the Indian software industry's accomplishments to date are considerable. For industrialising countries, India's entry into the software industry is a far more pertinent development model than that of Israel and Ireland. While the Israeli software industry is about the same size as India's and is also focused on export markets, Israeli firms produce highly sophisticated software products and packages. Moreover, they attract foreign investors who want to tap into the local entrepreneurial dynamics and R&D capabilities. Few other non-OECD countries can boast having such a highly educated and skilled workforce and sophisticated venture capital markets. Likewise, Ireland does not offer an appropriate road map for most non-member economies. Ireland's indigenous software industry is similar to India's in that its firms are less entrepreneurial and export a larger proportion of software development and support services. Unlike India and most non-member economies, however, Ireland offers a very attractive investment environment for firms needing an entry point into the European Union, and is thus the recipient of a good deal of foreign investment. Ireland has benefited enormously from both its geographic and fiscal environment. These conditions cannot easily be replicated elsewhere.

Characteristics that have aided the rapid expansion of software services exports from India include an abundant, skilled, English-speaking and relatively inexpensive labour force; an international diaspora which has provided initial business connections with export markets; non-invasive government policies and ready capital. While these conditions are not present in most non-OECD economies, Indian companies seem to believe that their experience in building an export-oriented software service industry can be replicated elsewhere. In fact, given that demand for software services continues to grow internationally and that the Indian wage rate is rising, it seems likely that other countries will soon emerge as software development centres. The challenge facing Indian firms is how to manage the transition to higher-value segments of the software industry in order to face new competitors.

The Indian software industry is estimated to have revenues of over USD 3 billion and employs nearly 200 000. When compared to Israel and Ireland, India has the largest number of employees in the industry and the highest rate of growth, but also the lowest revenue per employee. Whereas the Irish and Israeli firms appear to earn as much as USD 100 000 per employee or more, Indian firms earn an average of only about USD 15 000. This difference is intriguing, particularly when comparing Ireland and India. Somewhat like India, Ireland also appears to have a significant focus on software services and contract software development. Indian firms' low revenue per employee suggests that their customers capture a substantial share of the value generated by outsourcing.[15] This interpretation is consistent with the popular notion that offshore outsourcing is driven by cost considerations.

Correa (1996) distinguishes three main strategies that may enable developing country firms to trade in world software markets:

– Export of labour ("body shopping") to perform short-term work overseas. This a low-cost/low-risk strategy in which workers gain experience of foreign markets and software process management techniques but are confined to routine, low-value-added tasks. India and the Philippines have followed this strategy.

– Export of software development services. This is potentially more profitable but requires efficient/accessible local infrastructure development and support services. This strategy can also foster the development of project management skills. Some Indian firms have followed this path, as have firms in Chile and Singapore.

– Export of software products. This strategy requires considerable domestic capabilities and high capital investment levels, but has the potential to generate high profits and build knowledge as firms find their way to high-value-added services markets. Firms in Israel and Chile have pursued this strategy.

The Indian experience seems to indicate that countries can neither skip stages of development, nor expect easy transitions from lower- to higher-value-added segments of the software industry. It is far from clear how India's firms can become IT consultancies and create proprietary intellectual property. While a strong domestic market helps to some extent, the transition process cannot focus on internal markets, as the most demanding users are found in advanced economies. Since software is an input into other industrial sectors, product development and consultancy require a presence in or an intimate understanding of how these sectors work and their problems. In the near future, software houses in OECD Member countries are unlikely to be directly challenged by firms from non-member economies. However, each group needs the other's competencies.

Indian firms are embarking upon two strategies to change their position in the global software marketplace. First, they hope to use their existing links with the United States and other advanced countries to acquire domain knowledge and knowledge about their clients' industries, in order to use that knowledge to move up the value chain. The second strategy is to create intellectual property, often in the form of a core product or tool, that can be customised to meet clients' needs. This "productisation" of what was formerly a service will, it is hoped, increase revenue per employee and counteract the increasing shortage of skilled software professionals and rising wage costs.

Success is far from assured. There are two critical factors. The first is the response of incumbent consultants, both traditional ones and firms like IBM and Oracle that are developing large IT consultancy businesses. Incumbent consultants are likely to prevail in any direct competition but may not be willing to compete for the less lucrative and less familiar markets that Indian firms are likely to target. The second critical factor is the ability of Indian software firms to manage this transition. Although it is too early to tell, it is likely that a substantial share of the existing firms that try to move up the value chain and offer "productised" services will fail to do so. If the Indian software industry is to take the next step successfully, it is vital that at least a few of the established firms succeed. These firms can act as the nucleus around which the industry can develop and mature. Failing this, it is difficult to see how long the first mover advantage that India enjoys can be sustained in the face of rising wage costs.

In addition to corporate strategies, the role of public policy in contributing to success factors (governments as industry promoters) must not be underestimated. Heeks (1999) lists six main areas in which governments can act to support local software firms:

– F*inancing*: stimulating the supply of working and venture capital through private sector and overseas funding (*e.g.* Israel, Chinese Taipei).

– S*kills development*: providing education and facilitating training (including through public-private partnerships) (*e.g.* Ireland).

– R&D: in co-operation with the private sector, large investments in R&D are needed to modernise the existing infrastructure and focus on commercialisation of existing capabilities (*e.g.* Israel's multimedia projects and military-funded developments).

– Developing and strengthening IPR *frameworks*, including enforcement.

– Contributing to the *development of modern and accessible* ICT *infrastructure*: some countries such as Brazil have chosen to develop "software parks" which act as high-tech clusters benefiting from economies of scale and informal networking.

– Using *procurement strategies* to diffuse best practice among local firms.

NOTES

1. This chapter draws on research on the Indian software industry sponsored by the Alfred P. Sloan Foundation and draws upon "The Indian Software Services Industry", Heinz School Working Paper, 99-19, Carnegie Mellon University. Prof. V.S. Arunachalam provided valuable advice and guidance in the preparation of this report, and Jai Asundi and Ronald Fernandes provided expert research assistance. All errors and omissions are mine.
2. Other industry commentators have also linked the rise in offshore outsourcing to the shortage of software talent. Barr and Tessler (1996; 1998) argue that the shortage is part of a secular trend that had, in the past, been disguised by cuts in US defence spending between 1988 and 1993, which resulted in the laying off of 75 000 programmers in Orange County alone. The shortage was further masked by the downsizing in the Information Systems (IS) departments of many major corporations. Barr and Tessler claim that the shortage is part of a secular trend, as software penetrates virtually every industry, especially with the rise of embedded software. The value of the latter, they state, was greater even then than the USD 500 billion of software developed in house. By comparison, they estimate packaged software and software services at about USD 260 billion (all figures are for 1995), <http://www-scip.stanford.edu/scip/avsgt/how1197.pdf>.
3. This does not include the software developed by users themselves or embedded software. This suggests that the figure is underestimated. Estimates of market size are not very reliable.
4. Indeed, in the early part of 1999 there was a marked slowing of demand for custom software development, enterprise software and supply chain management software. Coupled with reductions in spending on information technology in the financial sector, this has lowered the anticipated growth of most Indian software firms. In mid-1999, the sector appears only likely to grow at 20% instead of the projected 60%. However, it is also likely that the growth rate will pick up ones time.
5. Some observers estimate that Y2K work now accounts for up to 40% of Indian software exports (Heeks, 1998).
6. The term “onsite” is used for work that is performed at the client’s site, while “offshore” refers to work done in India. See Gopal (1996) for a detailed description of the division of tasks within the offshore and onsite development context.
7. For a description of the life-cycle (or waterfall) model of software development, see for example Sommerville (1995).
8. Such as OCXs, Internet-based ActiveX controls, CORBA/DCOM-based systems and Java-based applications.
9. An Indian subsidiary of a large US-based telecommunications firm was one of the first business organisations in the world to attain CMM Level 5 (the highest given to any company). More recently, one of the largest software development and services firms was certified at CMM Level 4. A unit of another leading Indian firm, WIPRO, has recently been certified at CMM Level 5.
10. A report published by the Export-Import Bank of India (1996) estimates that for the industry to grow at a rate of 50% a year, the number of software professionals in the software export sector has to grow at an annual rate of at least 30% over the next five years.
11. The managers at a leading software product firm said that connectivity to India was poor and networks very slow, making onsite presence almost a requirement.
12. In late 1998, the Indian Government announced that a high bandwidth (2.5 gigabyte) fibre-optic backbone would be set up. This may open up many new possibilities, including a significant increase in the offshore component of software exports.
13. Managers at a leading electronics and telecommunications firm also mentioned that they needed to assign more engineers to a task in their Indian subsidiary than they would in the United States.
14. Mansell and Wehn (1998) highlight three main obstacles facing Indian firms attempting to enter higher-value-added markets: *i*) lack of maturity and insufficient software development experience; *ii*) an unreliable local ICT infrastructure; and *iii*) cultural differences related to perceptions of trust and confidentiality.
15. Part of the explanation for India’s low revenue per employee lies in the extremely low rates per employee received for domestic software services, on the order of USD 10 000 per person. By comparison, the rates for domestic work in Ireland are likely to be considerably higher.

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Chapter 7

AGENT TECHNOLOGIES FOR THE INTERNET*

Intelligent agents are fast becoming an important tool for navigating the World Wide Web and facilitating e-commerce. They are personalised to respond to an individual user's needs, can act autonomously, give advice and make decisions on a user's behalf. Many believe intelligent agents will soon be indispensable, since the Web's rapid growth makes it increasingly difficult for individuals to manage the vast amounts of information it contains. A first generation of intelligent agents already acts as shopping assistants, information retrievers and financial advisors. Despite the perceived need for their services, however, there are several barriers to their development. Some are technical, as further research and/or standards setting are needed to improve the ease with which intelligent agents can gather information, communicate with each other and their owners and make decisions. Others are related to the legal and economic environment in which agents operate. Trust, privacy and consumer protection are three areas that must be addressed if people are to place their confidence in intelligent agents. Furthermore, as agents become ever more independent economic entities capable of negotiating, collaborating and transacting, e-commerce market dynamics will need to be monitored for destabilising or anti-competitive effects. Agents have the potential to transform the Web-based marketplace. It is important for governments to be aware of the issues that may arise and to encourage the creation of innovative solutions by businesses on the Internet.

About intelligent agents

What do intelligent agents do?

Intelligent agents are software programmes designed to search for, retrieve and act on information automatically on behalf of their users in a network or database environment. They have been an area of computer research for many years, but massive consumer interest in the Web creates an environment particularly well suited for the commercial application of agent technologies. On the Web, intelligent agents are being developed to help users navigate vast quantities of online data to find information, services and products of interest. For example, they can be instructed to create custom newspapers, monitor stock prices, perform intelligent searches, or even find the best product buys available on line. These virtual assistants are becoming more sophisticated and thus play an increasingly important role on the Internet. This chapter discusses how they function, the applications which exist today, future developments, and policy issues deriving from the growing prominence of intelligent agents on the Web.

What makes intelligent agents special?

Intelligent agents are a new kind of software which the user employs to delegate a significant and often complex task. A typical example is searching the Web for product details and price information. The agent performs this task autonomously, that is, without the user's immediate supervision or input. Agents vary according to the kind of information they are designed to locate, how they search the Web, how much of the Web they search, and how much decision making they perform.

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The way intelligent agents work may be contrasted with the predominant "user interface" model for human-computer interaction. In the user interface model, a software programme provides a variety of application-specific tools or functions which remain inactive until the user gives a specific instruction. After performing the task, the programme passively waits for the next instruction. Intelligent agents, in contrast, are more autonomous and active. Ideally, they:

– Have knowledge of the user's wider goals and desires.
– Are capable of taking the initiative when given a broad task to perform.
– Change their behaviour according to accumulated knowledge.
– Are able to make inferences.
– Are "mobile" in that they can navigate the Web without direct guidance from the user.

It is envisaged that, in the future, agents will be able to interact meaningfully with each other and help negotiate deals on behalf of their human principals. All these properties make intelligent agents well suited to a wide variety of time-consuming and data-intensive tasks in the Web environment.

Box 1. **Agents outside the Web**

Software agents are not unique to the Web. They are also used in computer modelling to simulate processes such as evolution and market behaviour. The term "agent" is often used to describe a component in a kind of software architecture in which multiple semiautonomous software components work together and communicate with one another to accomplish a common goal.

Do intelligent agents exist today?

Truly "intelligent" agents with a large degree of autonomy do not yet exist. The above description of intelligent agents is more a research paradigm than an actual category of programmes. Nonetheless, many useful first-generation intelligent agents (or "bots", for robots) with some of the functionality described above operate on the Web today. The difference between today's intelligent agents and other utility programmes is a matter of degree. Virus checkers and e-mail filters have many of the properties associated with intelligent agents.

Why use them?

The main advantage of intelligent agents is to allow more efficient access to more of the Web than manual browsing or use of first-generation search technologies. They are, therefore, starting to play a role as knowledgeable experts that gather news and information and help users find goods and services on the Web. They provide a means of leveraging the Internet's advantages by examining a far greater portion of the available information and by acting to shield the user from the Web's confusion and complexity. In general, they can decrease the amount of random Web surfing by providing focused and automated retrieval of digital information.

The potential impact of intelligent agents

Intelligent agents have the potential to facilitate global information retrieval, electronic shopping and many other Internet-based activities. By increasing the information pool a user can draw on and reducing the search costs faced by potential consumers, their use may also improve efficiency and create online markets that approximate the theoretical model of perfect competition. The kind of online environment that may, in future, result from the development and widespread acceptance of intelligent agents has been described as:

> *"…a seething milieu in which billions of economically motivated agents find and process information and disseminate it to humans and, increasingly, to other agents. Over time, agents will progress naturally from being mere facilitators of electronic commerce transactions to being financial decision makers, at first directly controlled by humans and later with increasing autonomy and responsibility. Ultimately, inter-agent electronic transactions may become an inseparable and perhaps dominant portion of the world economy."*[1]

Although today's first-generation agents do not yet fulfil these promises, research in artificial intelligence and machine learning will make future generations of intelligent agents more versatile, better able to interpret users' requests, comprehend the information that exists on the Web and communicate and share information.

As the technology behind intelligent agents develops and they are more commonly used, a number of issues will need to be addressed. On the technical side, for example, special data protocols may be required to increase the efficiency of intelligent agents. Legal and economic issues also need to be addressed. By removing control from human users, is there a risk that some parts of the Web will not be searched and that decision making will be subtly biased as a result? Will consumers be prepared to accept the loss of transparency that comes with relying on an intelligent agent? How can the sensitive personal information intelligent agents carry about their users be kept secure? Do agents have the legal capacity to incur obligations and enter into contracts on behalf of their human principals? How will agents affect the market structure of electronic commerce? Will the increasing use of intelligent agents have undesirable consequences such as price wars and market instability?

Applications

Internet-based intelligent agents are barely five years old, yet they have already been put to a wide variety of uses.[2] For example, agents have been created that search the Internet for information, regularly scan news groups for postings that include keywords of interest to the user, perform product searches and price comparisons, keep track of financial information, create custom newspapers, check and inform users when specified Web pages are updated, and find people who share the user's interests. (Appendix 1 to this chapter gives a list of intelligent agents available on the Web as of 19 August 1999.) Of first-generation intelligent agents, the most common tend to fall into the following three categories:

- I*ntelligent shopping agents* search the Web for product details and make price comparisons or recommend products based on the user's preferences.
- I*nformation retrieval agents* perform advanced searches by combining and filtering the output from many of the existing Web search engines and are capable of creating custom newspapers tailored to the user's preferences and interests.
- F*inancial agents* can track stock prices, issue price warnings and make financial product recommendations.

Thus, intelligent agents perform multiple tasks for their users. They can: *i*) *search* for relevant information; *ii*) *compare* information from different sources, synthesising and presenting it in a useful form; *iii*) *make recommendations*; and *iv*) in rare instances *negotiate* to settle the terms of a transaction (see Appendix 2 to this chapter for Web sites about intelligent agents).

Intelligent shopping agents

The rapidly growing popularity of the Web, the increasing prevalence of electronic commerce and the difficulty of knowing which are the best sites to buy from have all combined to create a fertile environment for the application of agent technologies. Shopping agents are easily the most prominent type of agent on the Web today.

Looking to the future

Many commentators believe that shopping agents will play a central role in the future growth and development of electronic commerce. One reason is that such tools are an effective aid to online consumer behaviour. A survey by Jupiter Communications found that 77% of buyers go on line with a specific purchase in mind and that nearly 80% visit several sites before making a purchase.[3] These results lead Jupiter to conclude that shopping agents that search the Web for consumer-specified products and generate a list of merchants with the best prices will greatly diminish the time required for comparison-shopping.

Many people anticipate that the technology behind shopping agents will develop substantially. In the future a shopping agent should be able to:

– Interpret a command, such as "I want a round trip to Sydney and tickets to the opera with accommodation for Saturday night."

– Act as an expert sales assistant and search the Internet for the best combination of travel accommodation and seating arrangements given its knowledge of the user's preferences.

– Return this information to the user and, eventually, go ahead and negotiate a contract and authorise payment from the user's account.

Although it may be quite some time before the technology necessary to create an agent-mediated electronic economy populated by interacting and negotiating agents develops, many intelligent shopping agents already exist and have a strong online presence in retail electronic commerce.

Box 2. **Using an intelligent agent to purchase an air ticket on the Web**

Many Web sites now offer planning of air travel and online booking of tickets. The procedure in these reservation systems is essentially the same. The intelligent agent asks the user a series of questions:

– Where is the user travelling from and to?

– When does he or she intend to travel?

– How many people are travelling and what are their ages?

– What ticket class is desired?

– What are the user's preferences (direct flights, cheap flights, tickets without advance purchasing restrictions)?

The intelligent agent uses this information to find the best ticket options from its database and displays flights that match the user's search criteria. The user can then select a flight and make a reservation on line. On some sites, users can also find hotels and rental cars and add these to their itinerary.

Shopping agents on the Web today

In general, the current shopping agents perform one of two roles. Either they act as specialised search engines which examine a specified list of Web storefronts for price and other product information, or they act as intelligent product recommendation systems which attempt to find the products in their databases that best match the user's preferences and requirements.

Search-based shopping agents

Search-based shopping agents often look and act like normal search engines, but they provide more focused product searches than are possible using general engines such as *Excite*, *AltaVista* or *Lycos*. For example, if one uses an all-purpose search engine, the terms "mountain", "bike" and "sale" may return tens of thousands of "hits". In this case, a user seeking to purchase a bike faces the daunting task of visiting these sites to find those that actually sell bikes, discovering which supply a bike in the area where the user lives, and then comparing the available offers. A shopping agent can shorten this process by asking the user questions to narrow the range of products under consideration and by searching its database of online stores to provide information about price, terms and conditions of sale, and product availability.

BargainFinder is widely regarded as the first shopping agent to have appeared on the Internet. No longer available, it was an experimental system produced by Andersen Consulting. The user provided it with the name of a specific music CD and it returned the price (including shipping costs) being charged at each of a number of online music stores. In this way, a user could simply and quickly find the best online offer available. There are a number of reasons why CDs were a suitable test product for *BargainFinder*. First, buyers typically already know which CD they are interested in and do not care where they buy it. The only features to be considered are price and method of delivery. Unlike many products and services, CDs have little in the way of product differentiation or quality issues that need to be considered. The second important reason for choosing CDs was the existence of a large number of online music stores, as CDs were among the first products to be sold commercially in large numbers on the Web. The factors that made CDs well suited to shopping agent price comparisons also apply to books. Today many Web sites provide agent searches across online bookstores. *Acses* checks price, availability, shipping times and shipping costs for any book at over 25 online stores. Others are *bestbookbuys.com*, *BookBlvd.com*, *buybooks.com* and *BookFinder.com*.

The next step in the evolution of shopping agents was to move from single product agents to broad-based "clearing house" agents that index many different products through a database of merchant pages. *Fido the Shopping Doggie* was an early example that searched its database of merchant pages and produced a list of product descriptions and prices. *PriceSCAN* and *Roboshopper* operate similar systems, which have evolved into general virtual shopping malls or "portals" for a vast array of products. These virtual malls offer a consistent, easily accessible graphical entry point which leads to different product categories with their own search databases. These are typically linked to merchants affiliated with the company that runs the portal. These portals are perhaps the most visible application of shopping agent technology. Typical categories included in shopping portals include home appliances, sport and leisure, food and wine, health products, garden supplies, toys and games, computer software and hardware, home office products, flowers and gifts. While they all provide a similar service, there are differences as to the range of merchants and products indexed, the provision of product recommendations, the frequency with which material is updated, the affiliation of the shopping agents with the merchants they access, the existence of links to sources of consumer information and the number of factors on which comparisons are made.

Product recommendation systems

The second group of shopping agents recommend products to users. They search their database of product information and find one or more suitable products. The recommendations are based on either "constraint-satisfaction algorithms", which match a user's needs to a product's features or "collaborative filtering" mechanisms, which make recommendations on the basis of the preferences of people with similar tastes.

Constraint-satisfaction algorithms

One way of producing a product recommendation is to use a constraint-satisfaction algorithm which compares the user's requirements and preferences with the product's features, which are indexed in the agent's database. *PersonaLogic* is a constraint-based product recommendation engine which has been used to produce a number of recommendation systems for different types of products.

PersonaLogic's interactive decision guides enable users to identify products that best meet their needs by asking a series of questions in order to specify users' requirements (hard constraints) and preferences (soft constraints). The result is an ordered list of products that provide the best overall fit. Interactive decision guides have already been developed for many topics, including cars, trucks, dates, bicycles, cruises, mutual funds, fashion, gifts, computers, colleges, cities, camcorders and pets.

Box 3. **Which is the right mountain bike for you?**

The AOL's bike-finder guide is an example of a system based on *PersonaLogic*'s constraint-based search engine. The agent asks questions relating to the type of bike the user requires, the maximum amount to be spent, the relative importance of different characteristics such as weight and responsiveness, component preferences, suspension systems and any preference in terms of manufacturers. The result is an ordered list of the bikes that best suit the user's requirements and preferences.

Constraint-satisfaction systems may also be used to configure a product with many sales options. An example is Dell's "Build Your Own System"[4] which allows a prospective purchaser to choose a product, customise it to meet his/her needs and purchase it on line.

An important feature of constraint-satisfaction systems in general is that they can be programmed to "reason backwards" and explain why one product was recommended or another discarded. An agent's ability to make its reasoning processes explicit and to justify its decisions is an important aspect of fostering user trust. Otherwise, users will be unwilling to rely on an agent's recommendations.

Collaborative filtering

Collaborative filtering is another mechanism for making product recommendations. Here, recommendations are based on the preferences of people with tastes similar to the user's. *Firefly* is a collaborative filtering system that uses opinions of like-minded people to offer recommendations regarding products such as music and books. *Amazon.com's Book Matcher* allows users to rate books they have read and then uses this information to find people with similar preferences and recommends other books which those people liked. Such systems use the opinions of like-minded people to offer "word of mouth" recommendations.

Online auctions

Intelligent agents can also be used to run auctions on behalf of human users. Online auctioning has developed into a popular form of buying and selling both new and used products over the Internet. Intelligent agents, such as *AuctionBot*, allow users to create auctions by selecting from a variety of auction types and parameters and forming a framework under which prospective buyers will bid, thus allowing any person to run their own auction over the Internet. Unlike popular online auction sites such as *eBay*'s AuctionWeb or *OnSale*, which require consumers to manage their own negotiation strategies over an extended period of time, agents like *AuctionBot* assist the seller to negotiate transaction terms but let agents compete autonomously in the marketplace for the best bids.[5]

Information retrieval agents

While the vast amount of information available on the Web is one of its greatest strengths, it can also be one of its greatest drawbacks. With over 800 million documents on the Web in 1999, it is quite possible that the information a user wants is there, but that a conventional Web-based search engine will either not retrieve the desired page or that it will retrieve so much irrelevant information that the desired information will be swamped. To date, no single search engine indexes more than a third of the Web, and their indices are not always up to date.[6] Intelligent information retrieval agents attempt to improve information searches on the Internet. The two main functions they perform are metasearching and news retrieval.

Metasearch engines

Intelligent agents such as *Mata Hari*, *WebFerret*PRO and *BullsEye* are metasearch engines that work on top of the hundreds of existing search engines and databases on the Web to find, filter and manage the information a user wants. They are typically able to address queries simultaneously to many search engines and present results in likely order of relevance.

News-retrieval agents

Custom news services which e-mail news articles that fit categories identified as of interest to the user are increasingly prevalent on the Internet. Examples include *WiseWire*, CNN *Custom News*, *Crayon*, Excite's *NewsTracker*, Infoseek's *Personalized News*, and *NewsHound*. As with many areas of the Internet, the leading companies are a mix of traditional leaders in the field that have transferred their knowledge and experience to the Web and new upstarts who have seen a market opportunity and reacted quickly. These services ask the user to select which of a large number of categories he or she wishes to receive news about. A news agent typically collects news by visiting hundreds of Web news sources (such as magazines, newspapers and press releases) once or more a day. The information is categorised, either manually or automatically, and filtered according to the user's preferences. Finally, the matching articles are forwarded to the user.

News agents differ according to the breadth of their news search, technologies used to categorise the documents found, categories and keywords which the user can select, and whether machine-learning algorithms are used to refine the model to meet the user's interests and delivery options.

Box 4. **A custom newspaper delivered over the Web**

To take *WiseWire* as an example, a user can create a "Personal Wire" to specify the type of documents of interest. *WiseWire* uses a combination of content filters, collaborative filters (where other users' rankings of the available pages are taken into account) and learning agents to deliver pages of interest. *WiseWire* receives millions of documents a day, from private Web pages, news groups and commercial news agencies and sorts them into different content groups on the basis of the automated recognition of key terms. The user is then supplied with the documents most likely to be of interest.

Financial agents

Agent technologies have been used in many financial applications on the Web. The three main uses have been information retrieval, product recommendation and decision making.

Retrieval of financial information and stock tracking

These financial agents help provide pertinent financial information in a timely way. Many use the same technologies as shopping and information retrieval agents. Some improve access to financial information by indexing source materials mostly of interest to the financial world. Since the portion of the Web searched is more restricted, the information retrieved is more likely to be relevant. Examples include *just-quotes.com* and *FinanceWise*. Similarly, *InfoBeat Finance* uses the technologies that produce custom news to filter and deliver financial information.

Another group of financial agents delivers financial information by monitoring share prices, maintaining stock calendars, tracking portfolios, calculating trading profits and losses and even makes stock market predictions. Such agents can also filter information and warn the user when, for example, a share reaches a certain pre-set price. The agent is responsible for monitoring share prices so the user is free to do other things. *NetProphet* and *StockVue* are examples of such Internet-based stock tracking programmes.

Financial product recommendation

The constraint-based filtering technologies used by some shopping agents to help a buyer find the most suitable car, holiday, gift or pet can also be used to recommend financial investments. For example, *E*Trade* uses such a system to allow the user to search thousands of mutual funds to find the most appropriate one.

Decision-making systems

Some investment companies use automated or "programmed" trading to sell or buy shares when the price of a particular share reaches or falls below a pre-defined level. In the future, agent capabilities and user trust may evolve so that users will delegate more decision-making authority to their intelligent financial agents.

In sum, in their role as shopping, information retrieval, and financial agents, intelligent agents are quickly becoming a prominent feature of the Web landscape. These personalised, autonomous systems are perhaps best seen as an extension of existing search and decision-making technologies rather than as fundamentally different. However, they point the way towards the more "intelligent" systems capable of advanced functions like learning and co-operating which are likely to be developed in the future.

Technological issues

First-generation intelligent agents have some design and technology flaws which may hinder their widespread adoption in e-commerce. Some of the problems and proposed solutions are considered below. In particular, information and communication between agents and users as well as agent decision making are explored.

Information gathering and communication

Agents and information

Information gathering is one of the functions most commonly performed by intelligent agents. They are often sent to locate relevant Web pages and extract pertinent information. This may appear a relatively straightforward task, but it is complicated by the Web's decentralised, multi-format and non-indexed nature. For example, a shopping agent asked to compare prices for a particular kind of television needs to locate Web pages that deal with that particular product, identify which sites actually sell it and then locate pricing information, which may be on that page or on a different one.

Web pages are currently formatted according to the HTML standard (hypertext markup language), which makes it easy for Web page designers to specify a Web page's appearance, layout, text and picture content. It does not, however, label the information on the page according to its semantic content. That is, while HTML may label a piece of text according to colour, font and position, it does not distinguish between a price, an address, part of a product review or general text. Another problem facing agents is that Web pages receive input in various forms, such as Java applets and CGI scripts. This makes it difficult for an agent to know, for example, how to make a price inquiry.

Today, intelligent agents employ various techniques and technologies to cope with the different presentation systems and input procedures used by different Web sites. Typically, they use specially created "information adapters" or "wrappers" for each Web site that they visit. The wrapper specifies where and how to retrieve the required information from that particular site. Once the wrapper exists, the agent uses it to access the site, read the desired information and store it in its own data format. Such wrappers may be either hand-coded by the agent's designers (*BargainFinder* used this system) or partially automated (as in *Jango* and *MySimon*), where the agent learns from example by following a user accessing the site.

The need for wrappers creates problems when it comes to scaling agents from prototypes to systems capable of searching significant portions of the Web. Therefore, the search space of most first-generation agents is limited to sites identified in advance. Many users of intelligent agents may not realise this limitation and may assume that the entire Web has been searched. In fact, agents typically search only affiliated Web sites, those with an existing commercial relationship with one another. It is important for users to be aware of such limitations.

Blocking

Another issue related to the search space of intelligent agents is the possibility of "blocking". Some retailers may attempt to block agents from searching their Web sites to prevent them from making price comparisons. When intelligent agents were first developed, it was thought that this might become a major issue. For example, many merchants originally accessed by *BargainFinder* soon blocked access to their price information. However, this has become less of an issue over time. First, online retailers have accepted that being on the Web means that they will be compared with their competitors. Second, because purchases are increasingly made through intelligent agents, retailers have understood that they will miss out on a significant share of consumer traffic if they block agent searches. Finally, as a technological matter, an anti-blocking mechanism is likely to be developed in response to every blocking device created.

Communication between agents

Currently, there is little direct communication between intelligent agents. However, it is envisaged that agents will eventually communicate with one another, exchange useful information and even negotiate on behalf of their users. *Kasbah* is an experimental system which allows for multi-agent communication. It is essentially a Web-based classified ad system. Users who want to buy or sell an item set up a buying or selling agent which negotiates with other agents in a centralised market place. The agents attempt to negotiate a deal subject to user-specified constraints relating to, for example, maximum or minimum prices and an acceptable time frame. The development of such systems may greatly enhance the power of intelligent agents in the future.

First-generation intelligent agents are less mobile and less universal than much surrounding publicity would suggest. The development of intelligent agent technologies will be facilitated by the creation and adoption of standards for labelling the content of Web pages. One possibility is to use a data content language, which provides for the semantic tagging of data, when designing Web pages. XML (extensible markup language) is one that has received strong industry support from Microsoft, Netscape and from the World Wide Web Consortium.

User-interaction and agent decision making

User interaction with agents currently takes the following form. The user enters names or descriptions to be searched for or chooses one of a number of categories, such as news groups or product types. It is envisaged that agents will eventually be able to understand and act on natural language instructions, such as "Find me a cheap ticket to London for the weekend".

It is also thought that agents will be able to make increasingly sophisticated inferences and decisions. For example, given the above request, the agent may attempt to determine the best travel option given the user's preferences and also infer that it should research accommodation options. The ability of agents to perform such functions will depend on research developments in artificial intelligence. However, understanding natural language and common-sense reasoning have proven to be two of the most difficult topics in this field. Therefore progress in these areas may be quite slow. As progress is made, advances will be rapidly incorporated into future intelligent agents.

Economic, legal and policy issues

The increasing use and sophistication of intelligent agents will give rise to many issues in the areas of consumer trust, market efficiency, privacy and consumer protection. For example, it is not clear whether the widespread acceptance of agents will increase or decrease market efficiency, whether agents may prove to be a threat to privacy unless the use of the personal information they handle is controlled, and whether the possibility of agents entering into contracts which bind their human principals raises consumer protection and enforceability concerns.

Consumer acceptance of agent technologies

For agents to be effective and widely accepted, issues of trust, privacy and consumer protection must be addressed to the satisfaction of potential users.

Trust

Widespread acceptance of intelligent agents requires fostering consumer trust in these agent technologies. Specific concerns relating to privacy and consumer protection are discussed below; however, the "honesty" of agents is also important. For example, the image most frequently evoked to explain a shopping agent is the assistant who knows the user's tastes and preferences, has the knowledge of an expert buyer and scours the Web for the best deal available. However, in practice, most agents are affiliated to a merchant or a group of merchants and search only a portion of the Web. To generate trust and confidence, it is important that users know to which sellers an agent is linked and how much of the Web is searched.

Privacy

Protection of privacy and personal data is a general concern associated with the growth of the Web. A number of steps can be taken to ease potential consumer concerns over the use of their personal data by intelligent agents. First, at a technological level, agents should be designed to divulge the minimum amount of information necessary for a particular interaction and, where possible, to keep an audit trail of what information has been transmitted and to whom. Second, it is important that consumers who use intelligent agents are clearly informed as to what information will be held by the agent and how it will be used.

Consumer protection

The relation between consumer protection and intelligent agents is also very important. The use of agents creates new problems for commercial transactions, and consumers must have confidence and trust in agents if they are to be widely used in electronic commerce. The importance of these issues will increase as agents take on more responsibility in negotiating terms and conditions and in establishing contracts.

The contractual capacity of an intelligent agent

Given the general contractual principles that exist in most countries, there seems to be no reason in theory why a user could not delegate authority to an intelligent agent to enter a contract on his or her behalf. If it is accepted that intelligent agents can act in this way, arguments may arise over whether an agent needs to "understand" contractual terms before the contract can be binding or whether a user should only be bound by usual or reasonable terms.[7] Regardless of the legal disputes which may arise, it is likely that, for a considerable time, users will prefer to use agents that require the user to give final confirmation.

What if things go wrong?

A related question concerns liability if an intelligent agent acts in a manner unanticipated by the user. This again may be the subject of future legal arguments. One commercial possibility is that, to promote user trust and confidence, shopping portal operators will act as insurers to protect consumers when things go wrong.

Authentication

To promote retailer confidence, technological mechanisms such as digital signatures and audit trails could be used to so that online sellers know who the agent is acting for and the scope of the agent's authority to transact.

Effects on the market structure of electronic commerce

The Internet is a rapidly growing marketplace for all kinds of goods and services (see Chapter 3). The effects of increasing use of intelligent agents on the properties of electronic commerce may include:

- Bringing the economy closer to the ideal of perfect competition or, conversely, leading to anti-competitive behaviour.
- Lessening product differentiation.
- Increasing the risk of macroeconomic price instability.

Competition

A number of commentators have suggested that a pool of buying and selling intelligent agents exchanging bids and offers at high speed and low cost will greatly reduce information and transaction costs and create an online commercial environment which approximates the theoretical model of "perfect competition". For example, by automating the information gathering and decision-making processes, intelligent agents can facilitate online shopping by simplifying transactions and reducing information costs. They promise to provide shoppers with access to a wider selection of merchants and more product information than would otherwise be feasible and to automate product comparisons. The effect of lower information and transaction costs should reduce prices, expand markets for producers and increase consumer choice.

The common view of agent-mediated electronic commerce is that very large numbers of buying and selling agents will populate cyberspace and carry out independent negotiations on behalf of human users. However, there may be tendencies for less competitive structures to develop. Since agents will be able to communicate at low cost, there will be incentives for large numbers of buying or selling agents to communicate among themselves and to group together to increase their bargaining power. While this may produce economies of scale through bulk buying, it may also decrease market competition.

Another possible future issue is that Web sites that operate intelligent agents and act as gateways to Internet shopping[8] may restrict competition. Currently, some gateways are restricted to affiliated companies, while others charge vendors a fee to be included in the search space (as *Fido the Shopping Doggie* did), and some allow stores that meet certain entry requirements to enrol without paying a membership fee (*ShopFind* database). If the market develops in such a way that one or a small number of gateway sites dominate, it may be necessary to invoke antitrust laws to prevent monopolistic practices and ensure access by competing retailers.

Product differentiation

First-generation shopping agents only compare products on the basis of price. The automated comparison of other product features and differences among retailers (for example, quality, warranties, return policy, brand reputation, service contracts, availability, payment options, promotional offers and delivery times) is much more complex. Any of these features that increase the product's price – but are not taken into account by an intelligent agent – will decrease the chances of the product being sold. Therefore, as the use of shopping agents increases, sellers may be dissuaded from offering features that buyers may want but which are hidden by the agent's exclusive focus on price. In that case, both consumer and seller may be worse off.[9]

This problem is not, however, insurmountable. In the future, intelligent shopping agents may also be able to compare products on more dimensions than price. For example, they are beginning to include warranties, manufacturer reliability, method of payment, method of delivery and after-sales service in their product comparisons. Moreover, the shopping agent might provide links to online information sources, such as online consumer reports like *Consumer Digest*,[10] and names of local merchants where products may be inspected.

Price instability

While many commentators emphasise the effect that intelligent agents may have on improving the efficiency of resource allocations by reducing search and transaction costs and improving information flow, other research has shown that large systems of interacting, self-motivated agents may have undesirable macroeconomic effects.[11] For example, agent economies may experience price wars more frequently than human economies. This is undesirable if the result is disruption of commerce owing to frequent withdrawals of participants from a market or reduced consumer choice. Such price wars may be more prevalent in an agent-based economy than in one based on human interaction because the factors that tend to mitigate price wars – such as foreseeing the risk of price wars, frictional effects due to the cost of shopping around by consumers, shifting of prices by brokers – are likely to be weaker in agent-based economies. Such price wars will remain a theoretical issue until the prevalence, negotiating ability and authority of agents increase dramatically. As their use and sophistication increase, this issue may require further consideration by economic policy makers.

Conclusion

This chapter has considered the growing importance of intelligent agents on the Internet and has highlighted a number of technological, legal, economic and policy issues in relation to their future growth and development. It can be argued that the prevalence and importance of intelligent agents in e-commerce and Web browsing will increase rapidly in the near future. As artificial intelligence technology improves and Internet protocols develop and mature, intelligent agents promise to unlock a great deal of the Web's potential as an information resource and as an exciting medium for commerce. Like many developments in this area, it is important for governments to be aware of the issues that may arise but not to act too hastily and hamper the creation of innovative Internet solutions by businesses.

Appendix 1

SELECTED INTELLIGENT AGENTS AVAILABLE ON THE INTERNET

	INTELLIGENT SHOPPING AGENTS As of 19 August 1999
Shopping agents	<http://www.acses.com/>
	<http://bf.cstar.ac.com/bf/>
	<http://www.bestbookbuys.com/>
	<http://www.vsn.net/af/>
	<http://www.bookblvd.com/>
	<http://www.bottomdollar.com/>
	<http://www.bookfinder.com/>
	<http://www.shopper.com/>
	<http://www.mxbf.com/>
	<http://www.zdnet.com/netbuyer/>
	<http://www.netmarket.com/ctg/cgi-bin/NetMarket/netMarketMain/>
	<http://www.techweb.com/shopper/>
	<http://www.Expedia.com>
	<http://www.previewtravel.com>
	<http://www.travelocity.com>
	<http://www.priceline.com>
	<http://www.shopfido.com/>
	<http://www.pricescan.com>
	<http://www.roboshopper.com/>
	<http://www.excite.com/shopping/>
	<http://www.mysimon.com>
	<http://st2.yahoo.com/shopfind/>
	<http://shop.hotbot.com/>
	<http://www.shoppingexplorer.com/more/whatis.htm>
	<http://shopguide.yahoo.com/>
	<http://www.webmarket.com/>
	<http://www.worldspy.com/>
	<http://www.compare.net/cgi-bin/webc/home.webc>
	<http://www.buy.com/>
	<http://www.planetretail.com/>
	<http://www.infospace.com>
	<http://jango.excite.com/index.dcg/>
Product recommendation agents	<http://www.personalogic.com/>
	<http://www.dell.com/store/index.htm>
	<http://www/firefly.org/>
	<http://www.amazon.com/>
Online auctions	<http://auction.eecs.umich.edu/> (AuctionBot)
	<http://www.ebay.com/>
	<http://www.onsale.com/>
	<http://www.tete-a-tete.com/>
	<http://www.agromarches.fr/fr/frameset.html>
	INFORMATION RETRIEVAL AGENTS
Metasearch engines	<http://www.thewebtools.com/features.htm> (Matahari)
	<http://www.bullseye.com>
	<http://www.intelliseek.com>
	<http://www.ferretsoft.com>
	<http://www.savvysearch.com>

News retrieval agents	<http://www.wisewire.com/> <http://crayon.net/> <http://infosage.com/> <http://nt.excite.com/> (Newstracker) <http://www.infoseek.com/news?pg=personalize.htm> (Personalised News) <http://www.newshound.com/>
FINANCIAL AGENTS	
Information retrieval agents	<http://www.justquotes.com/> <http://www.financewise.com> <http://www.infobeat.com/> (Info Beat Finance)
Stock tracking agents	<http://www.neural.com/NetProphet/NetProphet.html> <http://www.stockvue.com/>
Product recommendation agents	<http://www.etrade.com/>

Appendix 2

SELECTED INTELLIGENT AGENT WEB SITES, PAPERS

INFORMATIVE WEB SITES ON INTELLIGENT AGENTS
Available as of 19 August 1999

<http://www.agent.org>
<http://www.opensesame.com/agents/>
<http://ecommerce.media.mit.edu/>
<http://planete-commerce.com/annuaire/agents/shopping.html>
<http://www.botspot.com/>
<http://www.consumerworld.org/pages/shopping.htm>
<http://www.sics.se/isl/abc/survey-resources.html>
<http://www.primenet.com/~terry/New_Home_Page/ai_info/intelligent_agents.html>
<http://china.si.umich.edu/telecom/net-commerce.html>
<http://www.cs.umbc.edu/agents/>
<http://ecommerce.media.mit.edu/>
<http://consumerdigest.com>
<http://www.agentlink.org/>
<http://www.cs.washington.edu/research/projects/softbots/www/softbots.html>

NEWS & RESEARCH ARTICLES ON INTELLIGENT AGENTS
Available as of 19 August 1999

"Aggregators' Retail Model Threatened by Shopbots" (8 May 1998)
<http://www.techweb.com/news/story/twb19980508s0024>

"Ghost in the Machine" (28 May 1998)
<http://www.techweb.com/wire/story/twb19980529s0020>

"Let Your Bot Shop Til it Drop" (16 July 1998)
<http://www.zdnet.com/anchordesk/story/story_2316.html>

"Net Watch Top Ten – Intelligent Agents/Information Agents" (1996)
<http://www.pulver.com/netwatch/topten/tt9.htm>

"Agent-mediated Electronic Commerce: A Survey" (R. Guttman, A. Moukas and P. Maes: Working Paper)
<http://ecommerce.media.mit.edu/papers/ker98.pdf>

"Agent-mediated Electronic Commerce: Issues, Challenges and some Viewpoints" (H. Nwana, J. Rosenschein, T. Sandholm, C. Sierra, P. Maes, R. Guttman)
<http://www.labs.bt.com/projects/agents/publish/papers/aa98_panel.doc>

"Are you Liable for the Acts of Your Intelligent Agents?" (J. Berman)
<http://www.weblaw.co.uk/artic04.htm>

"Dynamics of an Information-Filtering Economy" (February 1998)
<http://www.ibm.com/iac/reports-technical/cia98.pdf>

"Emerging Behavior in Information Economies"
<http://www.ibm.com/iac/reports-technical/reports-technical-info-econ1.html>

"Price-War Dynamics in a Free-Market Economy of Software Agents" (June 1998)
<http://www.ibm.com/iac/reports-technical/alife6.pdf>

"Spontaneous Specialization in a Free-Market Economy of Agents" (May 1998)
<http://www.ibm.com/iac/reports-technical/aa98.pdf>

"To Each and Everyone an Agent: Augmenting Web-based Commerce with Agents" (March 1998)
<http://www.sics.se/~sverker/public/papers/agentweb.pdf>

"Intelligent Agents, Markets and Competition: Consumers' Interests and Functionality of Destination Sites" (June 1999)
<http://www.firstmonday.dk/issues/issues4_6/jonkheer/index.htm>

NOTES

1. See Jeffrey O. Kephart, James E. Hanson, David W. Levine, Benjamin N. Grosof, Jakka Sairamesh, Richard B. Segal and Steve R. White, "Dynamics of an Information-Filtering Economy", <http://www.ibm.com/iac/reports-technical/cia98.pdf>.
2. For a comprehensive catalogue of the many different types of agents, or bots, which have been created, see the botSport Web site at <http://www.botspot.com/bot_descriptions/index.html>.
3. <http://www.jup.com>.
4. <http://www.dell.com/store/index.htm>.
5. See Patti Maes, Robert Guttman and Alexandros G. Moukas (1999), "Agents that Buy and Sell: Transforming Commerce as We Know It," *Communications of the* ACM, March. See also publications at <http://ecommerce.media.mit.edu>.
6. See S. Lawrence and C.L. Giles (1999), "Accessibility of Information on the Web", *Nature*, Vol. 400, 8 July 1999 and <http://www.neci.nj.nec.com/homepages/lawrence/websize.html>.
7. See, for example, proposed Article 2B of the Uniform Commercial Code in the United States, <http://www.law.upenn.edu/library/ulc/ucc2/2b398.htm>.
8. See *TechWeb News* (1998), "Aggregators' Retail Model Threatened By Shopbots", 8 May, <http://www.techweb.com/news/story/TWB19980508S0024>.
9. See R. Guttman and P. Maes (1998), "Agent-mediated Integrative Negotiation for Retail Electronic Commerce", May, <http://ecommerce.media.mit.edu/papers/amet98.pdf>.
10. <http://www.consumerdigest.com/>.
11. See Kephart *et al.*, *art. cit.*

Chapter 8

GLOBAL NAVIGATION SATELLITE SYSTEMS AND THE IT INFRASTRUCTURE*

Technologies that identify location are an increasingly crucial part of the information infrastructure. The ability to locate a person or object precisely at a particular time is necessary to tailor geographical information for a user (as in car navigation, emergency assistance) or co-ordinate remotely the movement and activities of multiple platforms (as in packets of information on the Internet or aeroplanes in flight). As computing becomes more mobile and integrated into a wide variety of platforms, the ability to locate objects and co-ordinate their activities will make the integration of locational intelligence with computing ever more useful. At present, location technologies are used mostly for navigation – land, maritime and air transport – but they are rapidly merging with information technologies.

The creation of a Global Navigation Satellite System (GNSS) has been the most ambitious location intelligence project. The backbone of the present generation GNSS (or GNSS-1) is two space-based navigation systems: the Navstar Global Positioning System (GPS) owned and operated by the United States and the Russian GLONASS. The European Union is seriously considering building a third system, Galileo. All seek to provide very precise time, location and velocity information so that receivers anywhere in the world can identify a unique physical address. By 2010, the second-generation GNSS (GNSS-2) could consist of three separate satellite systems. It will certainly consist of GPS, most likely at least one other satellite constellation and a variety of augmentation systems that deliver improved services.

Commercial exploitation of navigation, positioning and timing information has risen rapidly since the United States first offered the US Navstar Global Positioning System as a free public utility in 1984. In 1998, the GPS world market was estimated at about USD 4 billion; it has grown at over 50% a year in the 1990s. Prospects for further commercial growth are good, with estimates into the first decade of 2000 for GPS products and services of over USD 16 billion. If both GPS and the proposed European Galileo system are combined, prospects are even more promising. In the near future, the largest markets will likely be in land transport and consumer electronic applications. Present markets are in fact quite heterogeneous and new uses for time and location information are likely to continue to come from unexpected sources, especially as the data are increasingly integrated with other information and communication technologies.

At stake in the commercial development of GNSS are new products, services, companies and jobs. GNSS promises important productivity gains in some existing industries, notably the civil aviation and trucking and shipping industries but also in fields like insurance claim assessments. Perhaps most importantly, satellite navigation systems offer a "safety-of-life" function which may permit unprecedented advances in security through safer travel conditions, especially in the ever more saturated airspace, and decreases in emergency response times.

OECD Member countries have taken very different approaches to promoting GNSS as a civilian technology. The United States has made repeated promises to provide the GPS signal free of charge for the foreseeable future and to make key improvements in the civilian service as of the coming decade. The European Commission, which is reluctant to rely on dual-use technology controlled by the US

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Figure 1. GNSS timeline

	1973	1974/75	1976/77	1978	1979/80	1981	1982	1983	1984	1985	1986	1987	1988	1989/90	1991
Navstar GPS (United States)	Navy and Air Force GNSS programmes merged. Navstar GPS established.			First of 11 Block I satellites launched. Trimble navigation becomes first GPS firm.					President Reagan allows civilian access to GPS.			First of 25 Block II satellites with SA and AS capacity launched. Coast Guard made lead agency on civil GPS needs.			Selective availability first turned on.
GLONASS (Russia)							First of 10 Block I Glonass satellites launched. Pre-operational phase.			Operational phase Block II*a* and II*b* launched.					Russia to provide free and universal access to GLONASS for 15 years.
Galileo (EC)							ESA starts studies of NAVSAT which broadcasts ground generated ranging signals to users.								

Figure 1. **GNSS timeline** (*cont.*)

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004/5	2006	2007	2008
Navstar GPS (United-States)		IOC	FAA approves GPS for navigation, announces WAAS.	FOC	Presidential Directive on GPS policy.	First Block IIR.	Two new civilian signal frequencies announced.		WAAS operational.	Launch of Block I I F satellites with extra civilian frequencies begins.		LAAS operational.	.	Selective availability phased out.		
GLONASS (Russia)				Russian Federation declaration that GLONASS would be part of an international GNSS.												
Galileo (EC)			European Union Council proposes a two-part GNSS strategy. ESA starts work on EGNOS.					Expected start of Galileo project.	EGNOS in operation.	2001/5. Galileo test and validation phase.				2006/7. Galileo deployment phase.		Galileo operational.

Source: OECD.

Department of Defense, has recently proposed a civilian satellite navigation system to complement the GPS constellation. Other OECD countries, such as Japan, have concentrated efforts on promoting use of the GPS for domestic purposes. Many countries would welcome a second system to increase the robustness of the present GNSS. Since OECD countries have different strategies for promoting GNSS signals as part of the information infrastructure, there is some uncertainty about how this key element of infrastructure will be developed and managed globally.

Further commercial exploitation of GNSS signals raises policy challenges that need to be addressed at both national and international levels. All countries have a stake in the resolution of the policy challenges that this new service poses. The main problems revolve around the negotiation of standards and interoperability, the financing and governance of these systems, the maintenance of open markets, the protection of privacy for users and security concerns. National governments have a role to play in expanding use of GNSS signals by sponsoring projects to improve signal accuracy, availability, integrity and coverage. Governments will want to ensure reliable civilian access to the signal for both commercial and public safety reasons; they have a role to play in improving or augmenting the service in their region to encourage its exploitation by innovative users; they have a stake in keeping international markets for GNSS-based products and services open and large in order to take advantage of scale economies; they also have a stake in negotiating domestic and international standards so that users can communicate with one another.

What is the Global Navigation Satellite System?

At its core, a GNSS is an information infrastructure. It provides a service – in the case of GPS and GLONASS a free public service – in the form of continuously and globally available radio waves that make it possible to determine, extremely precisely, an exact location in four dimensions (longitude, latitude, altitude and time). Functionally, a GNSS makes it possible to assign a unique address to each location on the face of the globe without using any other reference point. Navigation, surveying and mapping are the most obvious uses of such information. In fact, the development of satellite-based positioning is the most significant improvement to navigation in decades.

The GNSS is a one-way system in which passive receivers pick up radio signals from a network of satellites. The system is in effect "dumb" but by retransmitting and/or collecting the data calculated by the receivers, it becomes an active network which reports the location of all the reporting receivers.[1] It is this two-way communication that gives GNSS its great potential as an information infrastructure and opens the way to monitoring and co-ordinating objects remotely, providing time- and place-sensitive information (traffic information, local yellow pages) to geographically dispersed users and even certifying when (and perhaps where) a commercial transaction occurred.

Like the Internet, the GNSS is a dual-use technology developed by and for the military but made available to civilian users. Both have become part of the information infrastructure, and both have created new industries and are changing the way business is carried out. The commercial benefits of GPS also far surpass what the designers of the system originally envisaged. As with the debate about electronic commerce, analysts are torn between enthusiasm about the commercial possibilities of GNSS and scepticism about the success of such endeavours. Similar to the Internet, the uses of the GNSS technologies are not fully mapped out, especially as the development of maps, databases, software and even regulatory structures are required in order for location information to be used effectively. Finally, the political decision to transform GNSS from a military to a civilian or dual-use technology has created – as was the case for the Internet – new stakeholders who clamour for a louder voice in policy decisions about the system's management, financing and standards setting.

History

Navigation systems are not new. Loran, TRANSIT and OMEGA, for example, predate the GPS. But none is at once as accurate, global in scope, or rich in information. It is only quite recently that a GNSS has been able to offer high-precision, around-the-globe, 24-hour coverage (Figure 1). The US Navstar

Global Positioning System (GPS) was born in 1973 as the fusion of two separate Navy and Air Force projects and by 1978, the Block I Navstar satellites were in orbit. In 1993, the Department of Defense declared Initial Operating Capability (IOC). This meant a full constellation of satellites in orbit, so that the signal would be available at all times, at every point on the globe. The Russian GLONASS system, technically very similar to GPS, launched its first satellite in 1982. Owing to financial difficulties, GLONASS is still not operational. GPS and GLONASS were initially developed for use as military navigation and guidance systems, but military purchases of GPS receivers now make up only 5% of total sales. The European Galileo project, which is specifically designed for commercial users, is in the development stage and is not likely to be operational until 2008.

Today, the United States offers Standard Positioning Service (SPS), which is available to all users free of charge and provides a baseline service and Precise Positioning Service (PPS) that is much more accurate but so far available only for military and other authorised users. Access to PPS is limited by use of a very long code (the P-Code) which receivers must know if they are to read the signal. Furthermore, as a security measure, a source of error (called Selective Availability – SA) is deliberately added to limit positioning accuracy for non-PPS-authorised users and creates up to 70 metres of positional displacement. For commercial exploitation, it is essential to reduce such distortions. Many users require greater accuracy than offered by SPS and some even more than that provided by PPS (Box 1).

Box 1. **GPS accuracy specifications**

The US Government provides Precise Positioning Service (PPS) and Standard Positioning Service (SPS). The SPS code is intentionally degraded through Selective Availability (SA). While there are many ways to reduce errors and increase accuracy to sub-metre position information for both services, their official published specifications without any such enhancements are:

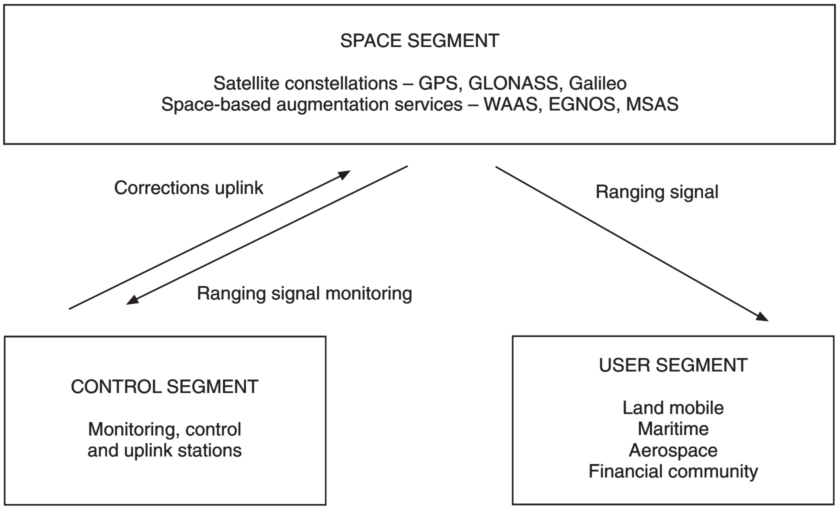
PPS	**SPS (with SA on)**
17.8 metre horizontal accuracy	100 metre horizontal accuracy
27.7 metre vertical accuracy	156 metre vertical accuracy
100 nanosecond time accuracy	167 nanosecond time accuracy

System architecture

To understand what a GNSS can do, it is necessary to know in general terms how it works. A GNSS has three functional segments: a constellation of space satellites, a control segment which monitors and corrects satellite positions and settings, and a user segment which consists of receivers integrated into a variety of platforms (Figure 2). Satellites carry atomic clocks to maintain highly accurate timing and continuously broadcast time data as well as a navigation message that includes positioning data for each satellite; these are transmitted to receivers by modulating the ultra-high-frequency radio waves emitted by each satellite. The control segment consists of monitoring stations that passively track the satellites visible to them and a control station that computes the parameters that describe each satellite's position and time data. The corrected data are then uploaded to each satellite so as to minimise errors in satellite signal reading.[2]

The user segment includes receivers and complementary services that enhance the accuracy or utility of the signal. Physically, receivers consist of an antenna that locates the ranging signal, a data processing component which calculates geographic position by triangulating distance from satellites overhead,

Figure 2. **The three GNSS segments**



Source: OECD.

and a way to display or communicate the calculated position, velocity and system time. There is an enormous variety in the cost and capacity of receivers currently on the market. They may be hand-held, stand alone units, which are now about the size of a cellular phone and cost only a few dollars. More sophisticated units are installed in cars, boats and planes, and can cost up to tens of thousands of dollars. Over the past two decades, receivers have become very small and many are simply integrated into semiconductor chips, as part of a computer, cellular phone, missile system, or other device. When integrated into an electronic device, users may not be aware they are using a GPS receiver since location and timing information is not always obviously displayed.

The basic GNSS architecture can be augmented in a variety of ways. Satellite signals are degraded by several sources of error – clock-timing error, ionospheric and tropospheric refraction, restricted satellite visibility, reflection of radio waves and even intentional errors. Reducing these distortions to the signal is key for commercial use. Differential GPS (DGPS) is one powerful technique for improving accuracy. It allows a receiver to estimate the error in the signals it receives (a reference receiver at known coordinates compares its location to the location given by the GPS signals and calculates an error estimate which it then sends out to nearby "roaming" GPS receivers so that they can correct their readings). Reference stations can be relatively inexpensive single units or part of a complex network of land- and space-based reference stations. The US Coast Guard, for example, maintains a network that covers the entire US coastline. Some of the most ambitious regional augmentation systems have been developed with the needs of the aviation community in mind: the European EGNOS, the Japanese MSAS, and the US WAAS (Box 2). With high-end receivers, sub-centimetre accuracy is possible, and for moving objects that need real-time position information, DGPS systems allow for sub-metre accuracy.

Many other strategies are available to compensate for GNSS limitations. Some solutions include improvements in receiver technology, pseudolites (ground-based pseudo-satellites) for locations where coverage is poor, and DGPS services. Both public and private agencies record DGPS corrections and distribute them to customers electronically. Private DGPS services lease FM sub-carrier broadcasts, satellite links or private radio beacons to transmit corrections for real-time applications. Because major enhancements like wide-area augmentations require such large systems and because the beneficiaries are so

Box 2. **Regional augmentation systems**

EGNOS – *European Global Navigation Overlay System*. An augmentation of GPS and GLONASS consisting of three satellites and a ground station network covering the European region. While it will be used by a wide range of industries – including maritime, road and rail – the specifications are being driven by aeronautical requirements. Initial operation capabilities expected by 2002.

MSAS – *The Multi-functional Transport Satellite* (MTSAT)*-based Augmentation System* is the wide-area augmentation system being developed by the Japan Civil Aviation Bureau for the Asia-Pacific region. It consists of two geostationary satellites and a ground monitoring network. It will provide navigation services en route and precision approaches for all aircraft. Full MTSAT operational capability is expected in 2005.

WAAS – *The Wide Area Augmentation System*. A nation-wide network of ground reference stations and communication satellites that broadcast corrections to the GPS signal. It is at the core of the new air traffic management system of the US Federal Aviation Administration. In combination with local area augmentations at airports, it will provide the specifications necessary to use GPS as a primary means of navigation and to fly precision approaches and landings in conditions of minimum visibility. WAAS will begin broadcasting differential GPS corrections and integrity messages in 1999 and will be ready for all categories of landings between 2003 and 2006.

fragmented, the public sector plays a central role in providing the service. However, these public projects can cause conflicts with private providers of augmentation who see government involvement as unfair competition.

The present generation GNSS is one of many different sources of locational intelligence (Box 3). The possibility of other satellite-based navigation systems aside, many existing technologies both compete with and complement existing GPS signals. Governments need to put the next-generation GNSS in context. It is an important infrastructure but it is neither the only solution to location information needs nor necessarily a stand-alone system.

Box 3. **Alternative location technologies**

Navigation. Loran-C radio beacons are still used by air and maritime vessels and will remain in operation as a back-up system to GNSS for marine navigation. In Europe, Euteltracs is a mobile satellite service which provides vehicles with position fixing and two-way communications, mainly for long-distance trucking.

Positioning and tracking. Positions can be calculated using cellular, paging and AM/FM signals. For example, to meet the US Federal Communication Commission's directive on locating emergency distress calls made from mobile phones, cellular phone operators are considering the possibility of triangulating the distance of the cellular signals from permanent base stations. Other positioning or tracking systems use a combination of dead reckoning, gyroscopes and map matching, as supplements or replacements to GPS signals. For example, radio frequency IDs can be used to tag containers or charge motorists on toll roads and while, unlike GPS, they transmit information only a few metres away, they also cost very little.

Personalised information. Some intelligent transport systems (*e.g.* Trafficmaster in the United Kingdom) transmit local traffic information to vehicles when they pass roadside sensors by broadcasting radio waves, while Smartraveler (United States) provides real-time traffic information accessible by telephone, e-mail, or pager.

Certification. GPS signals are already used to time-stamp financial transactions. One can imagine a world in which they might be used to location-stamp transactions, for tax purposes for example. However, GPS technologies would have to compete with existing on line certification services that are emerging for legal documentation.

Improvements for civilian applications

To encourage further civilian use of GNSS signals, OECD countries have to address technical and administrative bottlenecks. Civilian users would enthusiastically welcome improvements in the accuracy of position data and, within a few years, accuracy within 20 metres is likely with no augmentation (levels of centimetres can already be achieved with augmentation systems). In defining the next-generation GNSS, however, governments have to consider domestic user groups with different performance requirements, ability to define their needs and willingness to pay for service improvements. The parameters most often used to specify GNSS performance focus on accuracy, availability, integrity and continuity. However, other parameters are also relevant – coverage, fix rates, reliability, multi-path resilience, vertical or velocity accuracy (Box 3). These measures help to understand the limitations of the present GNSS, to define the enhancements necessary for further commercialisation and to distinguish the requirements of different user groups.

The present GPS-based system has a number of technical problems. Signals are not robust in urban areas or where there are overhead obstructions. Signal power is generally weak, slowing time to first fixes. Total loss of the GPS signal due to interference occurs occasionally and without warning. Signals were once jammed (blocked) when McDonald-Douglas was testing a jammer for use on fighter planes; in another case, the US Air Force was testing an antenna's reception and the five-watt transmitter was accidentally left running. There are also problems of interference from commercial TV and VHF broadcast signals as well as occasional interference from heightened solar activity.

Commercial use of GNSS signals requires different and sometimes higher standards than those demanded by the military. Civilian users want to ensure greater accuracy (for machine control, urban navigation), reliability (no jamming or interruption of service) and a guaranteed measure of integrity. OECD

Box 4. **Main GNSS specifications***

Accuracy. The degree of conformity between the *measured* position and/or velocity of a platform at a given time and its *true* position or velocity. Positions have longitude, latitude and altitude components.

Availability. The percentage of time that the services are available. This is a function of both the physical characteristics of the environment and the technical capabilities of the transmitter facilities.

Continuity of service/reliability. The probability that a service performs a specified function under given conditions for a specified period of time without interruption. The level of continuity is expressed in terms of the probability of not losing the radiated guidance signals.

Coverage. The surface area or space volume in which the signals are adequate to permit the user to determine position to a specified level of accuracy. Coverage is influenced by system geometry, signal power levels, receiver sensitivity, atmospheric noise conditions, terrain, foliage, buildings, etc.

Fix rate. First fix is the amount of time which elapses between when a system is turned on and the receiver generates its first position. Fix update rates are the number of position fixes and associated integrity checks per unit time. This is usually a property of the navigation system, not of the signal in space.

Integrity. The trust that can be placed in the correctness of the information supplied by the navigation system to the user. The integrity parameter includes a threshold value for the maximum allowable error after which an alarm is triggered and a time-to-alarm measure. Integrity is essentially the ability of a system to provide timely *warnings* to users as to when the system can no longer safely be used.

Service interruption thresholds. The maximum acceptable duration for any unintended interruption of service.

Robustness/resistance to interference. Mostly a property of the receiver and measured as the jammer-to-signal ratio in decibels.

* Many of these definitions are based on the European GNSS Secretariat's Land Mobile Advisory Forum working paper, "Application and User Requirements", unpublished, March 1999.

governments are finding that the identification of "civilian" requirements is far from simple, as industrial needs differ greatly. For example, aircraft landing approaches require high integrity; geographic information systems (GIS) and precision agriculture are much more concerned with accuracy. Time to first fix is important for uses like emergency dispatch services. Taxi and bus fleets in urban areas may care most about fix updates and effective urban coverage. Continuous availability is critical for use in communications, financial timing and utilities management.

Levels of service

While the overall architecture of the global navigation satellite system is quite complicated and involves actors from the public sector and many different industries, the service ultimately provided is simply a derived reading of time, position and velocity. Improving that service to encourage commercial exploitation of GNSS signals is a policy priority in many OECD countries. To that end, governments are interested in identifying the different GNSS user segments and their needs in order to expand the overall GNSS market. Users, however, demand different performance characteristics from GNSS and do not value similar services equally. Governments are trying to create different levels of GNSS service to target these different markets. Already, the United States has *de facto* created two service levels with its Standard and Precise Positioning Services. The European Union is especially interested in segmenting the GNSS market, because the success of the Galileo project rests on the ability to create a revenue stream from its commercial exploitation. If Europe can offer different levels of service for different prices by creating value-added elements such as performance guarantees or a communications payload, then a fee-for-service Galileo might be able to profitably co-exist with the free US GPS signal. Identifying groups that will pay for enhanced GNSS services is necessary in order to attract private sector financing for the development and launch of the Galileo system. The precise model for this public-private partnership has yet to be determined.

The roles of government

Whether the next generation GNSS consists of one satellite constellation or three, all OECD countries have a stake in influencing its development because, as a critical element of the information infrastructure, the GNSS is facilitating innovation in many fields. One option for government is not to get involved in the development of the GNSS infrastructure but to allow the private sector a free rein in providing the augmentations and improvements necessary for exploiting GPS, GLONASS and eventually Galileo signals. A few OECD countries have taken this route. A second option is to promote GNSS enhancements by demonstrating its utility in the public sector, for example for public transport or the police. However, most OECD Member countries are involved in some infrastructure building, such as providing DGPS service along coastlines (at least 30 countries have marine radio beacon DGPS services). Finally, a good number of OECD countries are actively involved in building important augmentation systems – ground- or space-based – to enable domestic industries to take better advantage of opportunities, to participate in global standards setting and to lessen the present system's vulnerabilities.

Commercial applications of GNSS

Markets and trends

What distinguishes the present generation of the GNSS from any previous global navigation systems is that it is explicitly understood to be part of the civilian information infrastructure. GPS can be used by any group or industry for which timing and location information are important. As a result, location information is being integrated into a wide array of activities. GPS alone generated a world market estimated at USD 4 billion in 1998. By some industry accounts, it will grow by over 30% a year through the early part of the 21st century (Table 1).

The surveying and mapping sectors first made commercial use of GPS signals, and this is still one of the largest (but most saturated) markets. Maritime and air transport also rapidly adopted GNSS. However, in-car navigation is the major civilian use of GPS equipment. It represents about a quarter of

Table 1. **GNSS market size estimates**

Millions of USD

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
United States[1]				366							3 500			
Europe[2]			150	175	229	290	350	425	525	675	825	960		
World[3]	510	867	1 270	1 890	2 850	4 360	6 070	8 180	10 700	13 450	16 420			
World[4]	510	867	1 266	1 974	3 074	4 855	6 416	8 470						
World[5]				1 500					6 500					16 400
World*[6]													40 000	
World[7]					3 100						14 500			

* In EUR millions.
1. Frost & Sullivan, excludes recreation GPS sales, as quoted in DOC study.
2. Frost & Sullivan, focuses on European GPS hardware market.
3. DOC, USGIC.
4. DOC, USGIC, as quoted in *New Tech Week*, Monday 29 June 1998.
5. Freedonia Group, as quoted in DOC study.
6. EC, BAH, includes space and control equipment sales.
7. Freedonia Group.

Source: OECD.

receiver revenues and is largely dominated by sales to the Japanese market. Some 1.2 million navigation systems were sold in 1997, of which 95% in Japan. The potential market is much larger, as 53 million automobiles were produced worldwide in 1997 (Comité de Constructeurs Français d'Automobiles). Other mass markets which could generate the next GNSS "killer applications" include:

– *Cellular telephones*. In 1997, there were 207 million subscribers worldwide, 82% of them in OECD countries. Cellular use grew at 52% a year over the 1992-97 period (OECD, 1999).

– *Portable computers*. In 1998, 17 million portable computers were shipped out of factories. They represent 19% of the PC market and, at 25% annual growth in the late 1990s, they are growing faster than the total computer market. Sophisticated displays, transportability and data storage capabilities make these an obvious market for various GNSS services (*e.g.* local maps, yellow pages, tourism guides) (IDC, cited in *Datamation*, February 1998, p. 84.)

– *Personal electronic devices*. The mobile computing market is rapidly moving towards ever smaller, lighter, hand-held devices, some of which already integrate GNSS capabilities. The market is new but shipments of hand-helds surpassed 3.9 million units in 1998, a 61.4% increase over 1997 (Dataquest Inc.). USGIC estimates 40 million potential users for consumer and recreational GPS, with a large proportion opting for GPS receivers in combination with other functions.

The future size of GNSS markets is hard to assess because of uncertainties about what fosters and limits their growth. Early in the next century, the size of the GNSS market is expected to exceed USD 10 billion. The European Commission forecasts much stronger growth if the private sector has access to the combination of Galileo, GPS and GLONASS. The extent of use will depend on the decline in unit costs of receiver chips. The types and reliability of services available are likely to affect commercial use as is the degree of international standardisation and harmonisation of GNSS applications. Finally, there are likely to be, yet to be identified, new fields and uses for GNSS signals.

The development of GNSS is seen as an important component of the ICT infrastructure, not so much because of its present size, but because of its growth potential and innovative effects for a wide variety of industries. Table 2 identifies the major sectors interested in GNSS applications, the platforms in which GNSS receivers are embedded, how industries are using the GNSS, and the growth potential of GNSS applications in these industries over the course of the next five to ten years. As this list indicates, GNSS has relevance that goes far beyond our traditional understanding of positioning and navigation. Location information and intelligent use of this information are vastly improving the efficiency with which all sorts of objects and data move through time and space. Essentially, GNSS allows a revolution in logistics management.

For navigation, GNSS signals can provide drivers, pilots and ship captains with better maps and a foolproof way of following them. Moreover, by tracking all the vehicles, planes or ships in an area and

Table 2. **GNSS industry applications**

Industry	Platforms	Uses	Growth potential
Road transport	Cars Taxis Trucks Buses	Navigation and guidance (IVNS) Fleet and freight tracking, scheduling, logistics Safety of vehicle and cargo Telematics: on-trip information access (travel or other), automatic vehicle location, "Mayday" messaging Emergency management Traffic control, other ITS uses Intermodal transport and terminal management Dangerous and valuable goods transport Electronic tolling	Medium to high
Railways	Trains	Positive train control & driverless trains Fleet tracking, management, spacing, logistics Passenger information systems Broken-down train detection, track monitoring Collision avoidance Hazardous cargo monitoring Emergency response	Medium
Aviation	Leisure planes Commercial planes	En-route navigation, direct routing Global airspace management, logistics Monitoring flight position/locations Approach & landing under CAT I/II/III conditions Airport surface traffic management Search and rescue Fleet management and tracking	Medium to high
Maritime transport	Leisure & recreation Fisheries Commercial	Coastal and ocean navigation Harbour approach Vessel tracking & management, logistics Automatic vessel identification systems Search and rescue Electronic charts and displays	Medium
Military	All vehicles Missile systems Hand-held	Navigation & guidance, smart munitions Fleet and troop management, logistics Remote machinery control, unmanned vehicles Enhanced battlefield simulations	Low to medium
Consumer electronics	Cellular phones PCs PDAs	Safety Information access Tracking Logistics	High
Communications, financial, utilities	Fixed receivers	Timing. Synchronisation of clocks located in different parts of the world. Synchronisation of communication network nodes to ensure smooth transfer of information at electronic relay stations. Time marking and tagging. Monitoring of powerline faults.	Medium
Surveying, mapping, GIS	Various, portable	Cadastral surveys, topographic maps, aerial surveys, monitoring of land movement, navigational charts, mapping for realistic video games, animation	Medium
Mining & construction	Various	High precision positioning & engineering alignment, monitoring for structural deformations, offshore platform displacements in oil drilling, automatic machine guidance	Medium
Agriculture & forestry	Portable receivers	High-precision agriculture Precision crop dusting Forest fire tracking, mapping, containment Unmanned ploughing, harvesting	Medium
Environmental uses	Various	Surveys and locations of hazardous waste sites Mapping of ecosystems, groundwater Resource and wildlife management Oil spill tracking and clean up Fishing vessel site monitoring	Medium
Recreation & personal	Various, portable	Navigation and routing Information on weather and conditions Remote guidance of equipment, *e.g.* golf carts Safety Electronic "guide dogs" for the blind	High

Table 2. **GNSS industry applications** (*cont.*)

Industry	Platforms	Uses	Growth potential
		House arrest monitors, Alzheimer patient monitoring, pet tracking	
Law enforcement & safety	Various, portable	Police, private security, soldiers, for example: Navigation Security and rescue, emergency medical services Tracking and fleet management, logistics Mapping sites of multiple accidents/crimes Monitoring movements – house arrest, Alzheimer patients	High
Scientific applications	Various Survey stations	Geodesy, seismic fault monitoring Oceanography Hydrography, sea-level studies (greenhouse effects) Absolute time distribution & determination Meteorology Ionospheric tomography Animal tracking	Medium to high
Other	Entertainment Mobile sales Insurance	Special effects simulation Navigation, information Claim location identification	

Source: OECD.

integrating real-time information on environmental conditions, traffic patterns and customer demands, movements can be co-ordinated, efficiency increased or traffic patterns smoothed. The nearest taxi can be dispatched to pick up a customer. Train collisions can be avoided. Cargo can be physically tracked and workers' schedules altered. Second, location intelligence also makes it possible to deliver relevant information or services on site quickly. In an emergency, knowing where an incident has occurred and facilitating the arrival of help through advanced traffic controls (*e.g.* timing traffic lights) are crucial. There are many other advantages to knowing where vehicles are, such as reductions of losses due to theft and hijacking, or better monitoring of hazardous or unusually valuable shipments.

Positioning information is clearly important for mapping and surveying. Somewhat less obvious is the importance of being able to find a position easily again, as when exploring for off-shore oil, identifying property boundaries, giving farmers exact locations for spraying pesticides, or locating hazardous waste sites. Positioning information is also being added to all sorts of databases on physical, environmental, economic and infrastructural conditions in order to create better geographic information systems.[3] Position information makes it simpler to superimpose and integrate information sources and is an invaluable tool for city planning, construction and economic policy making.

Trends towards greater ubiquity

Trends in GNSS equipment that will make location information a ubiquitous element of the information technology infrastructure include:

– *Integration*. Increasingly, information provided by GPS is being embedded in other applications so that the timing or positioning information is part of a more complex product. Location information is most valuable when used in combination with diagnostic tools, models and software. In fact, value added is more often in the software, data or services than in the hardware or the positioning information itself. Ideally, the GNSS signal *per se* disappears and is hidden in other applications and services. For examples, see precision agriculture and multifunction car computers.

– *Tailored and personalised information*. GNSS makes it possible to personalise or filter information on the basis of the receiver's position at a particular time. Intelligent transport system designers provide traffic information for a given area only to those people in the immediate vicinity. Some airbags are equipped with GPS receivers to immediately send a "Mayday" alert to police and emergency dispatchers when an accident occurs (a feature with privacy implications).

– *Mobility and miniaturisation*. Electronic products have become ever more mobile and GNSS receivers are becoming smaller, lighter and more affordable. The first commercial receivers built by Texas Instruments cost USD 150 000 and weighed about 50 kilos. In 1998, a hand-held receiver costs USD 100 and weighs less than 350 grams. Chipsets have fallen to USD 20-25 (with price drops of about 30% a year), and some are a few centimetres square and consume little energy. GNSS receivers are thus becoming convenient add-ons to other products, like mobile phones or PDAs.

– *Communications and networking capabilities*. From determining an object's position, GNSS is now being used to communicate an object's location and to control and co-ordinate multiple GNSS platforms. This is especially useful in air traffic, taxi fleet, and unmanned machinery management. The combination of GNSS capabilities with communication and information technologies is transforming it from a navigation technology into a key element of the information infrastructure.

– *Timing*. The most invisible of the GNSS applications is the critical role precise time plays in supporting wide-area communication networks and in time-sensitive industries such as telecommunications, finance, and utilities. In order to ensure that packets of information – voice, text, video – are delivered in the correct sequence to their destination, it is important that physically distant communication network nodes have synchronised time. GPS timing equipment synchronises internal atomic clocks and ensures the smooth flow of traffic. The need to rationalise bandwidth use as networks become increasingly congested makes the precise timing of handing off messages at nodes ever more important. If GPS were to go down, it is very likely that cellular and wireline communication would encounter disruptions.

In sum, GNSS signals are rapidly finding applications in a wide range of industries. The use of location intelligence is both ubiquitous and fragmented. Prospects for growth, especially in the in-car navigation markets, tracking, fleet management and electronics/communications are quite promising. Also, as GPS chips and receivers become cheaper, more mobile, more accurate and are supported by better data and software, their use is likely to expand, even as their presence as stand-alone devices declines.

The stakes and the competition

OECD Member countries have expressed strong interest in fostering the development of the GNSS markets for a number of reasons. First, markets for GNSS equipment, software and services are growing rapidly. Second, location and timing information is being integrated into the activities of a broad range of industries, promising productivity improvements and occasionally clearly delivering them. Third, the availability of GNSS signals has a strong public safety component. Fourth, governments are aware that GNSS signals are part of both the transport and information infrastructures, and this is blurring the boundaries between the two sectors and encouraging innovations in both. However, countries display important differences in the use of GNSS signals, both in terms of the generation of new products and firms and in the uses to which the signals are put. OECD Member countries would like to make sure that their firms are aware of the possibilities of exploiting GNSS signals, do not encounter barriers to market entry and can build business plans, secure in the knowledge that the system will be enhanced to meet their needs. At international level, governments are also concerned that the needs of their domestic industries are taken into account in standards setting and in the governance of the global infrastructure that is the GNSS.

At stake for OECD Member countries in the next generation GNSS, therefore, are productivity increases for a range of industries, the generation of new firms, an increased quality of life due to greater security, and a say in defining the system which is becoming an infrastructure element for a number of applications where time and location intelligence is key.

Productivity

In some sectors, productivity improvements due to the use of GNSS signals have been radical and relatively easy to measure. For example:

– The cost of surveying and the necessary man-hours have dropped precipitously since the introduction of civilian GPS in 1984. According to a report for the US Department of Commerce (DOC), "GPS was proven to enhance productivity by 100-300% in allowing smaller survey teams to more accurately cover wider areas in greater detail. As a result the cost of control survey point dropped from an average of USD 10 000 in 1986 to USD 250 in 1997, unadjusted for inflation" (Pace and Wilson, 1998). A single person carrying a single receiver can easily gather the information it formerly took a team painstaking hours of work to generate.

– In the mining industry, the Black Thunder coal mine in Wyoming (United States) claims to have experienced a productivity increase of 30% when it implemented a computerised mining system which included GPS (Carrier, 1998; Long, 1998). Also part of the modernisation was the use of DGPS, geographic information systems, computer-aided design software, and digital terrain models. The new system allowed mine crews to carry out faster surveys, guide equipment operators, monitor and dispatch vehicles, and automate some of the excavating.

In other industries, the productivity increases have been harder to measure to date, but many expect to see them emerge in the future. Often the improvements require concomitant changes in the operation of much broader systems and the education of target users. Productivity enhancement will not occur immediately or be attributable solely to GNSS use. For example:

– GNSS can contribute to the development of intelligent transport systems (ITS). ITS fuses information technologies with all aspects of land transport (*e.g.* in-car navigation, traffic control, tolling, public transport, intermodal connections) to increase capacity, efficiency and safety and to reduce environmental impact. An Australian study estimated that the minimum gain from implementation of in-car navigation systems that provide travellers with information about conditions was a 6% saving in travel time and a 3.5% reduction in air pollution (Table 3). Fleet management would result in 5% to 8% reductions in travel times and 5% reductions in operating costs. Other studies have demonstrated higher benefits: savings of up to 19% in travel time and an increase of up to 25% in numbers of deliveries per day.

– GPS is widely used by the aviation community, although not yet as the "sole means of navigation". GNSS signals promise greater efficiency through direct routing, reduced delays, fewer missed approaches and better use of equipment. Until recently, flights depended on ground radio transmitters to determine their location. Instead of flying directly to a destination, pilots veered from one beacon to the next in a somewhat jagged pattern when flying over land. With GPS, however,

Table 3. **ITS benefits which include GPS**

Application	Benefit measure	Change (%)
Australia[1]		
In-car navigation & traveller information	Travel-time saving	6.0
	Accident reduction	0.0
	Air-pollution reduction	3.5
Multimodal traveller information	Travel-time saving	8.0
	Accident reduction	4.0
	Air-pollution reduction	3.5
Commercial vehicle fleet management	On-time arrival increase	5.0
	Operating-cost reduction	5.0
Public transport fleet management	Travel-time saving	5-8
	Accident reduction	4.0
	Operating-cost reduction	5.0
Other		
Route guidance (US) for rental car travellers, FL[2]	Travel-time saving	19.0
Traveller information (US)[3]	Fuel, HC, CO emission reduction	
Bus fleet AVL (US), Baltimore, Maryland[2]	On-time arrivals	23.0
Bus fleet AVL (Toronto, Canada)[2]	Reduction in number of buses needed to serve routes	4
Freight industry AVL[4]	Cost savings	5.0
Computer-aided dispatching[2]	Increase in number of pick ups and deliveries per day	5-25

1. BAH, 1998.
2. ITS America, 1995.
3. Mitre Corp. 1996.
4. BAH, 1996.

Source: OECD Compilation, based on Booz-Allen & Hamilton (1998*a*).

pilots know their position at all times and can fly along the most direct routes. By saving flight time, airlines economise on fuel, crew pay, insurance, airframe and engine-leasing costs, among other expenses. A European Commission study found cost savings in air travel of between 18% and 24.5%, depending on whether the GNSS system consists of GPS and EGNOS or the fully fledged Galileo constellation (the latter likely costing more for aviation users). Some of the savings for aviation should be at airports if instrument landing systems (ILS) are replaced by DGPS systems (such as the LAAS in the United States). DGPS will allow up to 20% more landings per hour. DGPS ground stations cost about USD 600 000 and can cover several runways or even airports, whereas ILS beacons – although already installed – cost around USD 2 million per runway.

– Precise farming holds out the possibility of reducing the amount of fertilisers and pesticides applied to fields, because they can be targeted to the areas that need them most, and of reducing the amount of overlap in spraying by more accurate guidance. The DOC reports savings of USD 20-24 per field with the use of DGPS. Furthermore, unmanned tractors could work in conditions that would be difficult for humans, at night or in conditions of reduced visibility, such as fog or dust storms. In tests of a prototype developed by Stanford University and the John Deere company, GPS-steered tractors proved more precise than an experienced tractor steersman (Coale, 1997).

Safety and security

Governments are often involved in building the GNSS infrastructure precisely because of its "safety-of-life" applications. Government certification requirements and regulations are likely to play a large role in promoting GNSS technologies in such applications as harbour entry, en-route navigation approaches and landing by aeroplanes, train tracking and collision avoidance. GNSS – especially in automatic vehicle location and tracking – is also having an impact on emergency response times for police, fire and emergency dispatches. The private sector sees GNSS tracking as a way to reduce the incidence of lost and stolen cargo or of hijackings. Reductions in accidents, material losses and improvements in the number of lives saved are an important component of GNSS benefits.

– For air travel, the use of GNSS as a navigation tool is expected to reduce the distance at which aircraft need to be separated in order to be safe. For example, since GPS-equipped planes can transmit exact locations, controllers can fit more aircraft safely into a smaller section of the sky. Aircraft which had to maintain distances of up to 100 miles from one another can fly as close to 50 miles from one another when GPS is used and will soon be within 30 miles. In the near future, data links are expected to feed location data to navigational computers on board all aircraft in a designated area, allowing each aircraft computer to spot potential collision paths and alert pilots. In maritime transport, the European Commission estimates that Galileo could reduce the number of ship groundings and collisions by 8% (Booz-Allen & Hamilton, 1999).

– For emergencies, the Dallas Fire Department has reported that using automatic vehicle location units in ambulances results in a 3% reduction in response time, despite a 13.5% increase in incident calls over a 12-month period and no changes in fleet size (Booz-Allen & Hamilton (1998*a*). In addition, the US Federal Communications Commission has mandated that by 2001 cellular service providers must be able to position with an accuracy of 125 metres the location of automatic distress calls so as to speed the arrival of emergency crews. One solution involves the integration of GPS/GNSS chipsets into cellular telephones.

New jobs and industries

Trimble Navigation, founded in 1978 as a receiver manufacturer, was the first firm to make commercial GPS receivers in 1984. Since then, the number of companies that identify themselves as original equipment manufacturers (OEM) or service providers for GPS has risen steadily. (Of the three distinct segments in the GNSS system architecture – the space, control and user segments – only the last has a civilian market component open to international competition.) A good number of OEM manufacturers are large aerospace, consumer electronics or even automobile firms. There is room for new market entry, and there are quite a few start-ups, although publicly available information is sparse. GPS *World*, for one, provides annual data on companies that declare that they provide GPS products and services. In 1997, 301 companies offered 116 GPS-related products, up from 141 companies and 71 products in 1991 (GPS *World*, June 1997). The largest product categories include software, receivers, differential GPS equipment, mapping, vehicle location and tracking workstations, timing services and equipment. The desire to take advantage of growth in these markets has elicited some government attention. Of greater concern, at least to the European countries, is the absence of European firms in the space and control segments of GNSS.

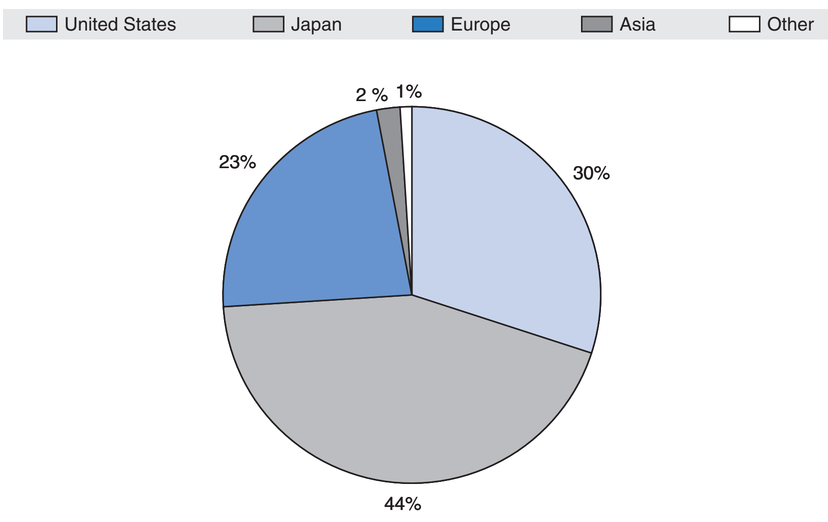
First mover advantage

The definition of standards is important for GNSS markets. The GPS signal structure itself is a *de facto* standard that the European Community will build on if Galileo goes ahead. If GPS is to replace existing navigation and landing systems, global standards will have to be set, for example at the International Civil Aviation Organisation (ICAO). Most OECD Member countries want to influence standards setting, definition of improvements, and governance of the next generation of GNSS, but this depends in part on whether a country has producer or user firms involved in the industry and whether they are organised to articulate their needs. At stake for OECD Member countries, therefore, are productivity increases for a range of industries, generation of new firms, better quality of life due to greater security and a say in defining the system which is becoming part of the infrastructure for a number of applications where time and location intelligence is key.

National differences in GNSS markets

The GNSS is by definition global in scope, but industries that offer GNSS-based products and services are far less so. OECD countries use GNSS signals for different purposes. Japan's is the largest market, accounting for 47% of GPS product and service sales in 1998, the United States is second at 32% and Europe a distant third with 18% (Figure 3). Over the next five years, the European market is expected to account for nearly a quarter of total sales, while that of the United States and Japan should shrink relative to Europe.

Figure 3. **Estimated world GPS market, 2003**



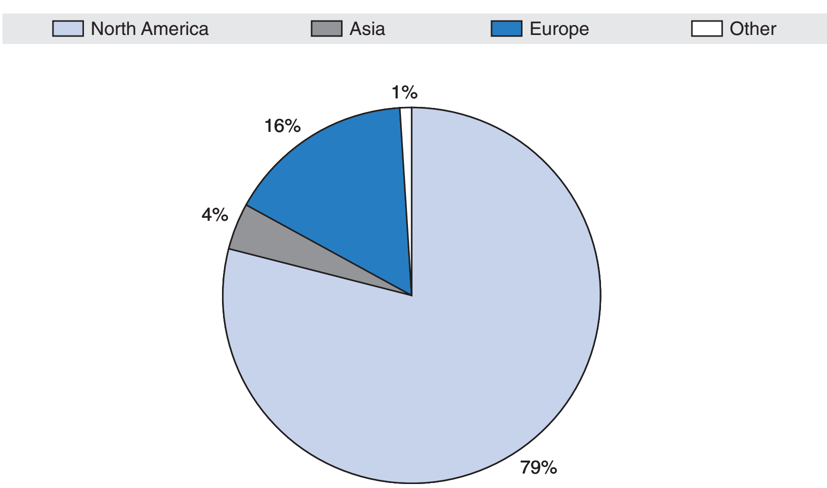
Source: Pace, 1998.

What sets Japan apart is the size of the in-car navigation market. In 1997, over 1 million in-car navigation systems were sold in Japan, compared to 50 000 in Europe and only 6 000 in the United States (Hanson Report on Automotive Electronics). Japan's system of addresses is based on neighbourhood and block numbers rather than street names and continuous building numbering, and this accounts in part for the broad acceptance of these devices. In-car navigation in Japan predates GPS: the first systems were introduced in 1981 and were based on gyroscopes and dead reckoning. In the late 1980s, Toyota, Nissan and Honda matched the gyro information to a detailed map, thereby radically improving the system's accuracy. At about that time, the Ministry of Construction developed special standardised and nation-wide digital road maps, which it provided to companies for a fee. In 1991, the first GPS-based system appeared on the Japanese market. Sales of GPS-based systems have essentially doubled every year since. Offered as a standard option on most cars, about 10% of new cars are bought with factory-installed navigation systems and almost as many navigation devices are sold subsequently (Stanford Resources, 1998).

Many industry observers believe that the US and European in-car navigation markets will overtake Japan's over the next decade. At USD 1 000, in-car navigation devices are considered expensive when compared to purchase prices of new cars (USD 20 000 in the United States), although the price will certainly drop. However, in the United States, video devices are prohibited within viewing range of the driver (voice guidance is the alternative) and navigable digital maps are of relatively poor quality. Furthermore, the United States does not have a seamless, nation-wide, low-cost and reliable wireless communication system like Europe's GSM, and the lack of universally compatible standards raises the cost of GPS-based products for mobile data applications. Autonomous navigation systems do not need to be tethered to a ubiquitous communication system, but a large, robust single database would be an advantage for many applications (GPS *World*, January 1999). Europe's navigation market and equipment industry is more mature, although its focus is on commercial trucking rather than individual consumers (Pace and Wilson, 1998). Europe will likely see faster growth in GNSS-based systems as prices come down.

Figure 4 shows a breakdown by region of the number of GPS-related product and service firms. At almost four-fifths of the total, the United States has the largest number of companies with GPS product lines. In terms of expertise, industry analysts tend to put North American firms in the lead for the devel-

Figure 4. **Share of GPS firms by region**



Source: Pace, 1998.

opment of GPS-based equipment and services, with Japan in second place and Europe in third. One survey estimates that Europe's share of the European GNSS equipment market is only 10% and that European companies have only 2% of the European original equipment manufacturer (OEM) market (Booz-Allen & Hamilton, 1998*b*). Half of US GPS sales were to export markets, confirming the lead of the US manufacturers.

Because firms from OECD countries have exploited the availability of GPS signals to different extents, this means that they are likely to approach the development of the next generation GNSS with different agendas, different strengths and weaknesses, and different ideas as to what role the government should play.

National policies

The United States

The US government has, on several occasions, reiterated its commitment to maintaining the standard GPS service as a free public utility, despite investment and maintenance costs which should reach USD 14 billion by 2016.[4] A March 1996 Presidential Decision Directive formally reaffirmed the no-direct-fee policy for peaceful civil, commercial and scientific uses and this became law in 1997. In addition, the President declared GPS to be an integral component of the Global Information Infrastructure and affirmed the intention to discontinue SA by 2006.

The United States intends to improve the service to make it more responsive to the needs of civilian users worldwide and to spur new commercial applications. In March 1999, Vice President Gore announced a GPS modernisation initiative involving two new civilian frequencies by the middle of the next decade: one for general use in non-safety-critical applications and one for safety-of-life applications such as aviation. Combined with the current civilian signal, these signals will improve the robustness and reliability of GPS. Other improvements include a planned increase in signal power, two new monitoring stations to improve stand-alone GPS accuracy and reliability through uninterrupted tracking of all satellites at all times and a back-up master control system to reduce risk of failure.

The United States has also been active in establishing GPS as a global standard and promoting its use for international navigation. For example, the Federal Aviation Administration has promoted GPS as the primary means of navigation in the United States and strongly encouraged its use for future air traffic management in forums like the ICAO. A particularly important initiative has been to defend GPS signal bandwidth from encroachment by mobile satellite services. Other countries have been consulted bilaterally, to raise their awareness of the utility of GPS and gain their support for a GPS-based system. In 1998, Japan and the United States signed a joint statement regarding the use of GPS. The hope is to create a stable international policy environment, expand the size of the GPS market by standardising and certifying equipment so that it is internationally compatible and to build alliances for the protection of the GPS radio spectrum.

Although the US government has encouraged the use of GPS as a key element of the civilian information infrastructure, it remains a military system controlled by the Department of Defense. The growing dependence of commercial interests on the signal has meant that these groups are demanding more influence on system parameters and governance. The greater the civilian reliance on GPS signals, the more the military must change its practices to preserve the security mission of GPS. US policy has been to maintain a dual-use and dual-mission GPS and to reconcile the needs of both groups.

The European Union

The European Union recently announced its intention to build a separate – but fully GPS-compatible – satellite navigation system specifically for the civilian community. European policy makers wish to have more control of the system and improve the ability of European industries to access the underlying technologies and compete in what is expected to be a very lucrative market. The European Space Agency (ESA) has been studying the development of civil satellite navigation systems since the

1980s. The perception that neither GPS nor GLONASS would meet the needs of the civilian community led in 1993 to the articulation of a two-track European approach to building a GNSS. The European Commission, ESA and Eurocontrol are developing an overlay to GPS and GLONASS called EGNOS, which will broadcast differential corrections and integrity messages by 2002, primarily for the aviation community. Policy makers have also explored how the European Union could best contribute to what they call GNSS-2: a worldwide civil navigation satellite system which meets the requirements of all categories of civilian users and is internationally controlled and managed.

Developing a separate GNSS, called Galileo, that would be fully compatible with the GPS system is presently the favoured option for both political and commercial reasons. However, Galileo also requires investments on the order of EUR 2.2-2.95 billion to set up the system, depending on the configuration chosen. To finance this project, the European Union envisages putting up about half of the funding from public sector programmes. The other half would be assembled through a public-private partnership (PPP) that would manage project development and tailor the system to meet multimodal industrial needs. Private sector involvement in a PPP requires identifying revenue streams from GNSS services so that investors can be assured returns of the order of EUR 300 million a year. This revenue stream could come from a segmentation of the services offered.

The European Union recognises the need for a strong political commitment to Galileo if the private sector is to have the necessary confidence for investing in the PPP. As a late entrant, and one whose primary objective is commercial, Galileo faces several difficult challenges:

- *Creating revenue streams in the face of competition from the free GPS service*. The solution envisaged is to offer different levels of service: level 1, a free baseline service of comparable or better quality than GPS; level 2, certifiable service with performance guarantees; and level 3, a service for safety-of-life and security applications. A fee-earning, partially restricted access system could also be created. Subscriber fees could be charged for levels 2 and 3, and some services might be mandatory. Levies could be charged for all satellite navigation equipment sold or manufactured in the EU. Charges for value-added services – such as maps, asset databases and terrain information – could generate the most PPP revenues. The mechanism is to be chosen at a later date.
- *Aggregating user requirements*. Galileo's civilian nature places greater attention on commercial standards and specifications than does GPS. European governments are therefore consulting with multimodal stakeholders in an attempt to define Galileo's platform parameters. There is also concern that fees be equitably distributed and market-priced as not all industries will use GNSS data intensively or be as willing to pay for services. Paying services will by default subsidise free services.
- *The security dimension*. Despite Galileo's civilian character, security issues must still be addressed at a European-wide policy level. Interest in military applications by European powers is to be expected. Also, since Galileo will become an important infrastructure element, its protection from attack must be assured. Users with high safety/security requirements need to be assured of its performance, while access to unfriendly users should be denied.

Japan

As the largest commercial market, the Japanese government sees the GNSS as an essential part of the information infrastructure. Japan is encouraging the development of commercial and civilian applications. In order to facilitate this process, Japanese policy aims to: *i*) maintain the GNSS as an seamless, internationally compatible, and affordable public utility; and *ii*) improve its safety and reliability. Domestically, the Japanese Government is developing its own GNSS-related technologies in order to better respond to user demands for more sophisticated and diversified services. It has ongoing research projects on atomic clocks, for example. In the near future, Japan plans to launch the first of its geostationary satellites for its satellite-based augmentation system, which would provide one of the first GPS-based air traffic management systems.

Internationally, Japan welcomes and encourages the US commitment to continue providing the GPS Standard Positioning Service on a free, worldwide basis for peaceful civil, commercial and scientific uses.

The free service has allowed the private sector to offer affordable GPS-based products. Japan has signed a bilateral statement with the United States on the importance of maintaining GPS as an infrastructure, and recognises the critical importance of protecting GNSS bandwidth from interference and encroachment. However, Japan would like to be able to address some of the deficiencies of the present GNSS in an international context. In particular, Japan feels it is indispensable that information related to user safety and signal reliability be disseminated in a timely manner.

Policy challenges at the international level

To summarise, governments have an important role to play in facilitating the commercialisation of GNSS/GPS signals by ensuring reliable civilian access to the signal and building augmentations or improving the existing system. All three regions are deeply implicated in the development of the next-generation GNSS and understand the importance of location information for industrial innovation and public safety. The United States has a head start in many respects. GPS use is promoted and augmented by several civilian agencies, thus encouraging its use by private interests. Its policy focus at international level has been to ensure that GPS becomes a global standard and that augmentation systems are interoperable. The European strategy, unhampered by the security considerations of the GPS, has been to rethink the GNSS system with a view towards commercial needs. In this respect, its position as a late entrant is an advantage. However, Europe has to work within the parameters set by the GPS system in order to interest its domestic equipment and user industries. Furthermore, its ambitious design for an independent GNSS constellation has made profit generation a constraint which has not been a concern for the United States. The success of the European Galileo system rests on its ability to form a public-private partnership, which in turn requires the identification of different levels of service which could generate revenue streams. Finally, Japan has forsaken the creation of a new satellite system, letting commercial applications flourish, while investing public monies in improvements and augmentations to the *existing* GPS service as well as auxiliary products such as digital maps. Like Europe, however, Japan is increasingly interested in defining the parameters of the next-generation GNSS in a yet-to-be-defined international context. So, while all countries are in agreement that the present GPS needs improvement in order to unlock the commercial potential of location and timing information, their domestic and international strategies differ.

The architecture of the global satellite navigation and positioning system is being reformulated. As control passes from American hands to a more international consortium, international discussions will be needed to help create standards, keep international markets open and large, co-ordinate system governance and resolve the security and commercial issues that emerge as GNSS becomes a shared infrastructure.

Standards: system interoperability

The world can expect to have at least two, and possibly three, independent GNSS systems early in the next century. The ideal, from a commercial perspective, is seamless and compatible systems so that users can access all signals simultaneously. This would increase reliability, improve performance and provide redundancy in case of failure. The worst-case scenario would be systems that are not interoperable and geographically split markets for GNSS products and services, as this would inconvenience commercial uses that span national boundaries and reduce the economies of scale that service and equipment providers can obtain for their products.

The present GNSS is composed of the US and Russian satellite constellations and national or regional augmentation systems. Galileo may become a third independent system, although discussions with the Russian Government are under way about a possible collaborative project integrating GLONASS and Galileo. The Europeans could then take advantage of the satellites already in orbit, of Russian experience in launch and constellation management and of established GLONASS radio frequencies. On their side, the Russians would receive badly needed capital for the upkeep and modernisation of GLONASS.

The US Government now recognises the advantages of a separate European constellation. It has proposed to make GPS an open system architecture, which essentially means having GPS and its augmentations be the standards for international use. Some of the standards of interest include use of the same frequency, geodesy, signal structure and time standards. The European Union is still considering whether a fully GPS-*compatible* system – a parallel system, in a sense – is in its best commercial interest. On the other hand, if the Europeans build on GLONASS, Galileo and GPS will be quite different (frequencies used, signal structure, etc.) and international negotiations will focus on how to make the two systems *interoperable*. Already, US-Russian bilateral experiments are under way to improve interoperability.

Standards: *bandwidth convergence*

As satellite data transmission explodes, the fierce competition for spectrum allocation affects the GNSS in two ways: existing bandwidths could be reallocated for other uses and interference becomes more frequent. In 1997, there was a proposal at the ITU's World Radio Conference (WRC) to share the bandwidth of the L1 civilian GPS band (1575.42 MHz) with mobile satellite services. At the time, reallocation was supported by INMARSAT and a coalition of European and Asian government and private interest groups but opposed by international aviation groups. At US insistence, the proposal was tabled for discussion until the WRC in 2000. There is now greater understanding of the role that GPS plays as a global infrastructure, especially for time-stamping and co-ordinating telecommunications. INMARSAT has since backed away from its proposal, and the United States has gained more support from other countries through a series of bilateral consultations about the commercial importance of protecting the GPS bandwidth. However, challenges to spectrum are likely to continue to emerge from other mobile satellite vendors in the future.

Bandwidth interference is one of the greatest threats to the commercial viability of GNSS services. A reduction of spectrum due to mobile satellite services and digital television would severely reduce the utility of GNSS and would also aggravate problems of interference and degrade the reliability of the signal. For these reasons, the United States is increasing the number of frequencies on which GPS signals are broadcast (Table 4). The GLONASS system is facing similar problems for its new GLONASS-M satellites. Russia will change the frequencies on which it transmits its signals in 2005.[5] The European Union must take this into consideration when deciding whether to collaborate with the Russians in building Galileo. Staking out new bandwidths for a third independent GNSS system may be difficult, but shifting bandwidths midway in the development process is not ideal either. In any case, all GNSS systems will have to stave off encroachment by other forms of data broadcasting in order to generate commercial confidence in their services.

Table 4. **GNSS bandwidths**

	Frequencies	Use
US Navstar Global Positioning System		
L1	1575.42 MHz	Primary civilian frequency
L2	1227.6 MHz	Primary military frequency
L2c	1227.6 MHz	Second civilian frequency for non-safety-critical applications
	1176.45 MHz	Third civilian frequency for safety-critical applications (aviation)
Russian GLONASS		
Pre-2005	1602.0-1608.8 MHz	Present civilian and military frequency range
Post-2005	1598.1-1605.4 MHz	Future civilian and military frequency range

Source: OECD.

International governance

The era in which the Global Navigation Satellite System is first and foremost a military technology controlled by a single country is coming to a close. While the provision of free and reliable GPS signals by the US Department of Defense has been the cornerstone of commercial development, Europeans have become increasingly wary of relying on a foreign power as sole provider. During times of conflict, civilian signals can be jammed or discontinued as a security measure. The US military has jammed civilian signals during conflicts (such as Kosovo) or even as a preventive measure (for example when heads of state assemble for summits in sensitive regions). This practice disrupts civilian use, sometimes with inadequate warning.

Galileo, which would serve the civilian community, would clearly change the dynamics of GNSS's international control and governance. Even without it, the strength of private sector user groups and the wide-area augmentations being developed by Japan and Europe dictate a broadening of stakeholder representation in GNSS management. The global community wishes to have a say in standards setting, management and governance of the next-generation GNSS. Europe has proposed to the United States a joint management board and a dispute resolution mechanism for the management of the GNSS.

The United States is unlikely to give up direct control of GPS or change it from a US government organisation to one managed by an international group, as happened with the Internet domain name system. Recognising the global nature of the infrastructure, however, the United States has proposed stronger international involvement and representation in GPS management. It is likely to be increasingly necessary to co-ordinate multiple systems – regional augmentation systems or entire constellations – so that they are integrated into a seamless global network, possibly co-ordinated by an international organisation. At present, the work of defining standards and interoperability is done bilaterally, but a more formal mechanism may eventually be necessary, whether or not a GPS open system architecture is adopted. Co-ordination is important for establishing standards for the signal in space and network interfaces. In addition, an international group could discuss what improvements and augmentations will be needed and how to pay for them. Finally, countries will eventually need to discuss security issues, such as what co-operative procedures should be followed when governments want to deny access to signals in a region for military or security reasons. The institutional framework for international co-operation has yet to be established.

Trade

If several independent GNSS systems coexist, trade barriers for equipment and services could become an issue. Equipment and service providers should be able to participate freely in markets worldwide and take advantage of economies of scale. Countries can discuss potential barriers to trade and how to minimise their impact. As they encourage the development of domestic GNSS equipment and service industries, issues may emerge in areas such as:

– *Certification requirements*. As these define performance for specific activities, they can encourage the adoption of new technologies, as happened in the United States for the use of GPS in national geographic surveys. However, a proliferation of divergent certification standards can segment global markets.

– *Regulations about the need for national control over safety-of-life applications*. This has blocked use of GPS for navigation in Europe. (The United States argues that Europe and Japan have complete control over wide-area augmentation systems that provide the navigation service and verify accuracy, integrity and broadcasting corrections or notices to users.)

– *Strategies for generating revenue streams*. For example, the addition of a communications payload to Galileo satellites, proposed as a way to add value to the signal, is being approached with caution because it can be interpreted as communication satellite subsidisation.

– *Taxation of* GNSS *hardware*. Though not a trade barrier *per se* when applied equally to imports and local production, it can discourage the development of GNSS applications.

– *Public sector procurement practices* (in space and control segments). These are not open to full international competition.

Privacy

GNSS signals by themselves do not give out location information. When used in combination with communications capabilities, however, the position of a user can be broadcast and recorded, as happens with logistics management for trucking, shipping and public transport. How the data generated from this "tagging" may be used has not yet been resolved in any OECD country. For the most part, the initial deployment of GNSS data for fleet management has been well received. The trade-off of privacy has been greater security (in emergencies) and better work organisation. Questions will eventually emerge, however, about how information on the movements of people can be legally used. For example, records of time, velocity and location could be used to verify that truckers do not violate regulations on the number of hours spent on the road in a given period or to notify speed limit infringements. More problematic is the fact that users may not realise they are using or activating GNSS receivers, for example, when these are linked to airbags to warn authorities in the event of activation. The problem will become more acute as GPS receivers are integrated into cellular phones, cars and portable digital devices.

Governments may eventually want to impose regulations or encourage self-governance rules in industry. ITS Australia, for example, has prepared a number of privacy principles for intelligent transport systems to ensure that its systems are designed and used so as to minimise the potential impact on the privacy and autonomy of individuals.

GNSS *as a critical infrastructure*

As a crucial element of the information infrastructure, the smooth functioning of the GNSS is of concern to governments worldwide. Jamming or spoofing (sending a false signal) are electronic warfare threats which could have repercussions for the private sector. Air traffic which relies on GNSS signals for navigation should be especially protected from jamming, which would force aircraft to fly blind. Similarly, it is important to guard against criminal spoofing of time-stamping in financial transactions. Protection of the signal in space is therefore an international security concern.

The GNSS system may also malfunction. For example, 22 August 1999 was the "roll-over" date for GPS. The system was initially designed to count 1 024 weeks, starting from 6 January 1980, after which its synchronised clocks reset to week zero. The problem is very similar to the year 2000 bug for computers. While the US Defense Department certified that the glitches were fixed in the space and control segments of GPS, private sector receivers built before 1997 were not all roll-over compliant. Fortunately, disruptions in service were reportedly scarce. In Japan, thousands of complaints were received from car navigation users but no accidents reported. In the United States, the Coast Guard received only few calls from boaters and no problems were reported to the Federal Aviation Administration. While the GPS rollover was smooth, it is important that governments guard against any future disruptions in service which could cause receivers to identify incorrect locations or times. Natural disasters such as meteor showers are believed to be one potential source of problems.

The potential vulnerability of GPS prompted the US Federal Aviation Administration to commission an independent study of its robustness as the sole means of navigation (to replace the existing Loran-C system). The study concluded that, if used with some improvements (LAAS or WAAS), GPS could safely be the only navigation system installed in aircraft. Nevertheless, one of the attractions of a separate European GNSS is that the two systems could function as mutual back-ups. All governments, therefore, have a stake in ensuring that the GNSS is as secure and robust as possible.

Certification and authentication

GPS is essential for providing synchronised time for the management of telecommunications networks and the transmission of Internet data as well as for switching access to utilities (*e.g.* power grid management). It is also used in the international financial community as a way of time-stamping transactions. It may eventually be used at the international level as a way to provide jurisdictional and tax information about where mobile customers engage in transactions. Establishing jurisdiction for electronic commerce is a big problem for fiscal authorities. While the focus is presently on the domain name system as an indicator of location, GNSS may in the future provide valuable information for creating tax and audit trails, since the data could show where people are physically located when they make a purchase. To date, no such plans have been articulated by government authorities.

Conclusion

The commercial development of GNSS applications is a concern for all OECD countries because the successful integration of location intelligence in a variety of industries will spur the development of new products and services as well as improve efficiency and cost savings in older sectors of the economy. Location intelligence allows the delivery of personalised and location-relevant information, as well as the management and co-ordination of geographically dispersed platforms. However, the GNSS is not a stand-alone system. It is part of an evolving information infrastructure which, together with improved communications capabilities, software and databases, is resulting in innovative business solutions.

The present GNSS, whose backbone is the US Navstar Global Positioning System, has given birth to a multi-billion dollar market for GPS products and services. Further commercial use requires that OECD Members address both technical and governance challenges. The shape of the next-generation GNSS is thus under construction, with individual countries choosing different methods of participation. Some have opted to simply rely on the signals provided by GPS and GLONASS; others sponsor projects that facilitate greater use of the signals and iron out potential problems; while yet others have invested in regional augmentation systems which would improve the service available for commercial applications within their territories. The United States is improving the level of service it provides for free to the civilian commercial community worldwide, while the European Union is considering the construction of an entirely new constellation dedicated to civilian needs. Identifying which parameters of the service if improved would have the greatest commercial impact is proving to be tricky as user groups are dispersed and their needs disparate. This is especially a problem when contemplating how to charge users in order to create a revenue stream.

As the GNSS is evolving into a system with multiple components, governance issues have come to the forefront of international discourse. Countries are already engaging in discussions about the compatibility and interoperability of GPS, GLONASS and, eventually, the European Galileo system. For commercial exploitation, the ideal would be a seamless and compatible system that permits users to easily access signals worldwide. Also, the convergence of information technologies and their use of wireless networks is putting pressure on the radio spectrum on which GNSS signals are broadcast. Countries are engaging in bilateral discussions to co-operate in securing GNSS bandwidths so that it will remain a reliable part of the information infrastructure.

While standards setting and interoperability can be done on a bilateral or *ad hoc* basis, it may be necessary in the future to consider other institutional forums for consultations about ongoing improvements to GNSS infrastructure and service. Agreement will eventually be needed about how to maintain the overall safety and security of this critical infrastructure and how to inform one another of modifications in services. The legal infrastructure may also need to adapt as governments consider how to protect the privacy of location data and consider the use of location information for financial certification and authentication in electronic commerce transactions.

As the number of industries and countries with important stakes in commercial GNSS applications multiplies, these stakeholders are increasingly demanding a say in the management and governance of the existing system. We can expect the make-up and governance structure of the Global Navigation Satellite System to change considerably over the course of the next decade. OECD countries should be aware of their stakes in this technology and the policies which will shape its future.

NOTES

1. Personal communication, Wayne Heiser, 30 July 1999.
2. For GPS and GLONASS, the space and control segments are government owned and operated, equipment is obtained through military contracts and bidding is not open to international competition. In Europe, the space and control segments of Galileo are likely to take the form of a public-private partnership.
3. A geographic information system is "a system of computer hardware, software, and procedures designed to support the capture, management, manipulation, analysis, and display of spatially referenced data for solving complex planning and management problems". GPS can easily collect the necessary positioning information for the wide variety of objects and features catalogued in GIS maps. GPS/GIS applications include utilities management, police incident reporting, resource management, etc. (French, 1996, pp. 187-89).
4. Estimates of procurement of satellites and military user equipment in the United States over the past 25 years are of the order of USD 8-9 billion.
5. GLONASS uses a range of frequencies as satellites do not all use the same broadcasting frequencies. The shift will then be from the present 1602.0-1608.8 MHz to 1598.1-1605.4 MHz after 2005.

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Chapter 9

PATTERNS OF FUTURE USE OF FLAT PANEL DISPLAYS*

Since the development of television in the 1940s, cathode ray tubes (CRTs) have been the predominant technology for the display of electronic information. Over the past half-century, CRT technology has been refined and has become an inexpensive way to display television or computer signals. Over 250 million television and computer displays containing CRTs are produced each year. CRTs have always had one obvious limitation – their size. Their depth is generally equivalent to the size of the display as measured diagonally. They also consume a great deal of energy. These characteristics have prevented their use in mobile devices. Moreover, CRTs are limited to screen sizes of less than 40 inches, for reasons related to manufacturing difficulties as well as size, so that they cannot be used in large-screen applications (with the exception of CRT projectors). Researchers have sought to overcome the limitations of CRTs by developing flat (or thin) displays. The earliest motivation was the notion of a "hang-on-the-wall" display, but in recent years, portability has been an equally strong motivation for thin, lightweight displays.

In the information technology industries, displays are one of the most important interfaces for accessing information. Smaller and lighter displays can be incorporated into new devices or old applications which were not previously interactive (electronic books or refrigerator displays, for example). The evolution of the display industry, therefore, is breaking down barriers between various electronic goods and information technologies. Cellular phones are already serving as Internet access devices, while automobile displays do double duty as televisions and navigation devices. In short, flat panel displays (FPDs) help make information technology a ubiquitous element of everyday life.

The growing importance of FPD technology has periodically caught the attention of policy makers. A decade ago, FPDs were believed to be a critical element of the IT industry; in some quarters it was argued that companies needed to be able to produce advanced FPDs in order to offer globally competitive computers and electronic products. In the extreme, it was asserted that, in many cases, the display would become the system, in which case inability to produce the display would mean inability to make the product. However, in key FPD segments, increasing standardisation and high-volume production and dramatic price declines over the past few years have demonstrated that this is a risky market still in search of a "killer application".

National security provided a related argument for the policy importance of FPDs: as defence systems have become increasingly dependent upon IT, lack of access to advanced display technology could put a nation at a military disadvantage. However, integration of FPD technology into military systems has been slow, and the demand for specialised displays has been satisfied by companies that modify commercial displays for military purposes.

The key issues for policy makers, however, revolve around the social implications of FPDs, which permit citizens to access information with greater mobility and flexibility, as the following examples show:

– *More access to information*. FPDs will continue to make possible new ways to access information. The most salient examples are found in mobile computing and communications; personal digital assistants, hand-held computers and mobile telephones all allow greater access to information in

* This chapter was prepared by Paul D. Semenza, Vice President, Stanford Resources, Inc.

mobile settings. However, concerns have arisen regarding the social impact. On the other hand, FPDs have been used to develop products only for accessing the Internet, thereby allowing those who cannot or will not use a personal computer to expand their ability to communicate.

– *Privacy*. As society becomes increasingly reliant upon mobile information devices, privacy of information becomes a greater concern. The "untethering" of workers from desktop computers means that they must use communication links and may rely increasingly on shared data on Web servers. This increases the possibility of inappropriate access to personal or corporate information. Also, with critical information stored on small (and valuable) electronic devices, the possibility of theft or loss might increase.

– *Medical applications*. Electronic displays are increasingly integrated into medical equipment such as patient monitors and diagnostic imaging systems. Greater use of displayed information could have an effect on the doctor-patient relationship.

Flat panel display markets and applications

There are several FPD technologies (Box 1). The most prevalent is the liquid crystal display (LCD), best known for its use in portable computers, mobile phones and hand-held games, as well as a myriad of applications in items such as watches, calculators and consumer electronics devices. LCDs used to display colour graphics on computer or video devices are typically of the active matrix variety, whereas displays for text, numbers, icons or simple graphics typically use passive matrix LCDs. In 1999, the average price of active matrix LCDs is USD 200, and for passive matrix LCDs it is USD 2.

Plasma display panels (PDPs) are the FPD technology likely to grow most rapidly. PDP technology is suitable for metre-sized televisions less than a tenth of a metre thick, and is well placed to become the long-sought "hang-on-the-wall" TV. Currently, PDPs are most often used in business settings, such as conference rooms, trade shows and public information settings. As screen sizes become larger and performance reaches the level needed to display high-definition TV signals, PDPs are projected to grow rapidly to surpass 2 million units by 2005. Average prices for PDPs should remain high, however, above USD 4 000 through the year 2000 and above USD 3 000 through 2003.

Many other FPD technologies have challenged the dominance of LCDs and CRTs. Most have been confined to niche markets or have become low-priced commodity devices. In terms of market value, commodity devices take the lead: light-emitting diodes (LEDs) and vacuum fluorescent displays (VFDs). These low-priced items are used to display numbers and simple text and graphics in clocks, audio systems, VCRs, automobile displays, household appliances, telephones and test equipment. They are likely to lose market share to a new type of display called organic LED (OLED), which may allow for adding colour graphic displays.

Other FPD types have been used in niche applications. Electroluminescent (EL) displays are used in medical, industrial and transportation systems; field emission displays (FEDs) are being developed for similar uses. An indirect type of FPD uses a chip-based micro-electromechanical system (MEMS) for reflecting light in electronic projectors.

Table 1 shows the projected market share of FPDs up to 2005. The total world market for flat panel displays is forecast to grow from 2.3 billion units valued at USD 16.9 billion in 1999 to 2.9 billion units valued at USD 34.9 billion in 2005, with a compound annual growth rate (CAGR) of 13%. Plasma display panels are projected to grow at a rate of 50% a year. Despite annual growth of only 2%, CRTs are likely to continue to be the main display technology through 2005, with a projected market value of USD 26.8 billion in that year. The second largest market segment in 2005 is likely to be that of LCDs, valued at approximately USD 21.8 billion, and PDPs are likely to be third at USD 2.5 billion, as the market for PDP-based television begins to grow.

Figure 1 shows market shares of the top product markets for FPDs over the period 1997-2005. The fastest-growing product areas are expected to be desktop computer monitors, with a CAGR of 57%; colour TV, with a CAGR of 54%; and conference room applications, with a CAGR of 51%. The combination of portable and desktop computer applications is likely to account for 45% to 55% of FPD market value throughout the forecast period.

Box 1. Flat panel display technologies

Flat panel displays (FPDs) are a class of electronic displays characterised by a construction in packages whose depth is much less than the dimensions of the display itself. A large number of approaches for constructing such a device have been devised, researched and implemented. An FPD can display images in three ways: it can modify an external light source as it is transmitted through the display; it can modify an external light as it is reflected by the display; or the FPD itself can emit its own light.

LCDs

A liquid crystal display does not produce its own light. It is a light modulator and needs external light to be viewed. Light can either be transmitted through the cell from the rear or shone on the front of the display, in which case a rear reflector is required in order to see the image on the display.

For twisted-nematic (TN) LCDs, each glass plate is coated with a thin film and then brushed in a single "alignment" direction. When the alignment directions of the upper and lower plates are rotated at an angle of 90 degrees relative to each other, the molecular chains form a uniform twist from one surface to the other. To view the electro-optic effect, polarisers are laminated to the outside surfaces of the plates, with the front polarisation direction rotated 90 degrees relative to the rear polarisation direction. In the "off" state, with no voltage applied, polarised light entering the front of the cell follows the direction of the twist and undergoes a 90 degree rotation as it exits the cell. This enables the polarised light to pass through the rear polariser unchanged. The "on" state occurs when voltage is applied to the cell.

A passive matrix TN-LCD consists of rows and columns of transparent electrodes connected to integrated circuit drivers that supply voltage. In operation, the display is scanned – or "multiplexed" – row by row, from top to bottom. The liquid crystal material reacts to the average of the voltage over time. When the proper voltage difference is generated across a row and column, the liquid crystal material at the intersection of these electrodes, which is known as the selected pixel, is activated. A result of this arrangement is that the non-selected pixels immediately adjacent to the selected pixels also receive some fraction of the voltage. This is a major limitation of the passive matrix display.

To achieve more acceptable contrast over a broad viewing angle, there are two general approaches: passive matrix and active matrix. Passive matrix refers to improvements in LCD geometry and the use of different physical/optical LCD effects to produce a cell with improved contrast characteristics. Examples include liquid crystal devices with memory, such as ferroelectric-smectic and cholesteric devices, and cells that incorporate a greater-than-90 degree twist (supertwist, or STN LCD). Active matrix refers to the addition of some type of non-linear switching device, such as a diode or transistor, at the pixel site to improve the non-linear response of the liquid crystal material. With active matrix devices, the pixel structure itself is relatively unchanged, but the devices can be complex. The most prevalent type of active matrix device is the thin-film transistor (TFT).

Other FPDs

Plasma display panels

There are two main types of plasma displays, AC and DC, differentiated by their driving technique and the required structural differences in the display panel. There are numerous variations on plasma display technology. There are several approaches to achieving colour in a plasma display, all of which utilise the ultraviolet light generated by the plasma discharge, rather than the orange glow of the plasma directly. A fluorescent material, such as zinc sulphide or zinc oxide, placed in the vicinity of the discharge, converts the ultraviolet light into visible light. This is the principle employed in the ordinary fluorescent tube. If the fluorescent material, called a phosphor, is doped with a small amount of a rare earth or other compound, it can emit light of various colours. By using red, green and blue phosphors, multicolour and even full colour (16 777 million colours) can be achieved. This is similar to the way colour cathode ray tubes for television and computer monitors are made.

The main advantage of the PDP over nearly all other display devices, is that it can be made into a display panel with diagonal sizes of 20 to 50 inches or more in the production or advanced prototype stages that is no thicker than 4 inches, including drive electronics. Moreover, these large panels can provide high information content and full-colour images. This makes the PDP the ideal technology for the fabled wall-mounted television.

Light-emitting diodes

Light-emitting diodes (LEDs) are typically fabricated as discrete semiconductor devices using gallium arsenide material; the combination of holes and electrons across a semiconductor junction results in the emission of light.

Box 1. **Flat panel display technologies** (*cont.*)

Vacuum fluorescent displays

Vacuum fluorescent displays (VFDs) use a flat, vacuum-tight glass package. They rely on the emission of light by phosphors exposed to electrons emitted from a series of filaments.

Organic light-emitting diode displays

More than 50 companies are investigating organic light-emitting diode (OLED) devices; the reason for the high level of interest is the convergence of positive developments: new materials, processes, electronics and more researchers along with the promising performance of the new prototypes. Added to these factors is the attractiveness of the ultimate device: a light-emitting, low-voltage, full-colour, monolithic electronic display.

Like their inorganic cousins, OLEDs rely on the emission of light produced by the recombination of electrons. They are created with transparent organic materials using large-area, thick-film deposition processes. Most are fabricated on a transparent anode layer, itself deposited on a glass substrate. The earliest devices used small molecules vacuum-deposited to form a hole transport layer, on top of which a layer of emissive material and metallic cathode are deposited. An alternative approach uses fluorescent polymers, prepared in solution and spin casted; inkjet printing techniques have also been used to pattern polymeric OLEDs.

Electroluminescent displays

Electroluminescent (EL) displays emit light through direct conversion of electrical energy. Stacked layers of metal electrodes, insulator, and phosphor material (typically doped zinc sulphide) are deposited by thin-film techniques.

Field emission displays

Field emission displays (FEDs) are vacuum tubes that use arrays of electron emitters (cathodes) to produce electrons which are accelerated towards a phosphor-coated faceplate, or anode, which absorbs the electrons and in turn emits visible light. While the general principle is the same as in a cathode ray tube (CRT), the electron emission is developed from a cold (room temperature) cathode. Also, a CRT uses one high-voltage cathode for each of the three primary colours; the electron beam produced by that source is focused by a gun and scanned by electromagnetic deflection coils. In the FED, there are numerous cathodes per pixel and a direct relationship between the cathodes and the associated pixel, so no focusing or scanning are required.

Microdisplays

Microdisplays are, as the name suggests, very small displays that are typically viewed through the use of optics. While no formal definition exists for the size of a microdisplay, they typically have a diagonal measurement of one inch or less. Two methods are used to implement microdisplays. Personal viewers, in which an optical system is used to project a "virtual" image (that is, one that appears to the visual system to be much larger than it actually is), are used for compact head-mounted or hand-held devices. Projection systems are designed to magnify a small image onto a screen for viewing by one or more users.

As with direct view flat panel displays, there are three types of microdisplays: reflective, which modulate an external light source by varying the properties of a reflecting surface; transmissive, which modulate an external light source as it is transmitted through the device; and emissive, which produce light internally. Transmissive and emissive microdisplays are mainly miniaturised versions of LCDs, ELs, FEDs and other types of FPDs.

The two main forms of reflective microdisplays are micro-electromechanical systems (MEMS) and liquid crystal on silicon (LCOS). MEMS devices utilise semiconductor fabrication equipment and processes to build miniature systems that have both mechanical and electrical components. They rely on physical movement of a display element to modulate the amplitude or phase of an external light source. LCOS are similar to direct view active matrix liquid crystal displays (AMLCDs) in that they utilise the light-modulating properties of liquid crystal materials. LCOS displays substitute a silicon substrate for one of the glass plates; instead of thin-film transistors on glass, they use bulk silicon devices to control the pixels from outside the optical path. The silicon chip serves as both the active matrix and the reflective layer, on top of which a thin layer of liquid crystal, glass plate and polariser are deposited.

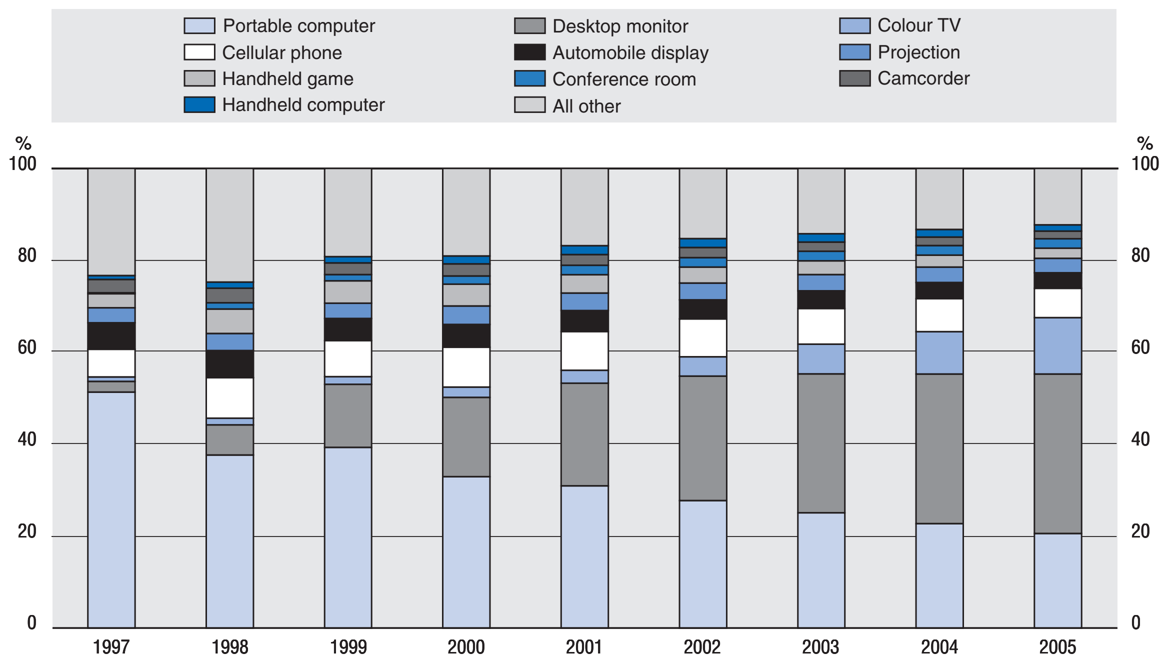
Table 1. **Worldwide electronic display component market, 1999 and 2005**

Billions of USD

Display type	1999	2005
Liquid crystal displays (active)	11.3	23.7
Liquid crystal displays (passive)	3.8	4.1
Plasma display panels	0.5	5.2
Other FPDs (EL, FED, MEMS, LED, OLED, VFD)	1.4	2.0
All flat panel displays	16.9	34.9
Cathode ray tubes	23.5	26.8

Source: Stanford Resources Inc., 1999.

Figure 1. **Breakdown of top applications for FPDs by value, 1997-2005**



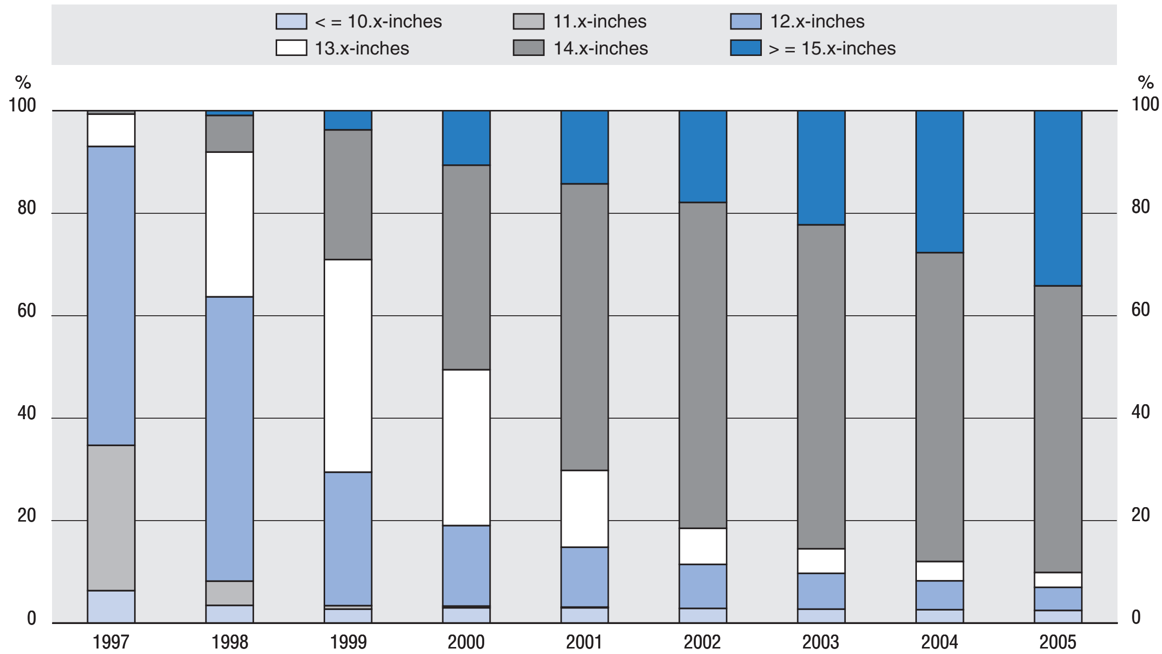
Source: Stanford Resources, Inc. 1999.

Computer applications

In terms of value, computer applications, including desktop monitors, portable and hand-held computers and computer peripherals, represent the most important market for FPDs. The worldwide market for computer products is valued at USD 9.2 billion in 1999, or 55% of the total FPD market, and it is estimated to grow to USD 19.8 billion by 2005, or 57% of the overall FPD market. In addition, the computer market is also the primary source of demand for LCD panels nine inches and larger in diameter. Currently, the notebook computer market drives the demand for large LCDs, but increasingly, it is expected to share this role with desktop computer monitors, which are projected to surpass notebooks as the largest source of demand in 2003. For LCD manufacturers, large panels are attractive in terms of their ability to generate revenue, but investment in expensive capital equipment and changing screen-size requirements make them a risky venture.

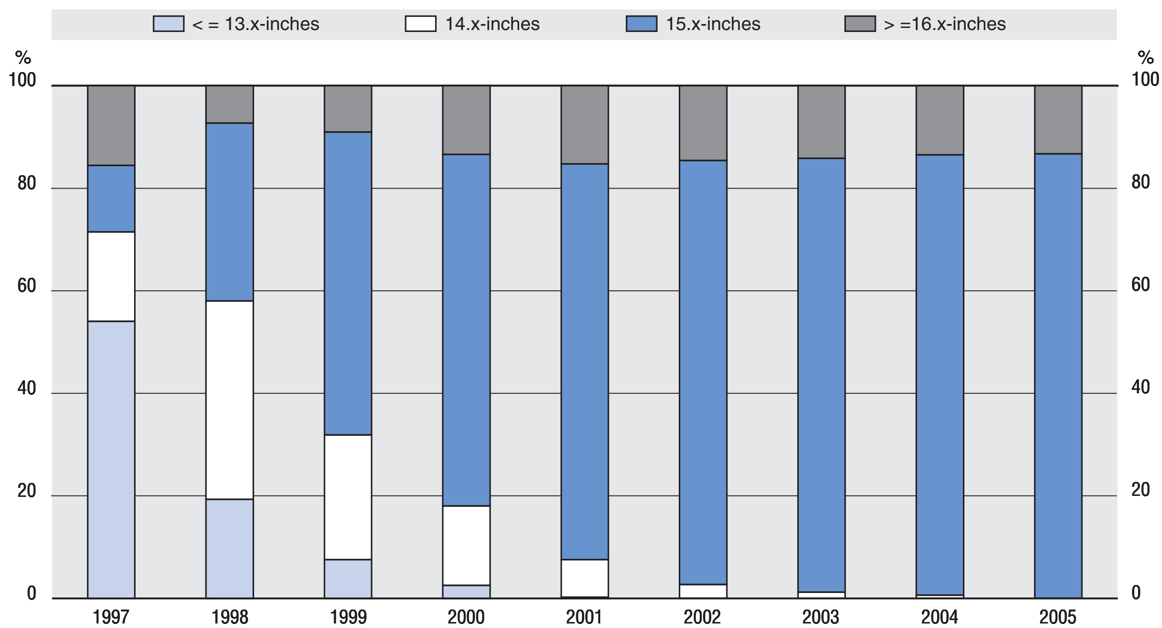
In both notebook computers and desktop monitors, the product trend is towards larger panels. In portable computers, the dominant size is moving from 11 and 12 inches in 1997 to 14 and 15 inches (Figure 2). For desktop computer monitors (Figure 3), screen sizes of 13 and 14 inches – the majority of

Figure 2. **Breakdown of portable computer LCDs by screen size, 1997-2005**



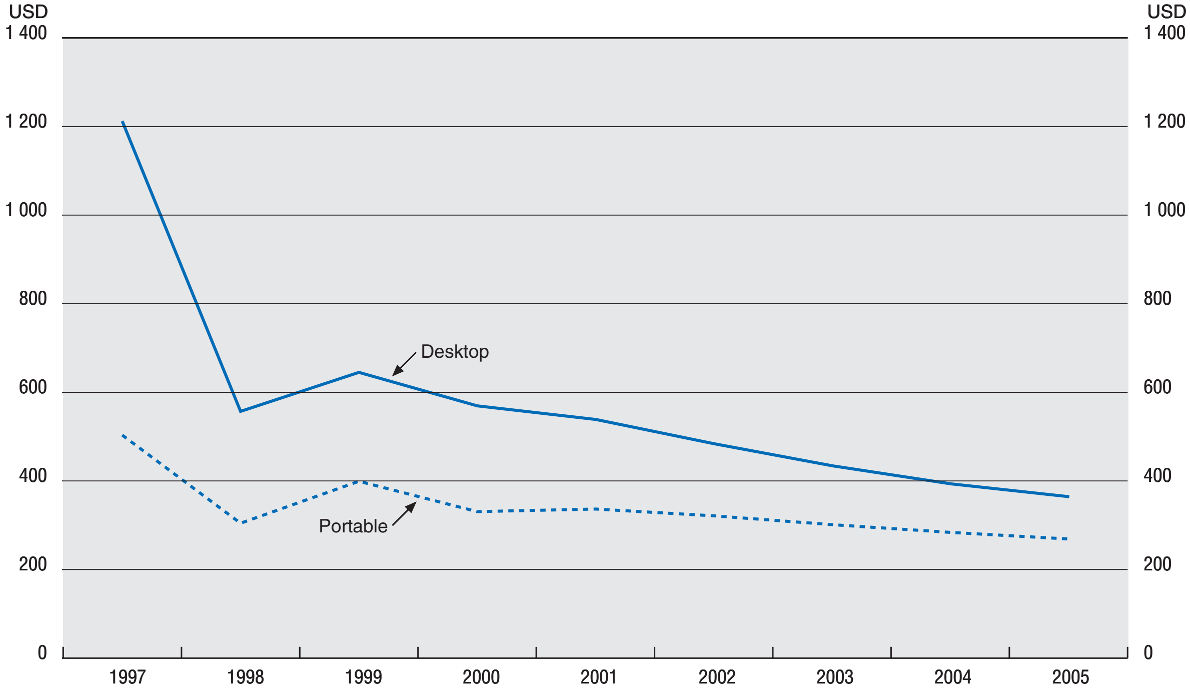
Source: Stanford Resources, Inc. 1999.

Figure 3. **Breakdown of desktop monitor LCDs by screen size, 1997-2005**



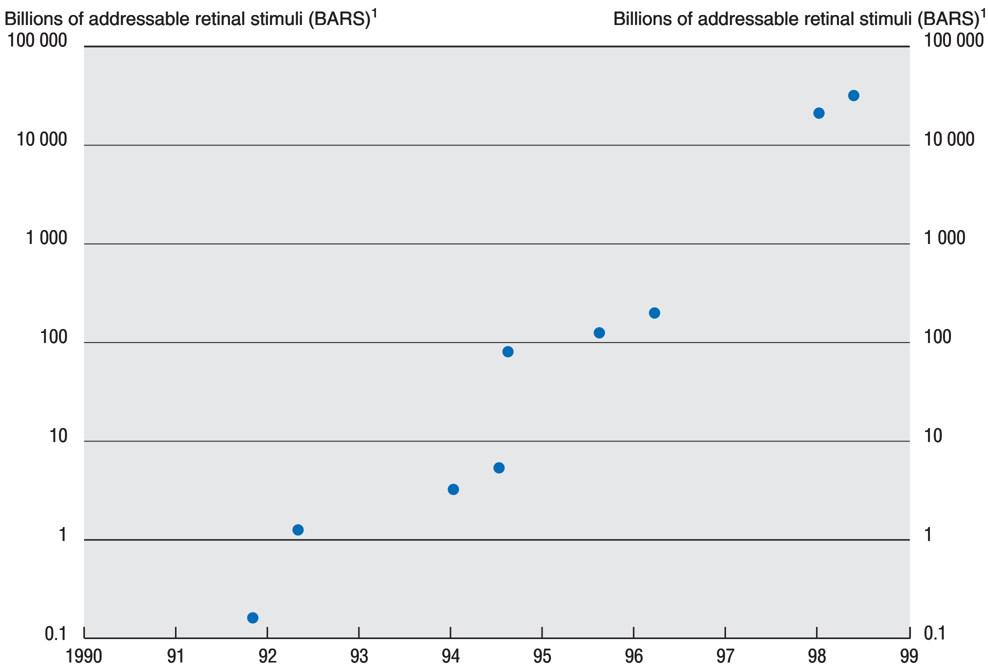
Source: Stanford Resources, Inc. 1999.

Figure 4. **Large LCD panel prices, 1997-2005**



Source: Stanford Resources, Inc. 1999.

Figure 5. **LCD information capacity, 1991-99**



1. BARS is the product of the number of pixels and the number of colours available on the display.
Source: OECD, adapted from the *IBM Journal of Research and Development,* 1998.

LCD monitors in 1997 – are being displaced by 15 inch LCDs, and moderate growth in larger sizes is expected through 2005.

Despite the move to larger LCDs (with higher numbers of pixels), which are more costly to produce, average prices in both of the key demand areas are falling. After severe price fluctuations in 1997-98, prices for large LCD panels are forecast to fall by 5% to 10% a year from 1999 to 2005 (Figure 4).

In addition to being the largest market, computer applications have driven LCDs to higher and higher levels of performance. The information capacity of LCDs improved dramatically during the 1990s. Figure 5 plots the performance of LCDs in terms of the product of the number of pixels and colours available on LCDs each year. As this number increased, so did the brightness of LCDs, while weight and power consumption decreased. Prices fell as well.

Consumer applications

Consumer applications for FPDs include televisions, VCRs, audio systems, home appliances, electronic games and toys, video, still and film cameras, clocks and watches, etc. Currently, consumer applications for FPDs are dominated by small LCDs for hand-held games and video camera displays. In 1999, LCD hand-held games represent an estimated market value of USD 817 million and camcorders USD 432 million. In both cases, the availability of light, low-energy-consumption FPDs has led to the development of a large market that would not have otherwise existed. Alphanumeric displays for appliances, audio systems and other consumer electronics products are another large portion of the consumer FPD market.

Future consumer market growth is likely to be largely due to the adoption of large plasma display panels for television systems, a market projected to reach nearly USD 4.3 billion in value in the year 2005. This is another example of the growth of an FPD market around an existing CRT market. While CRTs are expected to continue to dominate the market for TV sets for the foreseeable future, future growth of the TV market should centre on large-screen sets (screen diagonal greater than 40 inches), too large for standard CRTs and currently only available with projection systems. As PDPs can be made much thinner and have a wider viewing angle than projection systems, they are ideal for large home-TV systems. PDPs able to display some of the signals specified as high-definition television (HDTV) have been produced in sizes up to 60 inches (diagonal). While the PDP TVs currently available are priced in excess of USD 10 000, manufacturing improvements are expected to bring prices down to a level acceptable to high-income consumers within the next several years.

Business applications

Business applications for FPDs include electronic projectors and presentation displays, gaming and vending systems, cash registers and point-of-sale displays, balances and scales, copiers, fax machines and other office equipment. The largest business application is for the miniature LCDs and micro-electromechanical-based (MEMS) displays found in data and video projectors. These sophisticated displays have made possible the creation of projectors weighing as little as 5 pounds which can be connected to portable computers, enabling "road warriors" to make professional presentations away from the office or home. The value of displays sold for business projectors is projected to grow from USD 561 million in 1999 to nearly USD 1.1 billion in 2005.

The second largest application in this category is also used for presentations. Instead of portable projection systems, the conference room application has large wall-mounted PDPs, which are connected to computers and video players. The market for such displays is projected to grow from USD 230 million in 1999 to USD 720 million in 2005.

Communication applications

The communication segment is dominated by cellular telephones, but also includes pagers, telephones, transceivers and other radio equipment. This segment is valued at USD 1.6 billion in 1999 and is expected to reach USD 3 billion in 2005. The cellular telephone market first used analog technology and one-line LED displays, but with the rapid shift to digital technology, display screens have shifted to LCDs, and LEDs are fast losing ground. The market is also rapidly shifting to multi-line displays, and demand is increasing for graphic displays. In 1997, about 20% of cellular telephone displays were graphic, jumping to 29% in 1998. By 2000, more than 50% of displays are expected to be graphic LCDs.

Transportation and industrial applications

Transportation and industrial applications include automobile displays, aircraft and marine instruments, passenger entertainment systems, medical instruments, test and analytical equipment and other industrial systems. Automotive displays account for approximately half of the value of displays in this category; displays for these applications are valued at USD 1.7 billion in 1999 and are projected to reach USD 2.3 billion in 2005.

Throughout the 1990s, VFDs and passive matrix LCDs have had many uses in automobiles. The greater complexity of the information available (navigation data, maps, Internet access, etc.) has driven the need for displays with higher performance. However, the widespread adoption of active matrix LCDs has been limited because of high prices and performance problems related to temperature and environmental requirements. The concept of rear-seat passenger entertainment systems is just being introduced. With world sales of more than 50 million motor vehicles a year, the potential is large, but because of costs and other factors, these products are likely to remain luxury items for some time.

In 1991, the first widely used in-car navigation system was introduced. Early in-car navigation systems had many problems, including inaccuracy and the inability to operate in certain places. Improvements in global positioning system (GPS) sensors and map-matching technology improved their accuracy and greater demand for automobile navigation systems has recently increased the demand for active matrix LCDs. This application has been very successful in Japan owing to the difficulty of navigating in Japanese cities and has also gained momentum in Europe, but the North American market has been very slow to accept automobile navigation systems. Japanese and European automobile manufacturers are now integrating navigation systems into their American-made automobiles.

Creating new applications

Continued growth in the FPD industry requires developing new sources of demand for high-value displays. The first FPD markets in the 1970s were for watch and calculator displays. Pocket TVs were developed in the 1980s and demand for notebook computers attracted huge investments in the 1990s. These markets are all flat or growth is slowing. The focus for the post-2000 period is desktop monitors, but the high cost of large LCDs compared to CRTs is restraining growth. Many ideas for new applications focus on new forms of home entertainment and on the ability of miniature displays to allow instantaneous and ubiquitous access to information.

HDTV

The television (TV) market has always been dominated by the CRT. Many FPD manufacturers hope to displace some (and eventually all) of the CRTs in the millions of TV sets sold each year. While LCDs, and to a greater extent PDPs, will increasingly be used in conventional TV sets, the high price of large FPDs limits the penetration of FPDs into the TV market. Manufacturers hope that the growth of high-cost advanced TV services will better support the costs of FPDs.

The concept of advanced TV was initiated by consumer electronics manufacturers as a way of increasing interest in and support for costly consumer electronics devices. The goal of the television broadcasting industry has been first to secure valuable electromagnetic spectrum, and second to maximise advertising revenue from that spectrum. The easiest way to maximise advertising revenues is to increase the number of programming channels. However, given a fixed allocation of spectrum, the ability to broadcast high-definition signals is limited.

Digital broadcasting began with direct satellite broadcasting in the early 1990s, and has attained 10% penetration into US households. In other regions, it is increasing rapidly, although from a small base. Satellite broadcasts in Europe and the United States make very good use of digital broadcasting. While the high quality of the digital signal is clearly an attractive characteristic of satellite service, it is less important than the capacity to deliver 150-200 channels with many options for pay-per-view and special interest channels. This is what provides the revenue base that makes the satellite system work. The fact that the picture quality is noticeably better than a typical analog cable picture has not been a strong selling point and cable TV companies have responded by offering what they call "digital cable TV".

High-definition TV demands a large screen display. As originally conceived, HDTV was predicated on the use of a 40-inch diagonal screen, thus eliminating direct-view CRTs, the largest of which today have a 36-inch viewable diagonal. One of the most pervasive misunderstandings regarding HDTV is the notion that only flat panel displays can deliver HDTV quality. The reality is that most HDTV-capable sets use either CRTs in direct-view format or projection CRTs. Rear projection TVs with three CRTs are very effective for screen sizes of 40 to 80 inches. Plasma displays are available now in the 42- to 50-inch range, but production models are only at the minimum HDTV standard, although steady improvements are being made. Experience with the first plasma displays shows that 42 inches is the entry level screen size and even 50 inches is marginally acceptable, at least in the US market. Direct-view CRTs will clearly be limited to the under 40-inch size range by the properties of the tubes themselves. Eventually, very large plasma displays (more than 55 inches) will be available and affordable for the TV market.

Microdisplay applications

Microdisplays have finally made the concept of hand-held or head-mounted "personal viewers" a reality. From the perspective of new market development, these applications face little competition from other display technologies. Potential new markets for microdisplays include cellular phones, pagers, digital cameras, desktop monitors, hand-held games, headsets and medical instruments. However, users' reaction to such displays is uncertain, owing to the novelty of the format.

Personal viewer applications have been developing for some time; there have been many false starts, particularly for headsets. With the increasing demand for hands-free access to information in medical and industrial settings, these applications may finally be poised to enter a phase of strong growth. Other information-intensive products provide the opportunity for microdisplay developers to displace existing display technologies in large, fast-growing markets.

Display headsets could be used in a wide variety of applications, including computer monitors, televisions and DVD players. This market represents approximately 50 000 units in 1999. Of particular interest in the market's early stages are monitors for display of video and other data for surgeons and technicians, as medical and industrial customers are more willing to pay for hands-free operation than customers in the much larger consumer and computer markets. The minimum pixel format required for such applications is generally 640 x 480.

Along with the rapid worldwide growth in mobile communications devices, demand for higher pixel count displays is increasing. In anticipation of higher bandwidth wireless communications systems, manufacturers of mobile communications devices are integrating e-mail and Internet access capabilities and creating demand for microdisplays with 800 x 600 and higher pixel formats. Graphic displays for these markets total approximately 54 million units in 1999. Aggressive pricing is extremely important in these applications, as the users' hardware costs approach zero.

Another established but rapidly growing application market is hand-held computers, or personal digital assistants, which use proprietary operating systems or Windows CE. The 1999 market for colour displays in these applications, currently met by STN- and TFT-LCDs, is about 1.5 million units. A great deal of effort is being put into low-power, reflective, colour TFT-LCDs, and low-temperature polysilicon TFT-LCDs are also in development for these applications. Given the demanding colour and resolution requirements of these devices, pricing is somewhat more relaxed than for consumer devices.

Head-mounted displays (HMDs) have attracted a lot of attention as the concept of virtual reality has evolved. Two displays are needed to display a stereoscopic image generated by a fast computer. HMDs are used to display medium resolution images for belt-mounted, voice-activated computers in maintenance applications. Head-mounted display companies are currently targeting three application segments: home entertainment, PC gaming and virtual reality. PC gaming, which uses HMDs in the USD 250-350 price range, is expected to have the largest market segment. Manufacturers' profit margin on each display will be very small, owing both to the manufacturing price and to competition. Home entertainment and virtual reality HMDs will be in the USD 600-8 000 range, depending on the overall design of the system. One manufacturer is working on an HMD with twelve 0.7-inch colour TFT-LCDs that will fully immerse the user in a virtual environment.

The HMD market is still in its early stages and the future is very uncertain. Several key safety issues must be resolved before this market can increase further. Some dozen head-mounted displays plug synchronised sensory input into a user's ears and eyes, but overuse, misuse or poorly engineered products can cause problems, ranging from nausea and eyestrain to other medical problems.

A new opportunity may present itself in the future for using an HMD to facilitate the work of a technician probing a circuit on a bench in an instrumentation test. Technicians are continually challenged by the need to probe the circuit card carefully with one hand, while adjusting the scope settings with the other and simultaneously turning to see the scope somewhere on the bench. The probe often slips, and it is bothersome to shift constantly from the card to the scope and refocus the eyes. An HMD would alleviate this problem. The display would be a peripheral device that plugs into a VGA video display port, now common on many bench instruments. The technician would put this lightweight system (weighing slightly more than a set of stereo headphones) through a visor, dropping a small display in front of his eye. The system would work in a look-around mode. While this would not eliminate the need for the display on the instrument (several people often have to view a trace simultaneously), it could have significant potential in the industry if sold as an instrument peripheral.

FPDs are predominantly intermediate goods. As such, they are constantly at the mercy of the growth and price trends of the final products in which they are embedded. The history of the industry has been one in which new technologies are first adopted in simple applications with low information content and are then, through better performance and lower prices, adopted in more and more uses and in applications with more information content. The use of active matrix LCDs in computer screens is in a sense the end-point of this process; no other applications demand such high performance and ship in the tens of millions of units a year. The TV market is larger, but at present is driven by low-cost, medium-performance CRTs, because the information content is significantly lower than in computer displays.

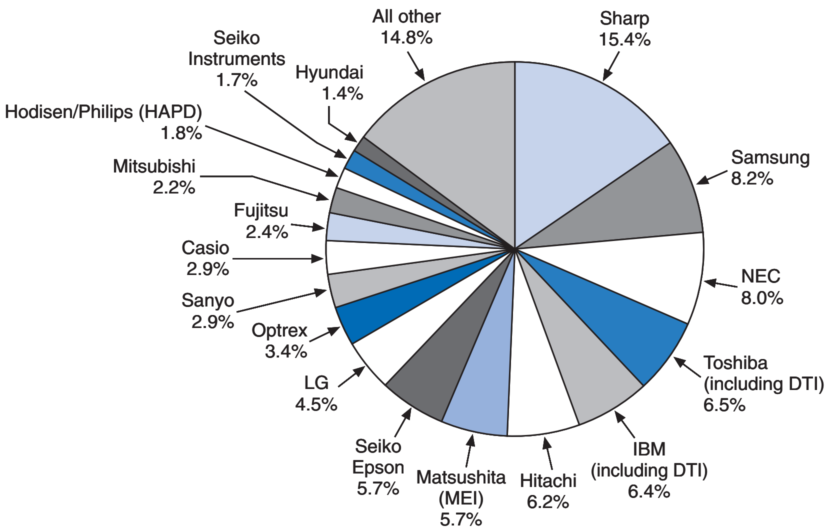
Growth in the existing computer and TV markets is, in one sense, the best hope for growth in FPD markets. However, in the FPD industry itself, the creation of new products that would not be conceivable without FPDs could also lead to significant growth. Products such as hand-held calculators, pocket televisions, flip-up video camera viewfinders, and notebook and hand-held computers embody this trend. New applications, mostly related to utilising the ubiquitous wired and wireless access to computer networks, e-mail and the Internet, will likely encourage it. Devices that fuse the capabilities of mobile phones and personal digital assistants, electronic books and wearable computers will all rely on lightweight, low-energy, high-information-content FPDs.

Industry analysis

Industry structure

When one looks at the largest part of the FPD industry, the production of passive and active matrix LCDs, it is clear that the industry is not very concentrated, although production is localised in Asia. In terms of value, Sharp was the only producer with more than 10% of the market in 1998; it competes with seven producers with 5%-10% market share and another six with 2%-5%. In 1998, production of plasma displays was much more concentrated, with 90% of production accounted for by five firms; however, this market is in the nascent stage, and production is likely to be shared by ten or more firms as the market grows. In other FPD markets, light-emitting diode production is not concentrated, and while electroluminescent and vacuum fluorescent displays are both led by a producer with more than 50% of the market, there are substitute display technologies for each (Figure 6).

Figure 6. **Worldwide LCD market shares (value) by firm, 1998**



Source: Stanford Resources, Inc. 1999.

Regional production trends

Over the past decade, the FPD industry has been dominated by large, vertically integrated electronics conglomerates. Japanese companies created the LCD manufacturing industry as it is now known, having developed and led FPD production for three generations of LCD manufacturing. Sharp has been a leader in LCD production for 25 years; as of 1998, it was still the largest producer, with over 15% market share in both active and passive types. NEC followed Sharp in active matrix LCD production with just over 12% of the market; in passive matrix LCDs, Seiko Epson and Optrex follow Sharp with 10% or more each.

Other LCD producers include conglomerates such as Hitachi, Matsushita, Fujitsu and Mitsubishi, as well as smaller firms such as Casio and Sanyo. However, there have been two joint ventures involving Japanese companies. Toshiba is allied with IBM (Japan) in a venture called Display Technologies Inc. (DTI). Since the partners split the production output evenly and DTI does not sell to any other firm, the firm's output is typically assigned to IBM and Toshiba; taken as a whole, DTI was the largest active matrix LCD producer in 1998. In another alliance, Philips (Netherlands) has taken majority control of Hosiden, a small active matrix LCD producer.

As of 1998, nearly 80% of active matrix LCDs were produced in Japan (including the joint venture operations noted above). Japanese companies accounted for nearly 70% of passive matrix LCD production, but some took place in Japanese-owned factories in China and Southeast Asia. However, these numbers will likely fall over the next few years; fierce competition from Korea, negative profits and macroeconomic conditions have resulted in a halt in investments in new LCD production capacity in Japan.

In Korea, a similar industry structure has evolved over the past few years, with Samsung and LG emerging as fierce competitors of the Japanese leaders. These two companies, along with Hyundai, accounted for nearly 20% of active matrix LCD production in 1998. Within a few short years of commencing production, Samsung has become one of the largest producers of active matrix LCDs large enough for notebook computers and desktop monitors, surpassing Hitachi, IBM and Toshiba in 1998 and was overtaking NEC and Sharp in 1999. LG sold half of its LCD division to Philips in 1999.

Companies in Chinese Taipei have produced small amounts of passive matrix LCDs and small active matrix LCDs, but until 1999 did not produce any high-value LCDs for computer displays. In 1999 and 2000, six new active matrix LCD plants are to begin operations. Unlike the competition between Japanese and Korean LCD manufacturers, these plants embody a new type of formal co-operation with Japanese LCD manufacturers. The alliances announced to date are Mitsubishi-Chungwha, IBM (Japan)-Acer, Matsushita-Unipac, Sharp-Quanta, Fujitsu-Chi Mei, and Toshiba-HannStar. In general, these alliances involve the supply of technology (typically in the form of engineers) from the Japanese firms, and the technology is then implemented in factories owned and staffed by the Taiwanese companies. Prime View is also building TFT-LCD production facilities, but without the use of formal partnerships with existing manufacturers.

Production of passive matrix LCDs and other simple displays takes place in other countries in Asia, including China (primarily in Hong Kong), Malaysia, Singapore and Thailand. There is very little production of FPDs in Europe or the United States.

Industry trends

The aggressive entry of Korean suppliers into this market had a powerful impact on panel pricing, with prices of active matrix LCDs for computers falling 50% or more from the end of 1997 to the end of 1998. The dramatic price reductions of 1998 were a result of lower-than-expected notebook computer demand, higher production levels, and increased inventories of 12.1-inch TFT-LCD panels. While manufacturing costs determine the minimum price at which LCD panels are sold, the oversupply forced many panel suppliers to sell below cost.

Supply and demand balanced out by the end of 1998, resulting in price stabilisation. On the supply side, LCD suppliers delayed investing in next-generation plants because of oversupply and the Asian economic crisis. On the demand side, the LCD monitor market emerged as a viable market fuelled by very low panel costs. The notebook computer market also bounced back from disappointing growth in the first half of 1998. These trends created a tight supply situation in 1999, leading to rare increases in prices.

However, the LCD industry is subject to cyclical supply and demand trends, and the seeds have been sown for the next round of price decreases. The supply situation is expected to improve in the second half of 1999, with increased production from Korea and product introductions from Chinese Taipei. Increased panel prices and preoccupation with the Y2K problem should affect demand negatively in the second half. By the last quarter 1999, supply and demand should balance out again and the end of the year may see price reductions. Prices are expected to fall in the first half of 2000, but the industry may again face oversupply.

The price declines resulting from the increased competition of the past few years have led several companies to the brink of exiting the market, and no TFT-LCD operation was profitable in 1998. This is due to the commodity characteristics of the TFT-LCD market. Many producers offer like products mostly for one application – notebook computers. While LCD manufacturers are hopeful that the desktop monitor market will rapidly adopt LCDs, TFT-LCD desktop monitors still accounted for less than 5% of the total FPD market in 1998, as opposed to 36% for TFT-LCD portable computers. Compounding the problem for LCD manufacturers is that they sell to an industry dominated by a few powerful buyers, such as Dell and Compaq.

FPD ***production in the*** **United States** ***and*** **Europe**

Companies that have invested in factories to make TFT-LCDs have not followed the traditional analytical approach often taken by firms in Europe and the United States. This is why there are no major TFT-LCD plants outside Japan and Korea. Western analysts could not justify the tremendous sums required to build TFT-LCD factories, given the uncertainty of the technology. While American and European companies were busy doing the analysis – and concluding that it was not an attractive investment – Japanese and Korean companies were busy building factories and making the technology work.

Several firms in the United States and Europe took an alternative path, building display companies around contracts from government agencies (most notably US military branches). Government support was driven by military needs as well as a sense that FPDs are a "critical" technology, *i.e.* one that an advanced industrialised nation must have the capability to produce, lest it fall behind in high-technology competition. These views were somewhat based on misunderstandings regarding the level of competition in the FPD industry and the fact that, while FPDs are very sophisticated and important devices for computers and consumer electronics, the forces in these industries lead towards the commoditisation of most components.

The tie between government funding and private business plans reached a peak in 1994 with the US National Flat Panel Display Initiative, although EU programmes such as Esprit had long been active. However, there are tremendous difficulties in building an FPD business around niche markets, where the requirements are stringent compared to high-volume applications. In addition, for military programmes, volumes are very low, spread out over years, and often subject to political changes.

In North America over the past years, the business model of making specialised displays exclusively for military and industrial markets has died through attrition. dpiX (partly spun off from Xerox), OIS, Litton Systems (Canada) and ImageQuest have all gone out of business or abandoned the military display market they originally set out to supply. Most of these companies received development contracts from the Department of Defense (DoD). Five years after the initiation of the National Flat Panel Display Initiative, there is no doubt that DoD will have to live with "ruggedised" versions of commercially produced displays, something it has been doing for years anyway.

Two companies in the United States can be characterised as major display producers. Planar Systems has evolved from a technology-focused developer of electroluminescent (EL) displays to a full-service supplier of display systems of all types, with production in the United States and Finland. Last year, Planar acquired passive matrix LCD producer Standish Industries; more recently, it had agreements with OIS and dpiX to supply the TFT-LCD panels which Planar was integrating into military displays. The other major producer is Three-Five Systems, which has shifted its approach from passive matrix LCDs for cellular phone manufacturers to a broader portfolio of advanced addressing technologies to compete with TFT-LCDs and LEDs, as well as development of microdisplays. In Europe, the strongest presence in displays is accounted for by the industrial conglomerates Philips, Thomson and Siemens.

Microdisplays and organic light-emitting diode displays are now the source of most of the new display activity in the United States and Europe. What is interesting about the microdisplay activities is that they are largely being carried out by start-up firms, some of which either have no plans to do their own manufacturing or plan to contract out parts of the manufacturing. Liquid-crystal-on-silicon (LCOS) technology is one of the most heavily investigated to date; companies such as Colorado Microdisplay, Displaytech, Microdisplay, Inviso and Spatialight, as well as MicroPix in the United Kingdom, have come into existence to develop microdisplays using liquid crystal layers on silicon in a reflective configuration. Kopin has developed a process for producing transmissive LCD microdisplays in which silicon substrates are used to develop the active matrix (produced by Unipac of Taiwan) which is then transferred to glass sheets.

Most types of emissive displays are being investigated for microdisplay configurations as well. Planar has shown active matrix EL devices in miniature packages, as has Micron with FEDs. Microvision and Reflection Technology are developing scanned LED microdisplays. FED Corp., having moved away from FED technology, has licensed patents from Kodak, a key developer of OLED technology. Finally, Display Research Laboratories has demonstrated a microdisplay using an active matrix vacuum fluorescent display.

The key feature of most microdisplays is that they are fabricated on silicon (or quartz) substrates, rather than on glass as in the production of direct-view flat panel displays. This feature has led to production arrangements that are a departure from those typically seen in the display industry. Rather than new investments in production that use increasingly large glass substrates, microdisplays can be fabricated on existing semiconductor equipment, leading to the possibility of flexible arrangements between display developers and semiconductor firms. The exception to this trend is the large investment that Texas

Instruments (TI) made in developing its digital micromirror device (DMD) technology and producing DMD chips.

Currently, semiconductor firms such as National Semiconductor and UMC/Unipac are developing the silicon backplanes for microdisplay developers; Hewlett-Packard is also bringing its processor development expertise to a partnership with Displaytech. Microdisplay backplanes do not require the most advanced semiconductor fabrication techniques and equipment, and the volume of microdisplays will be minuscule compared to memory, microprocessors and ASICs. Microdisplay developers will thus be able to contract out for their silicon requirements and concentrate on design and cell assembly (which is also outsourced in some cases). Thus, this leads to the possibility of FPD companies which do not themselves engage in production.

OLEDs represent another opportunity for entry into the FPD market. A variety of companies and research groups have shown interest in OLEDs, including Eastman Kodak, Du Pont, Dow Chemical, Seiko Epson, Pioneer Electronic, Philips, Siemens and Hoechst. Many of the leading display manufacturers in Japan and Korea are actively researching OLED technology. As with microdisplays, several start-ups in the United States and Europe have built their business plans around this new technology, including Cambridge Display Technology and Opsys in the United Kingdom and Uniax and Universal Display Corp. in the United States.

Conclusion

Increasing demand for constant, ubiquitous access to information networks and graphical interfacing with information have made FPDs a crucial part of information access. At the same time, FPDs have made it possible to access information in ways not imagined a decade ago. Even for devices not connected to some sort of information network, the growing use of embedded microprocessors in systems ranging from cameras to home appliances to automobiles has increased the importance of FPDs.

It is important to consider, however, that while FPDs indeed allow manufacturers to build higher and higher levels of functionality into products (as measured by information content, portability, ease of use, etc.), FPDs are not, in and of themselves, increasing access to information around the world. Education, standards setting, competition policies and infrastructure investments ultimately determine the level of access in societies. FPDs merely allow for embodying sophisticated forms of access to and interaction with information. To the extent that ubiquitous access causes difficulties, in terms of ability to be detached from work or other concerns, and that such access creates concerns about the ability to keep personal and other confidential information private, FPDs could exacerbate social concerns regarding access to information.

This is a different view of the importance of FPD technology than what was common in advanced industrialised nations in the early 1990s. At that time, the prevailing concern was that a nation's companies and military would be hindered from developing profitable products and mission-critical systems if that nation did not possess the capability to develop and produce state-of-the-art FPDs. Technological and industry developments over the past few years have resulted in a wide array of sources for high-performance displays with significant (if uneven) price declines. Indeed, in 1998, the crucial question was whether LCD producers could remain in business given record low prices. In 1999, prices increased, but the long-term trend is lower prices for larger and higher-quality FPDs.

The definition of standards is largely carried out within the display, computer and consumer electronics industries. However, in areas such as digital television, some standards setting will require increasing co-ordination among governmental and international bodies. Difficulties in agreeing on a single standard for HDTV broadcasts in the United States is an example of the impact of poor co-ordination on the development of new markets. Similar, though less constricting, problems have affected the growth of digital FPDs as replacements for analog CRTs in desktop computer monitors, and the development of a digital computer monitor standard has not gone smoothly. This is an area that requires the attention of all interested parties in industry and government.

Annex 1

STATISTICAL PROFILES*

National information technology policy profiles are available at the following URL:
<http://www.oecd.org/dsti/sti/it/prod/it-out2000-e.htm>

* For sources, notes and methodology, see the corresponding section in Annex 2.

Australia

Australia's ICT sector is mainly oriented toward services, as manufacturing ICT accounted for only 11% of total ICT sector revenue in 1995-96. Telecommunication services predominated, followed by wholesale trade with 42% and 28%, respectively (Figure 1).

In 1995-96, the ICT sector accounted for around 3% of GDP and 2.4% of employment, the latter having increased from 1.8% in 1992-93. In 1996-97, ICT industries accounted for around one-quarter of Australia's total business enterprise R&D expenditures. ICT services industries accounted for more than 60% of ICT R&D, a third of which concerned computer services (Figure 2).

Employment in ICT industries grew rapidly in the first half of the 1990s (CAGR of 13% between 1993-94 and 1995-96), especially in the computer wholesale sector, owing to the shift of the ICT market from big businesses to more widely dispersed ones, and in the computer services sector. Despite a CAGR of 10%, the manufacturing sector accounted for less than one-third of ICT employment in 1995-96 (Figure 3).

IT occupations have increased their relative share in all industries, except for a slight decline up to the mid-1990s for electric and electronic engineers. In addition, IT occupations have grown faster in IT industries than in total industries, again with the exception of electric and electronic engineers. This may reflect a trend towards outsourcing IT activities to specialised IT companies or towards vertical disintegration as a mode of entry into the computer services industry (Figure 4).

Since 1990, the ICT trade balance has consistently been negative. This is mainly due to a trade deficit in ICT equipment (goods), which was amplified by the Asian crisis between 1996 and 1998. The decline in ICT exports to East Asian economies was compensated by exports to other destinations, and ICT equipment imports from some Asian countries, particularly China, Malaysia and Chinese Taipei, were marked by a strong increase. The information services trade balance has been positive, and software and communication services only very slightly negative (Figure 5).

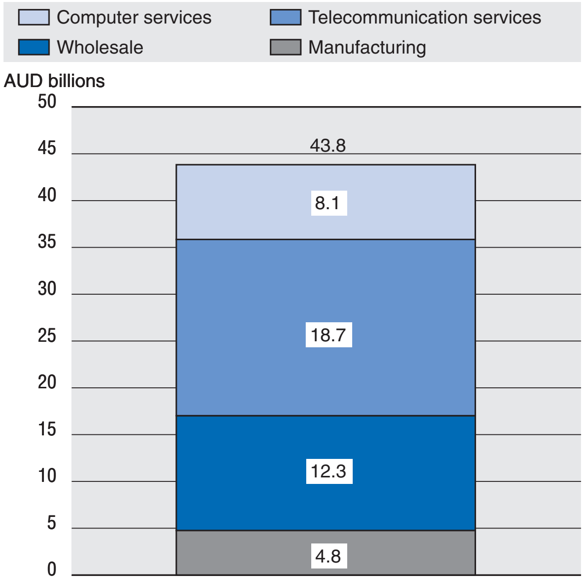
Various ICT goods and services are rapidly penetrating the home (Figure 6). In May 1999, almost one household in two had a home computer, against around one in four in 1994. Among households with a home computer, nearly one in two could access the Internet, against only one in three a year earlier. Moreover, 40% of households with a home computer but without home Internet access intended to acquire home Internet access in the following 12 months. As a share of all households, more than one in five had Internet access from home in May 1999.

Outside the home, the Internet is becoming increasingly pervasive, as more than 40% of the adult population accessed it from one site or another in the 12 months to May 1999, against only 26% a year earlier. Businesses accounted for only 31% of the income of Australian Internet service providers in June 1997, households for 61%, and government for 6%.

In June 1998, 64% of businesses used computers, against 49% in June 1994. However, computer usage depended on firm size, as all large businesses used computers but only 55% of microenterprises. The mining sector makes the most intensive use of computers, followed by services industries such as business services, wholesale, finance and insurance and communication. Cultural and recreational services are the only sector for which the rate decreased between 1994 and 1998.

In June 1998, the rate of Internet access for businesses was 30% on average against 24% a year earlier but still depended on business size. Property and business services and communication services were among the most connected, while accommodation, cafes and restaurants and retail trade sectors were among the least (Figures 7 and 8). In June 1997, 5% of firms were doing business via a Web site/home page, but the Internet was mainly used for e-mail (20%) and information gathering (18%). In June 1998, 3% of businesses used the Internet for selling goods or services and 6% for purchasing them (against 1% for both a year earlier). Large and medium-sized businesses have shown particularly strong growth between 1997 and 1998, with 12% of medium-sized businesses and 13% of large businesses selling over the Internet, and 15% and 16%, respectively, using it for purchasing.

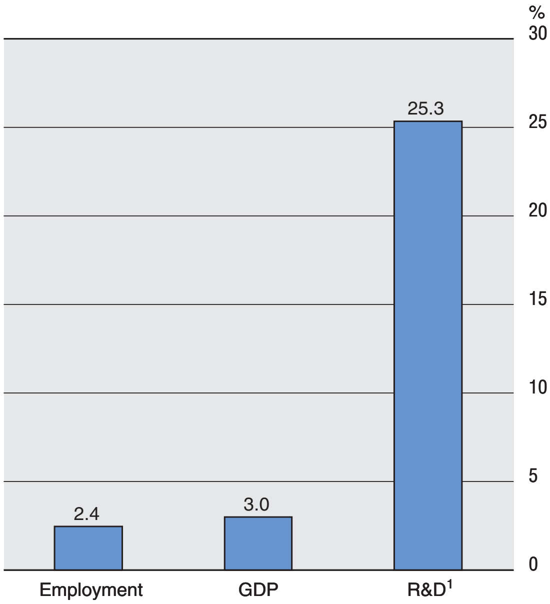
Figure 1. **ICT[1] revenue,1995-96**



1. ICT excludes information content industries and business equipment wholesale.

Source: ABS, *Information Technology 1995-96*, Cat.N. 8126.0, December 1997.

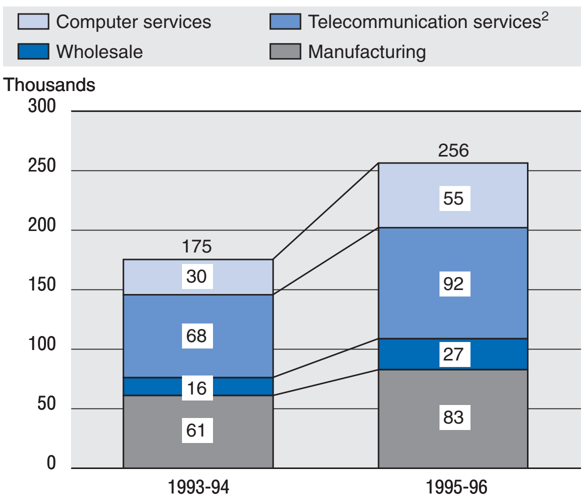
Figure 2. **Share of the ICT sector in employment, GDP and R&D, 1995-96**



1. 1997-98 instead of 1995-96. ICT R&D as a percentage of total BERD.

Source: OECD estimates; ABS.

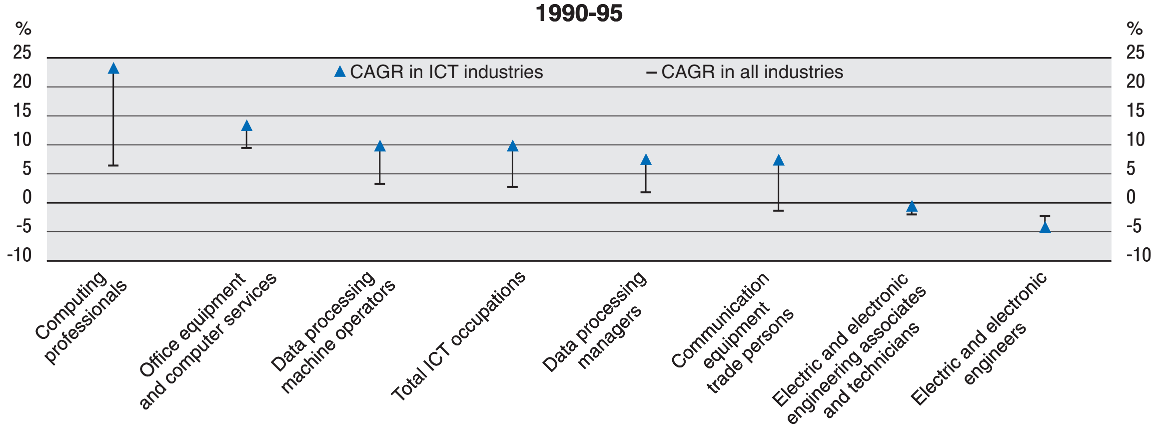
Figure 3. **ICT[1] employment by industry, 1993-94 and 1995-96**



1. See Figure 1, note 1.
2. 1993-95 data calculated from the Telstra *Employment Equal Opportunity Report* estimates of full-time equivalent employees.

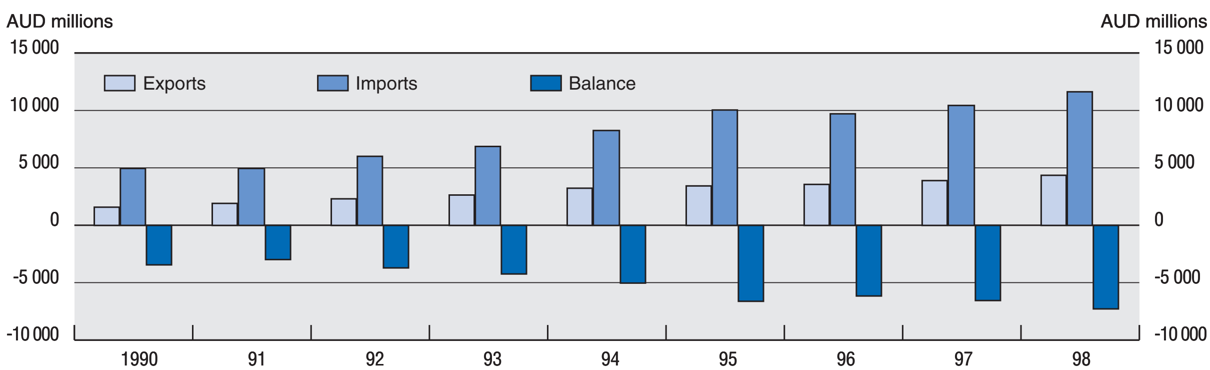
Source: Based on data extracted from John Houghton, *Information Industries Update 1999*, Table 3.1, Centre for Strategic Economic Studies, Victoria University, Australia.

Figure 4. **Employment growth by selected ICT occupations in ICT industries and all industries, 1990-95**



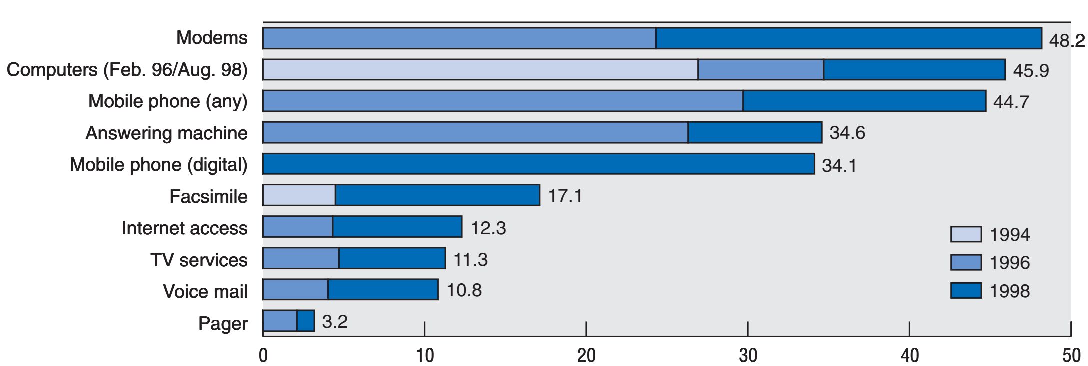
Source: Based on unpublished ABS data; J. Houghton, M. Pucar and C. Knox, *Mapping the Information Industries*, July 1996.

Figure 5. **ICT manufacturing and services trade,[1] 1990-98**



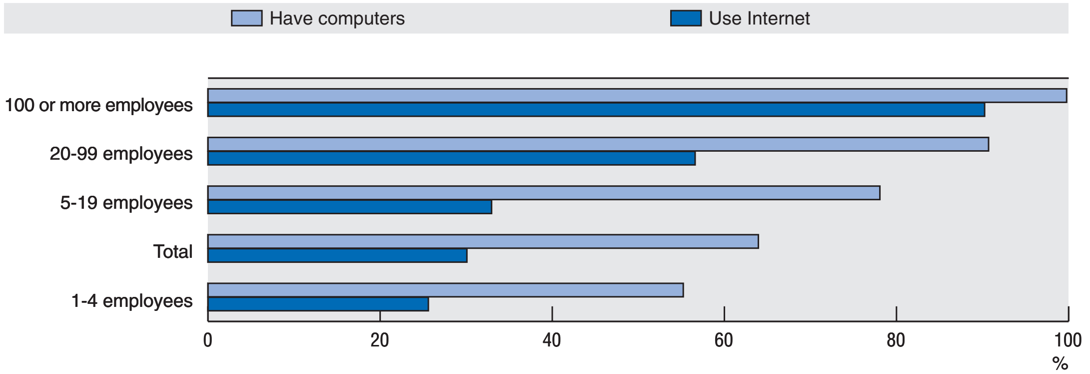
1. All data are current value. 1990-91 services estimated. Services data relate to financial year, while goods data relate to calendar year.
Source: John Houghton, *Information Technology Trade Update 1999*, Centre for Strategic Economic Studies, Victoria University, Australia.

Figure 6. **Households equipped with selected ICT equipment, 1994/96-1998**
Percentages



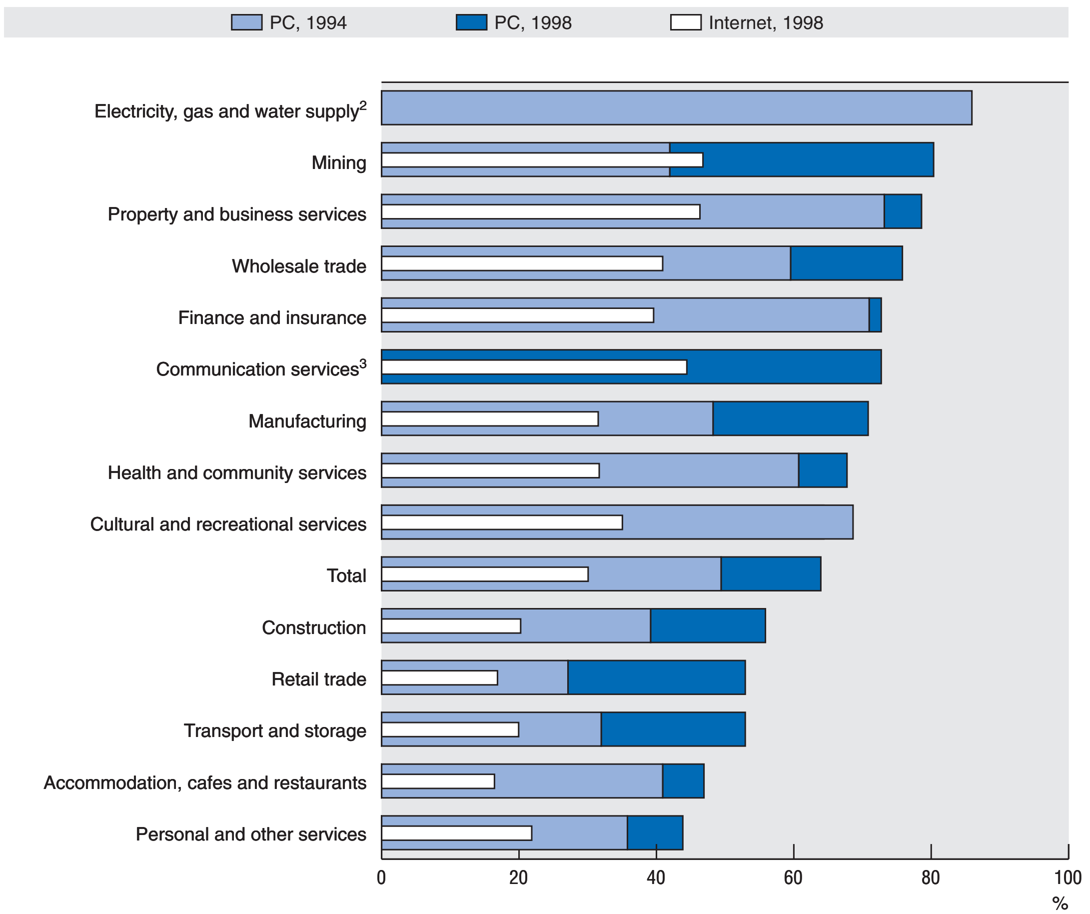
Source: ABS, *Household Use of Information Technology*, Cat.N. 8146.0, May 1999.

Figure 7. **Business use of computers and the Internet by size, 1998**



Source: ABS, *Business Use of Information Technology*, Cat.N. 8129.0, May 1997 and Cat.N. 8133.0, April 1999.

Figure 8. **Business use of computers and the Internet by sector, 1994 and 1998**[1]



1. As of end of June of each year.
2. Not available for 1998.
3. Includes telecommunication services and postal and courier services in 1998.

Source: ABS, *Business Use of Information Technology*, Cat.N. 8129.0, May 1997 and Cat.N. 8133.0, April 1999.

Canada

The ICT sector is of continuing and growing importance to the Canadian economy and represents a major share of investment. ICT's contribution to growth of GDP has clearly outweighed its share in GDP (Figure 1).

Despite the ICT sector's significant share in investment and GDP, its share of employment is lower, although it is growing and now accounts for 3.5% of total employment (Figure 2). Employment growth in the ICT sector between 1990 and 1997 is mainly due to software and computer services and to a lesser extent to ICT wholesaling. On the other hand, telecommunications services lost around 20% of their personnel over the period, and employment in ICT manufacturing has dropped slightly. As Canadian service industries have restructured and grown dramatically, the software and computer services segment has grown and accounted for more than one-third of ICT employment in 1997, against less than one-quarter in 1990 (Figure 3). Employment in this segment reached 1.5% of total Canadian employment in 1998.

The share of R&D in the ICT sector has also been increasing and now accounts for over 40% of total Canadian industrial R&D. This suggests that not only is the sector a major driver of investment but that Canadian technological performance more generally is underpinned by R&D in the ICT sector (Figure 2).

Canada's ICT trade has consistently been negative, although the trade deficit in ICT goods and services has tended to flatten out (Figure 4). International trade is more favourable in ICT services than in goods; it consistently shows a surplus, whereas trade in ICT goods consistently shows a large deficit.

Use of ICT is high in industry, education and households. Use of the Internet is relatively high; this may be partly due to rapid provision and uptake in schools and libraries. Diffusion rates have been very high, and as of 30 March 1999, every Canadian public school, First Nations School and public library wishing to be connected through Industry Canada's SchoolNet partnership was brought on line (Figure 5).

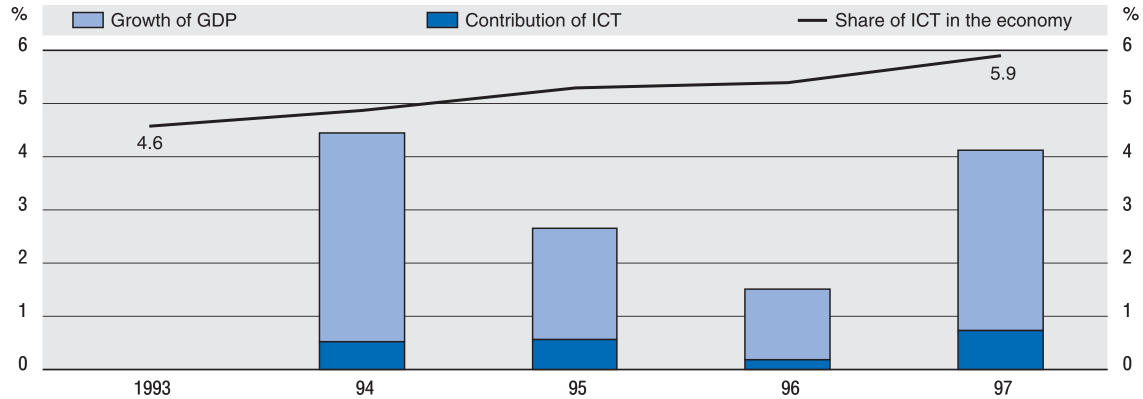
Similarly, the diffusion of various forms of electronic interchange has been high in industry. Service industries, where the use of PCs is widespread, are to some extent leading the way, followed by wireless communications technologies. Internet use was high already in 1996, suggesting that the ease of use and open system characteristics of the Internet had already begun to complement and possibly supplant dedicated proprietary EDI (Figure 6).

Firms in the manufacturing industry have adopted the Internet as an advanced technology which is a key component of innovation, technological development and competitiveness. The Internet was widely used in 1998, with 57% of manufacturing establishments reporting that their firm had a home page. More than two-thirds of manufacturing establishments use e-mail and the Internet. More than one-third sell or purchase goods and services over the Internet (Figure 7). Internet use is also growing rapidly among Canadian SMEs. In the first half of 1999, 61% of business owners were connected to the Internet – almost quadruple the number three years previously: 15% at the beginning of 1996. Almost 88% of business owners employing between 100 and 499 employees are hooked up and among the smallest firms, those employing fewer than five people, Internet use has moved past the 50% mark for the first time.

ICT diffusion in the home reflects the standard pattern of diffusion of established and emerging technologies. TVs, radios and telephones are now ubiquitous. VCRs, tape recorders, cable services and CD players are becoming so. Use of computers, modems, the Internet and new consumer durables is progressing (Figure 8). Canadian households are rapidly becoming connected. In 1998, 35.9% (or 4.3 million households) of Canadian households were regular users of computer communication from some location or another, up sharply from 29.4% a year earlier. It is worth noting that among the regular home users, the purposes for which computer communications are used are quite varied, although e-mail and general browsing are clearly the most popular online activities (Figure 9).

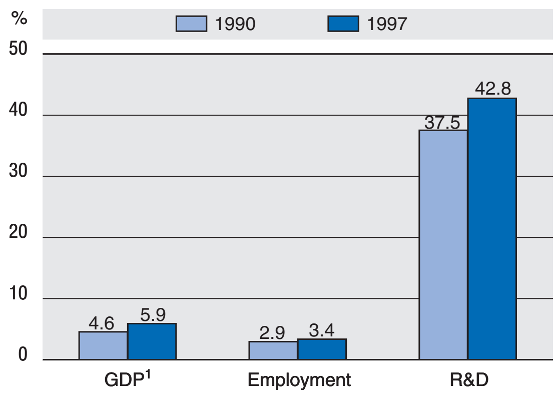
Figure 1. **Contribution of the ICT sector to GDP, 1994-97**

1992 constant CAD



Source: Statistics Canada.

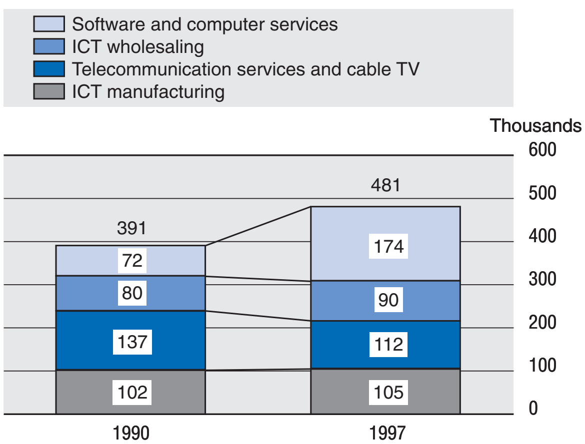
Figure 2. **Share of the ICT sector in GDP, employment and Canadian industrial R&D, 1990 and 1997**



1. 1993 instead of 1990.

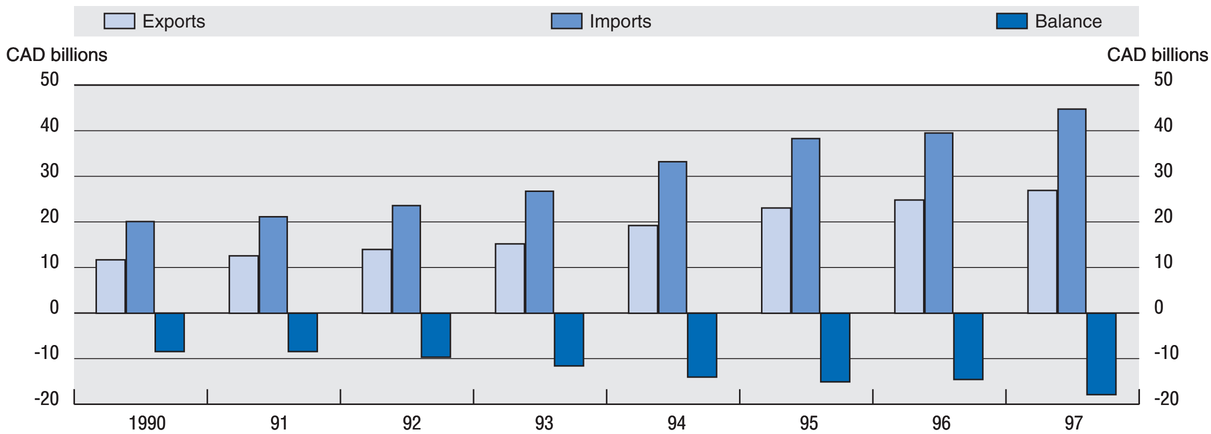
Source: Statistics Canada and OECD.

Figure 3. **ICT employment by industry, 1990 and 1997**



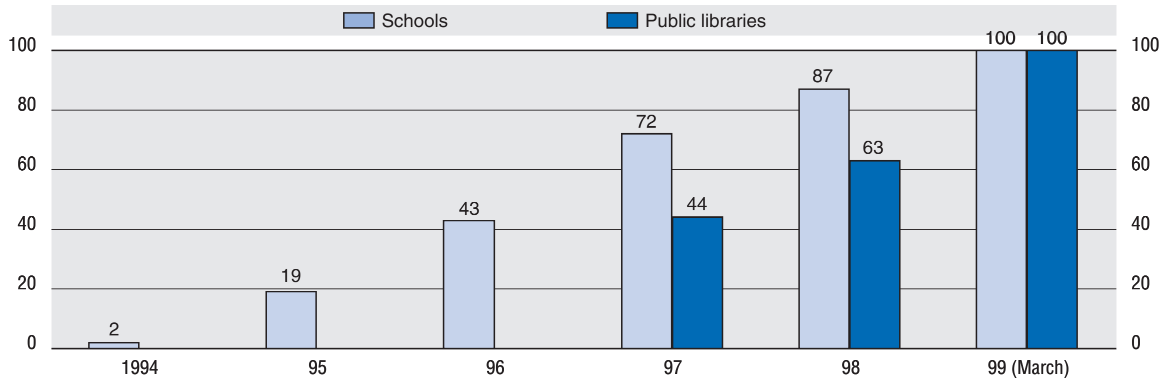
Source: Industry Canada.

Figure 4. **ICT manufacturing and services trade, 1990-97**



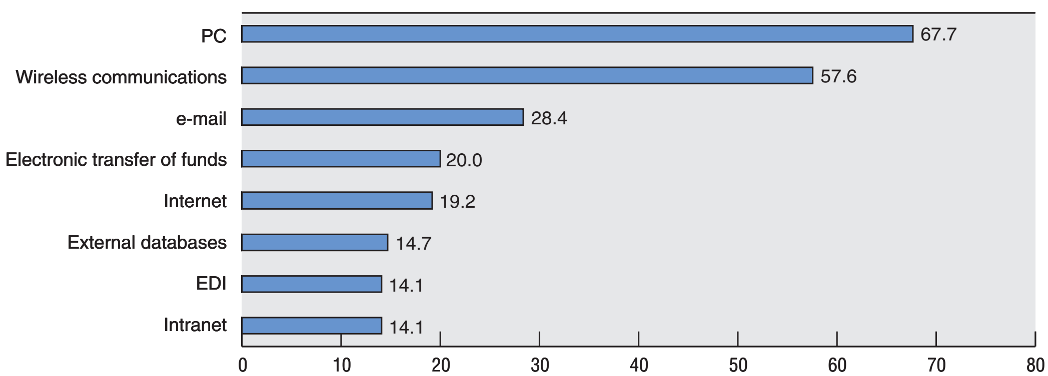
Source: Industry Canada.

Figure 5. **Schools and libraries connected to the Internet at year-end, 1994-99**
Percentages



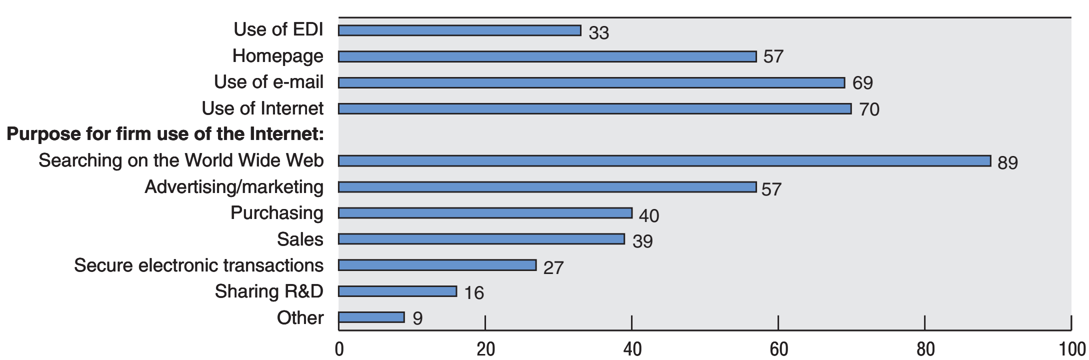
Source: Industry Canada, based on numbers provided by provincial governments and provincial education networking organisations.

Figure 6. **Use of selected ICTs in service industries in Canada, 1996**
Percentage of firms



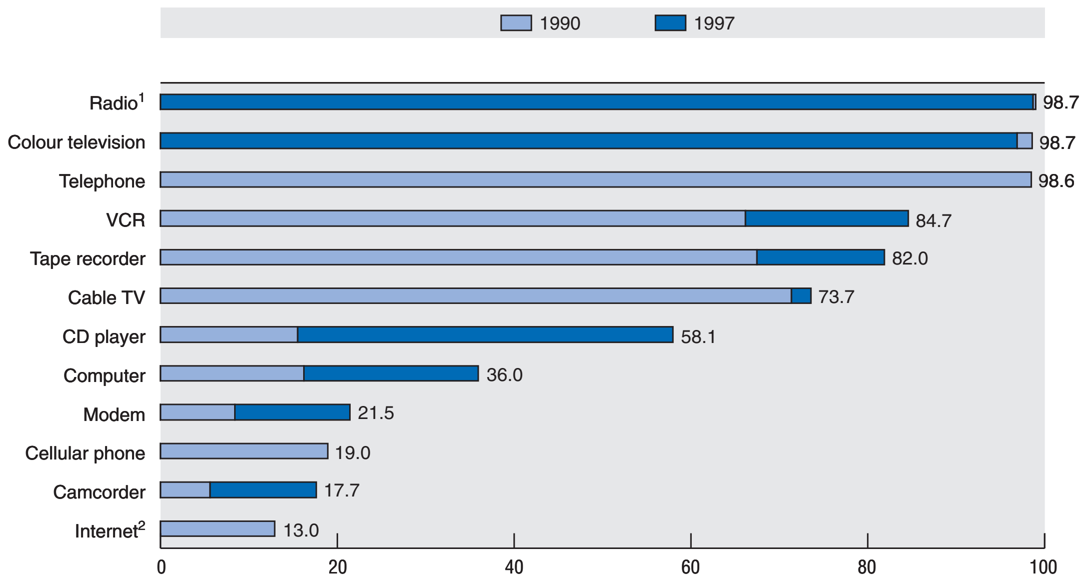
Source: Statistics Canada, *Survey of Technology Diffusion in Service Industries*, 1996. Available online at: <http://strategis.ic.gc.ca/SSI/it/survey.pdf>

Figure 7. **Firm use[1] of Internet in the manufacturing sector, 1998**
Percentages



1. Establishment-weighted.
Source: Statistics Canada, *Technology Adoption in Canadian Manufacturing, 1998,* August 1999.

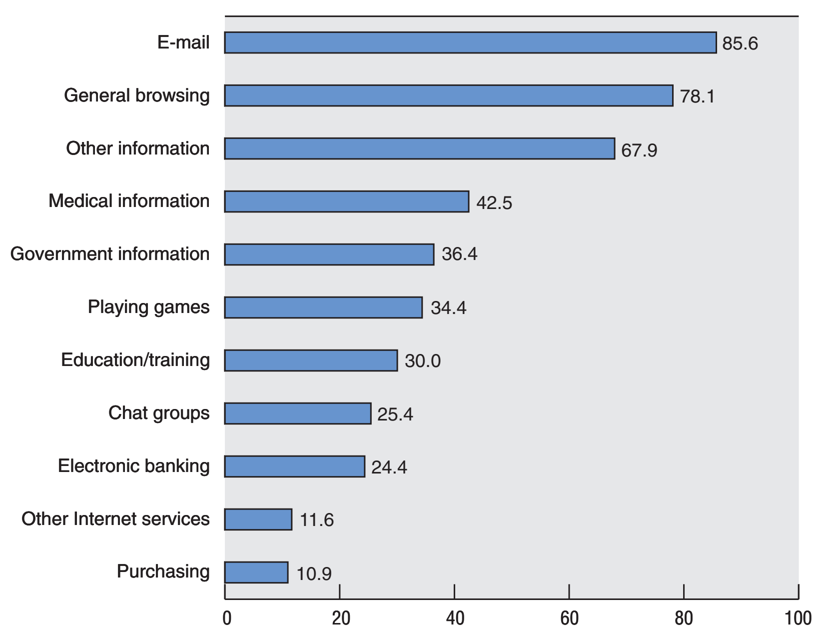
Figure 8. **Overall ICT penetration in Canadian households, 1990 and 1997**
Percentages



1. In 1990, 99.1% of households were equipped with radio.
2. 1990 not available.

Source: Statistics Canada.

Figure 9. **Purpose of online activities from home among regular home user households, 1998**
Percentages



Source: Statistics Canada.

Denmark

The ICT sector's share in the economy declined slightly between 1992 and 1996, mainly due to ICT manufacturing and wholesale activities, which stagnated over the period. ICT growth was in fact negative in 1993 and 1996, but while all sub-sectors suffered in 1993, the 1996 decline was mainly concentrated in the wholesale sector (Figure 1).

Over the same period, the ICT sector's share in total employment rose slightly. This was the result of a combination of a decline in ICT manufacturing activities and a strong increase in telecommunications and computers and related services. In 1996, ICT services activities accounted for almost 80% of ICT employment compared to less than 75% four years previously (Figures 2 and 3).

In 1996, the ICT sector accounted for almost 6% of private businesses and more than 17% of business enterprise R&D expenditures (Figure 2).

In 1998, PCs and workstations were widely used by businesses in all sectors of the economy, and in 44% of firms at least three-quarters of employees used these tools. Manufacturing and building and construction industries, with corresponding shares of 28% and 25%, respectively, were relatively less-intensive users. Business services industries use PCs or workstations most intensively, with at least three-quarters of employees using them in eight firms out of ten (Figure 4).

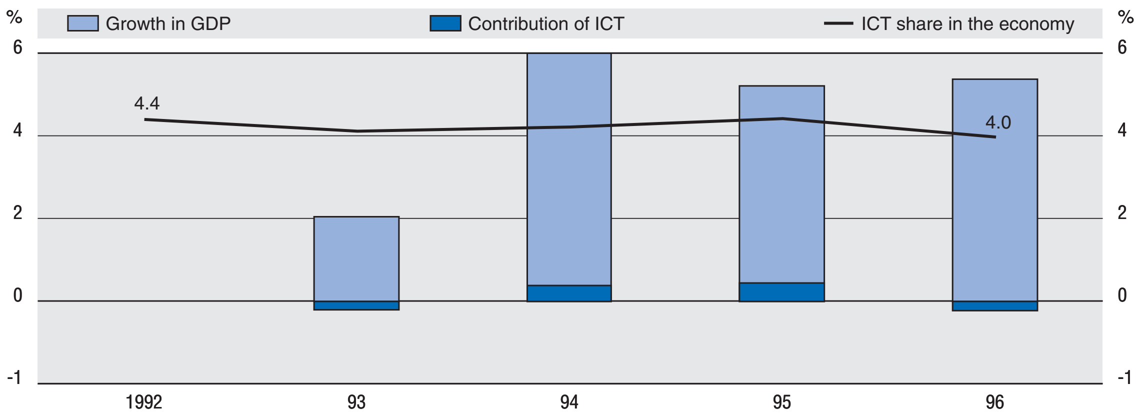
The introduction of Internet has been progressing rapidly in almost all businesses, and 89% should use it in 1999, against only 40% in 1997. SMEs are also participating in this trend, with 38% of firms with two to five employees – the least connected category of firms with less than 20 employees – connected in 1998, as were 71% of firms with between 20 and 49 employees. By industry, business services are the most connected (82%) and building and construction the least (58%). Intranets and extranets are also spreading rapidly, and the former should equal EDI penetration in 1999.

In 1996, 42% of households had a PC and 5% could access Internet (Figure 5). More recent figures from private sources show that the shares reached 52% and 31%, respectively, at the end of 1998. The strong growth of home PCs might also be due in part to the fact that, in 1999, almost four businesses in ten were considering offering to pay for a home PC for their employees (Figure 6). Another factor may be decreasing Internet connection costs for private consumers, mainly due to declines in Internet subscription prices, as telephone costs have dropped only slightly. Recent data from private sources suggest that less than 2% of the Danish population purchase goods and services over the Internet.

Electronic commerce is increasingly a reality for Danish businesses. More than half have a home page for advertising and selling and one in five use the Internet for receiving orders. One in three is prepared to order goods and services electronically and almost one in five accepts to pay for them electronically. Digital goods and services are received via the Internet by almost half of businesses and are supplied by 10% of them (Figure 7).

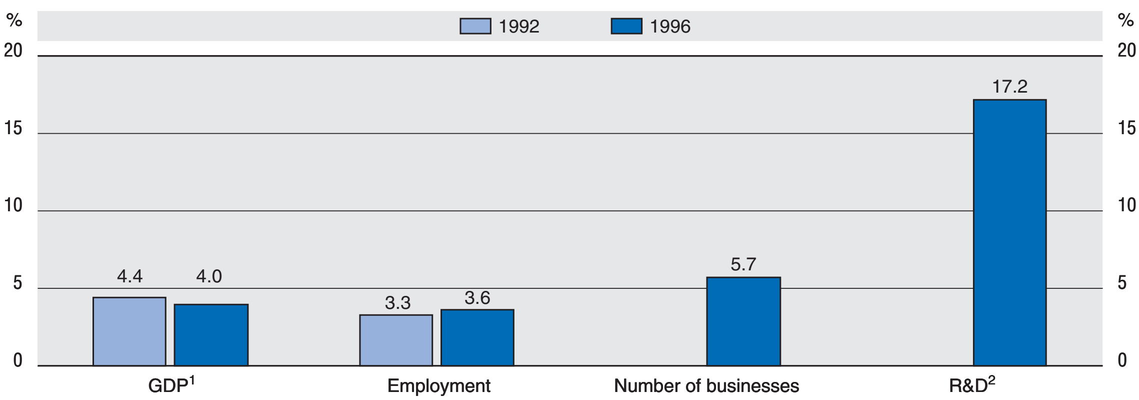
In terms of their propensity to engage in electronic commerce as suppliers, business services are clearly ahead, followed by trade, while hotels and restaurants and building and construction lag behind (Figure 8).

Figure 1. **Contribution of the ICT sector[1] to GDP, 1992-96**



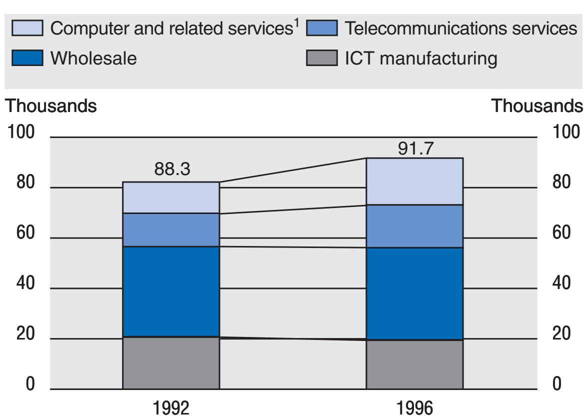
1. Excluding telecommunications.
Source: Statistics Denmark and OECD.

Figure 2. **Share of the ICT sector in GDP, employment, number of businesses and R&D, 1992 and 1996**



1. Excluding telecommunications.
2. Share of business enterprise R&D. 1995 instead of 1996.
Source: Statistics Denmark and Ministry of Research and Technology.

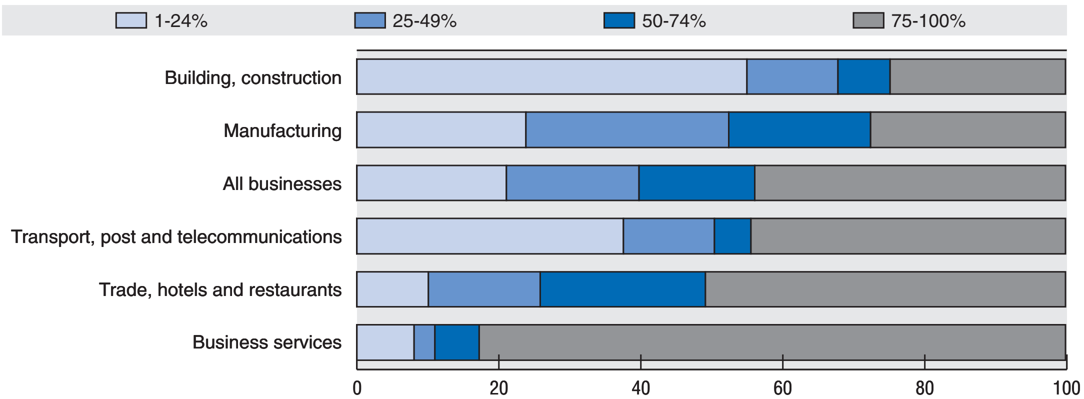
Figure 3. **ICT employment by industry, 1992 and 1996**



1. Includes rental and leasing of office machinery and equipment.
Source: Statistics Denmark.

Figure 4. **Employees using PCs or workstations, by sector, 1998**

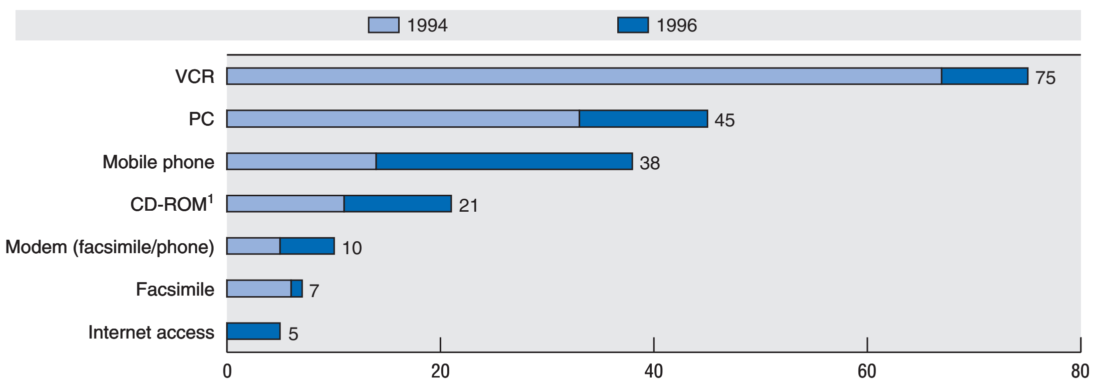
Percentages by quartile



Source: Statistics Denmark, April 1999.

Figure 5. **Diffusion of ICT in households, 1993-96**

Percentages

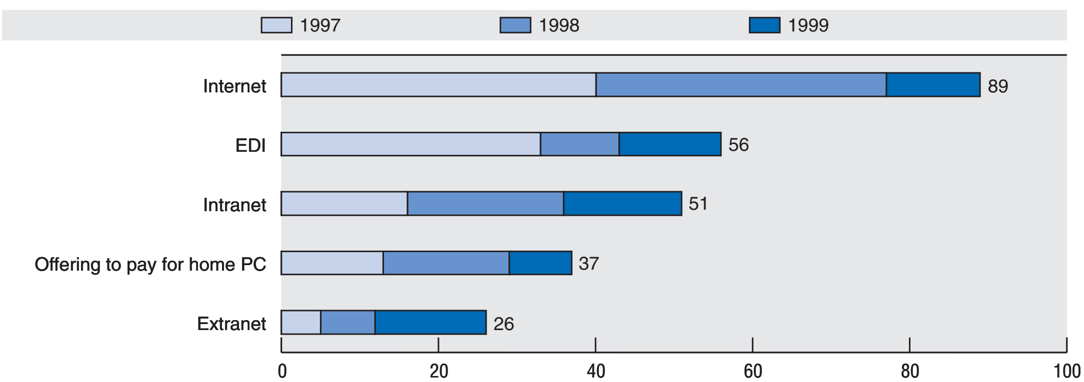


1. 1995 instead of 1994.

Source: Statistics Denmark.

Figure 6. **Diffusion of selected ICT in businesses, 1997-99**[1]

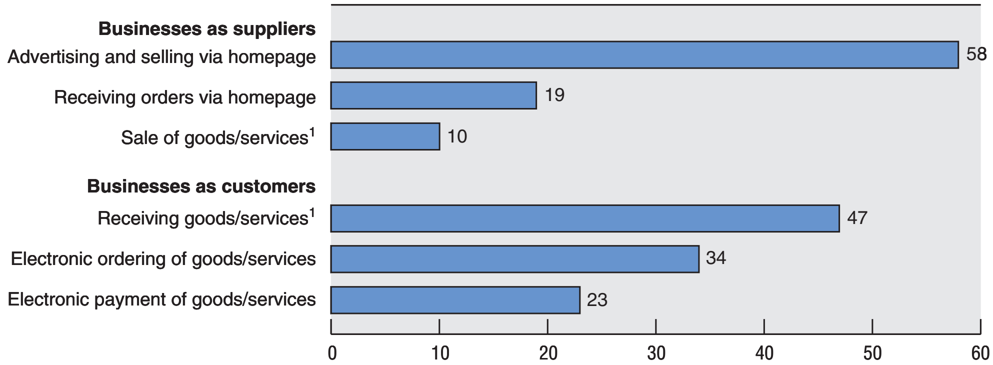
Percentage of all businesses



1. 1999 figures based on company forecasts at end of 1998.

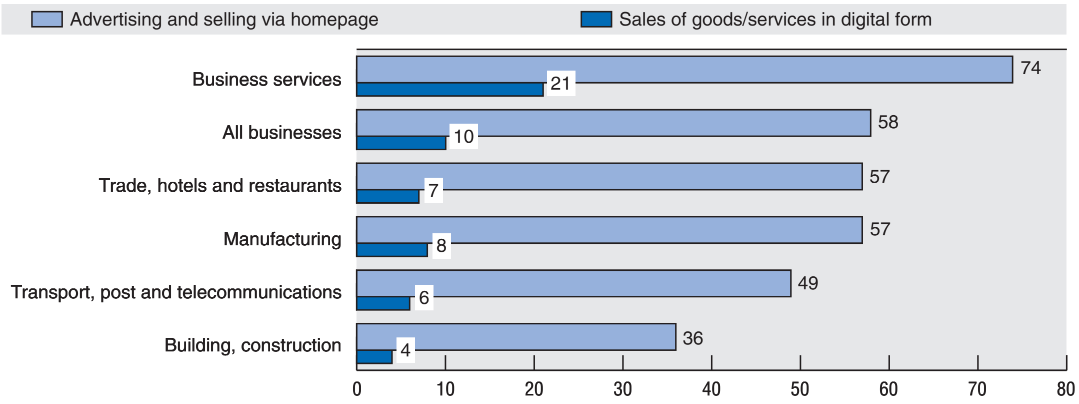
Source: Statistics Denmark, *Danish Business Use of IT 1998*, 1999.

Figure 7. **Internet use by businesses, 1998**
Percentage of all businesses



1. In digital form.
Source: Statistics Denmark, April 1999.

Figure 8. **Internet use by businesses, selected sectors, 1998**
Percentages



Source: Statistics Denmark, April 1999.

Finland

Finland's ICT industry has seen very rapid growth since the economic recession of the early 1990s. In 1997, the ICT sector accounted for only 2.4% of total enterprises but more than 9% of turnover, against 5% four years earlier. Manufacturing activities remained the main contributor, with almost half of the sector's turnover. Computer and related services activities have grown most rapidly, at an average annual rate of 39% between 1993 and 1997, reaching around 15% of total ICT turnover (Figures 1 and 2).

In 1997, the number of jobs in the ICT sector increased by around 11 000 from 1990, whereas the total for the economy as a whole decreased by almost 310 000. ICT jobs have risen from 2.8% to 3.8% of total employment over the same period. Unlike the situation in several other OECD countries, growth is mainly due to goods-producing sectors, especially manufacture of radio and television transmitters and telecommunication equipment, including mobile phones and network equipment. If content-producing sectors are included, the share of total employment would be 5.5% (Figure 2).

Employees in the ICT sector are on average younger than those in other sectors. In 1997, 77.8% were under 45 years of age, against 61.3% of all employed persons. They were also more qualified, as almost one-third had tertiary-level education, as compared to one-fifth of all employed persons (Figure 3). Recent figures show that the ICT sector recruits more intensively among students than do other branches of the economy. When the content-producing sector is included, graduates accounted for one-third of new employees in 1997. In 1995, the share was 25%. In 1997, more than 8% of all new students were enrolled in the IT and media fields, against slightly less than 6% in 1990.

R&D expenditures by businesses in ICT sectors accounted for around 47% of total BERD in 1997. At the level of product groups, ICT products accounted for 52% of R&D in 1997, against 28% in 1989 and 36% in 1993 (Figure 1).

Trade in ICT goods as a share of total trade in goods has increased regularly during the 1990s, from 7% to 20% for exports and from 10% to 17% for imports. The balance became positive after 1993, mainly due to exports of communication equipment, the value of which has increased over eight-fold over the period. On the other hand, except for medical electronics, other categories have been in deficit. Computers have become the largest category of imports, ahead of electronic components (Figure 4).

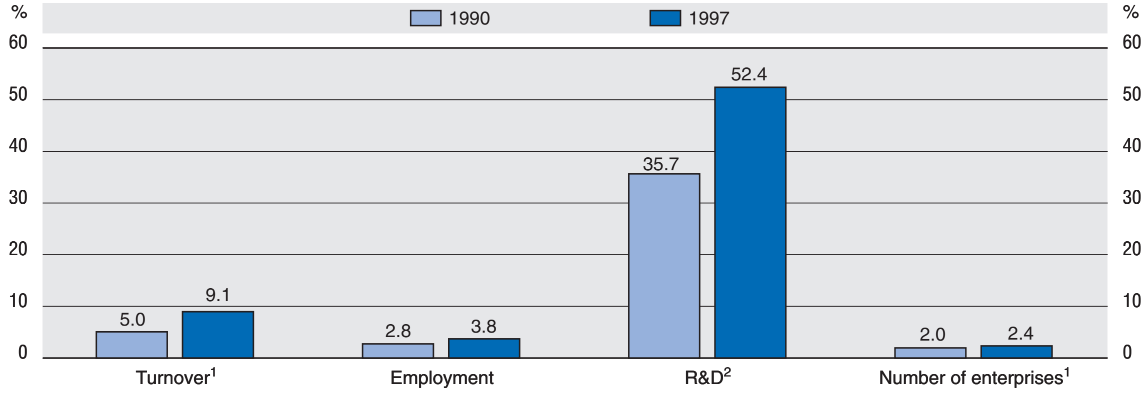
Between 1993 and 1998, firms made intensive efforts to connect to the Internet and to use e-mail and to a lesser extent, EDI. Services sectors were earlier users than industrial sectors and now have the highest share of employees using computers at work. At the end of 1997, two out of three employees used IT at work compared to less than one in five in 1984. Between 1990 and 1997, IT use by employees increased strongly in all sectors, and was especially high among white-collar workers and central government employees (Figure 5).

The diffusion of ICT goods and services in households spread rapidly during the 1990s and accelerated from the middle of the decade. Mobile phones appear to be having a substitution effect with respect to fixed-line subscriptions, which began to decrease in the third quarter of 1998. At the end of the first quarter of 1999, 75.7% of households had mobile phones and 79.1% had fixed lines, but already at the end of 1998, the total number of individual mobile subscribers had exceeded that of fixed-line subscribers (Figure 6).

In terms of equipment penetration and expenditure, households have increased the amount of voluntary consumption devoted to information-related goods and services (see Annex 2), both in relative and absolute terms. The time devoted to the consumption of mass media has increased significantly since 1994, and electronic media – especially the Internet – are attracting increasing numbers of users. Around 22% of households had access to the Internet from home in February 1999, and the number using Internet at least once a week had almost doubled in one year to more than 1.1 million persons. In September 1998, out of four persons with an Internet connection at home, only one did not use it. In the population as a whole, out of 100 persons, 13 accessed the Internet at home, nine used e-mail, eight conducted electronic banking, and two shopped on line. Among home Internet users, 87% used information services, 65% e-mail, 64% electronic banking, more than one-third downloaded digital products, 16% shopped on line and 12% booked tickets.

Use by enterprises of Internet and various functions connected with electronic commerce have increased strongly since 1997. More than one firm in two had made extensive use of commercial databases or services up to 1998, and a strong increase was forecast for 1999. Up to 1998, more than one in three firms had ordered goods and

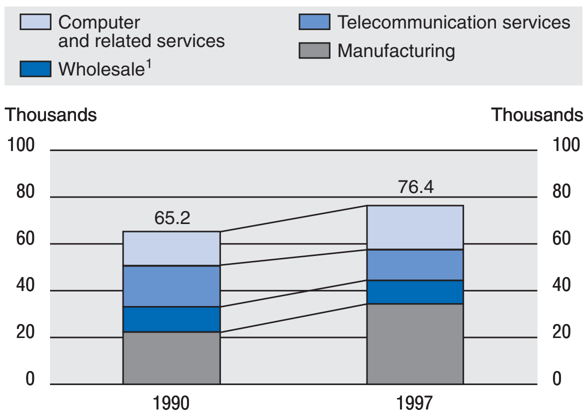
Figure 1. **Share of the ICT sector in turnover, employment and R&D, 1990 and 1997**



1. 1993 instead of 1990.
2. R&D expenditures by product group (share of ICT products).

Source: Statistics Finland (1999).

Figure 2. **ICT employment by industry, 1990-97**

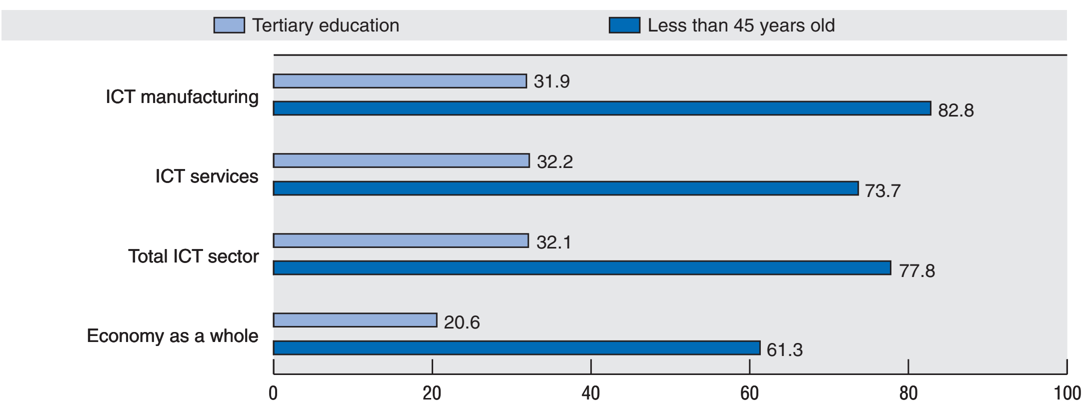


1. Includes rental and leasing of office machinery and equipment.

Source: Statistics Finland (1999).

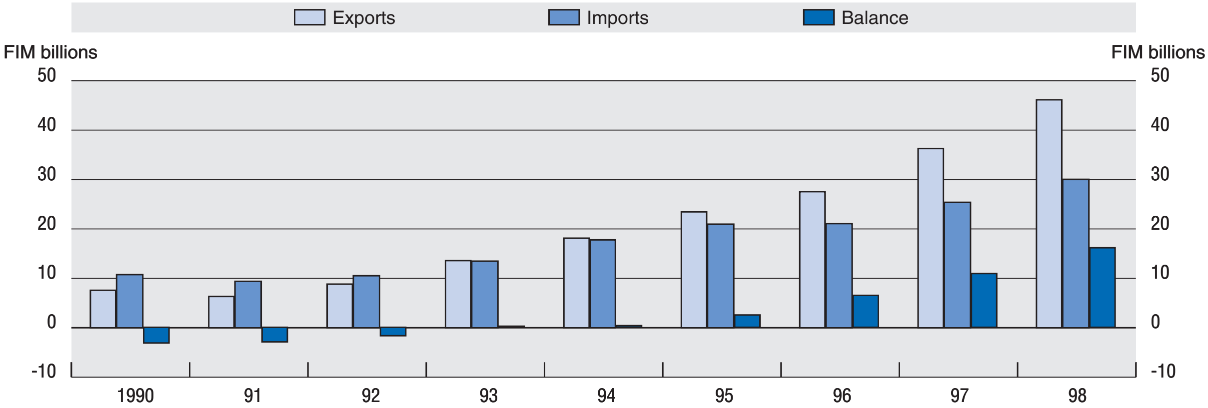
Figure 3. **Structure of ICT sector employment, 1997**

Percentage of the active labour force



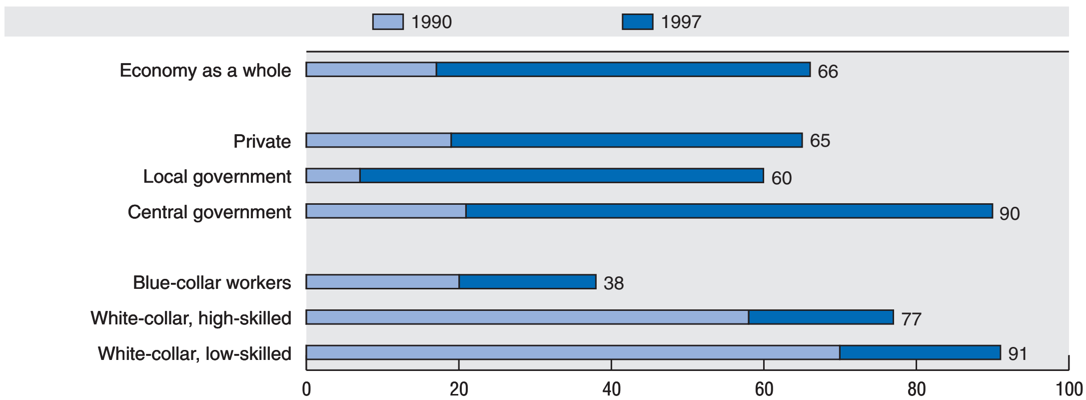
Source: Statistics Finland (1999).

Figure 4. **Trade in ICT products, 1990-98**[1]



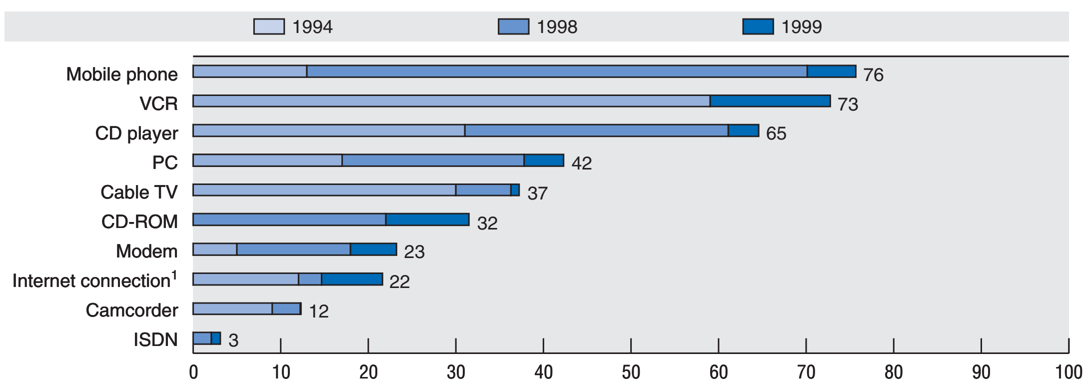
1. Excluding services.
Source: National Board of Customs, ULTIKA.

Figure 5. **Use of IT by employees, 1990-97**
Percentages



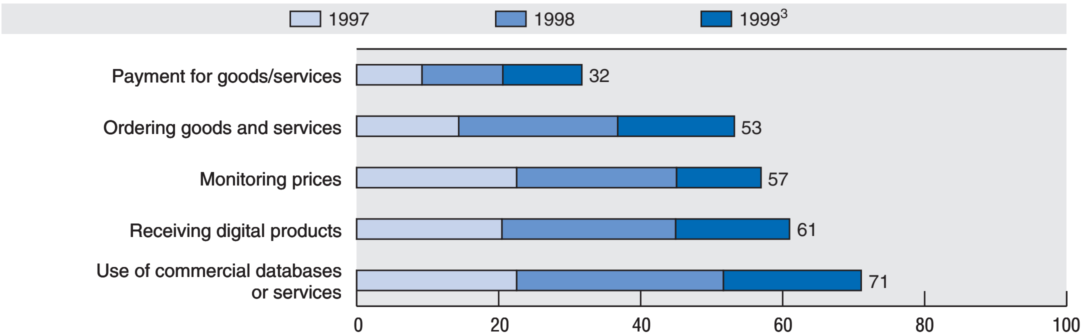
Source: Statistics Finland (1999).

Figure 6. **ICT penetration in Finnish households, 1994, 1998 and 1999**
Percentages



1. 1997 instead of 1994.
Source: Statistics Finland, consumer surveys, various years.

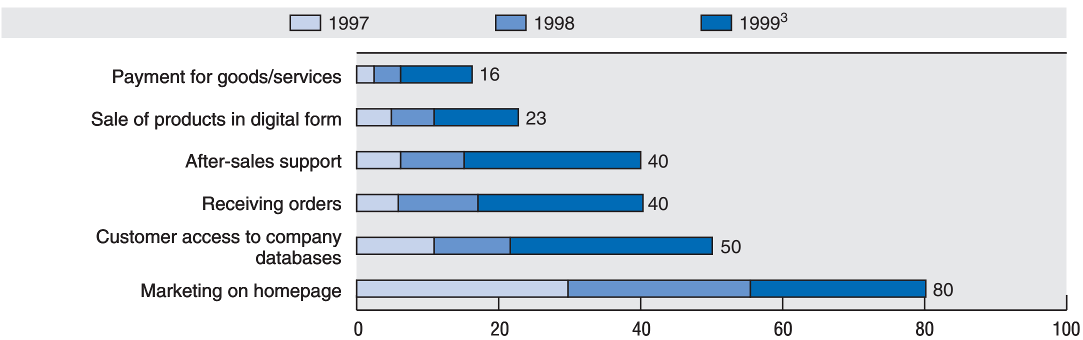
Figure 7. **Use of the Internet by enterprises, 1997-99**[1]
Percentages (initial use)[2]



1. Enterprises with at least 20 employees.
2. Have been used or are expected to be used for the first time in the year 19xx.
3. Forecast.

Source: Statistics Finland (1999).

Figure 8. **Enterprises providing Internet services, 1997-99**[1]
Percentages (initial use)[2]



1. Enterprises with at least 20 employees.
2. Have been used or are expected to be used for the first time in the year 19xx.
3. Forecast.

Source: Statistics Finland (1999).

services over the Internet and one in five had paid for goods and services. In 1998, 45% of firms used the Internet as a price-monitoring tool (Figure 7).

More than five out of ten firms had established a home page in 1998, and the share was expected to reach eight out of ten in 1999. In 1998, about one firm in five provided access to the company's database for customers, and slightly fewer could receive orders via the Internet. One firm in ten sold products in digital form, a share which was expected to more than double in 1999. Payment for goods and services via the Internet was rare in 1998 but was expected to be made available by one firm in six in 1999 (Figure 8).

Firms' expectations regarding the development of e-commerce in the next few years depend on the degree to which they are already involved. Firms already involved in that market anticipate far more positive prospects for e-commerce than firms that are not.

France

In 1995-97, ICT industries represented a relatively small but slightly increasing share of the French economy, in terms of both GDP and employment. More recently, they have played a more prominent role. In 1998, computer services and telecommunications services were among the most dynamic industries, with growth in volume terms of 13% and 10%, respectively. If the printing and publishing industries are included, ICT industries represented around 5.2% of GDP in 1998 and are estimated to have contributed 0.5% to GDP growth in 1998 (*i.e.* 15% of the 3.2% of real GDP growth). The software and computer services industry accounted for half of the jobs created between 1989 and 1996 in the ICT sectors (excluding public telephony operator employment) (Figures 1 and 2).

Although figures on the aggregate ICT trade balance are not available, trade in ICT goods showed a high overall deficit in 1997, except for certain electronic components and integrated circuits, chip cards and certain communication equipment and computer systems. The trade surplus in ICT services was mainly due to computer-related services, with a surplus of over FRF 8.2 billion in 1997, as communications (including postal services) recorded a deficit of FRF 200 million.

ICTs are diffusing rapidly in businesses, government and households. With an installed base of around 7.5 million Minitel terminals, France is by far the leading country for use of videotext terminals, but since 1993, emulation cards in PCs are increasingly used to access Minitel services. The progressive switch to Internet-related services has meant a decrease in the volume of Minitel traffic (households and businesses), from 90 million hours in 1993 to 83 million in 1997 and an increase in Internet access, which reached 7 million connection hours for individual subscribers in 1998.

On the demand side, household consumption, which accounted for two-thirds of GDP growth in 1998, has been especially dynamic for mobile telephones and PCs as well as for telecommunication services (+9.3%). ICTs were also a significant component of investment. Business investment (excluding financial institutions) has grown strongly in computers and office equipment (+21%) and in software (+18%). Government investment was slightly less dynamic; most growth was due to computers and office equipment and software.

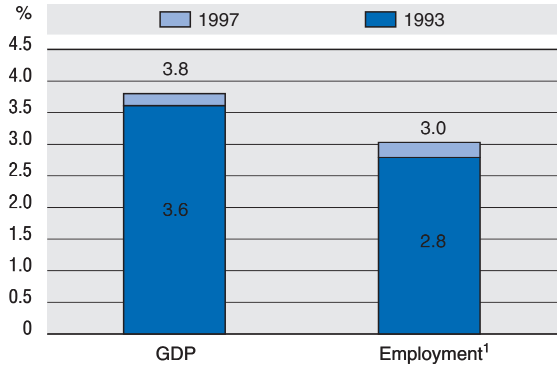
PC diffusion in households has grown rather slowly from around 9% in 1990 to 19% in June 1998 but is still less widespread than the Minitel (Figure 3). However, recent growth has been strong, partly driven by PC price declines. In May 1998, 15% of PC users were connected to the Internet, and an additional 33% were considering connection within the next two years. Among those without a home PC, almost one person in two was also considering connection within the next two years. In April 1999, around 10% of the population aged 15 and over had used the Internet during the previous 30 days, compared with only 5.2% a year earlier. PC use is also spreading in the educational system. In January 1999, the average number of students per computer was down from 26 in May 1997 to 17 in colleges and from 12 to seven in high schools.

IT use at work has increased significantly during the last decade. In May 1998, more than one employee in two used a computer at work. All occupational categories have increased their use of computers, with growth particularly strong for less qualified occupations (Figures 4 and 5). More highly qualified occupations are now noticeably higher users of portable computers and the Internet.

In May 1998, the Internet was used at work by only seven employees out of 100 on average. Computer engineers and researchers were the most intensive users (over 90%), and the only category among office clerks and workers that was above 5% was administrative office clerks in enterprises. On average, one firm in four was estimated to have access to the Internet in April 1999, but there is wide disparity by sector and size of firms. More than half of SMEs were connected at the end of 1998, while 90% of industrial businesses employing more than 2 000 people were connected to the Internet at the end of 1997.

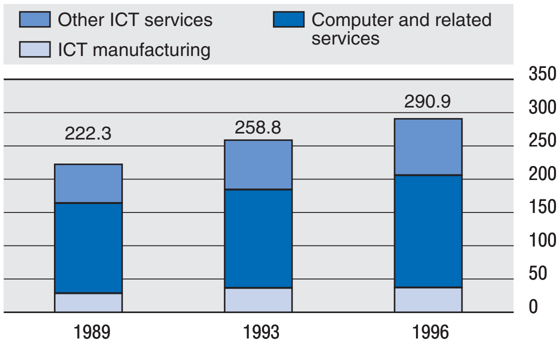
Electronic commerce has existed in France for some time via the Minitel. In 1997, 39% of businesses with more than ten employees were involved in some form of electronic commerce. In 1997, businesses used the Minitel on average twice as much as they used the Internet (22% and 11%, respectively). Use of electronic commerce increases with business size, from 35% for firms with ten to 20 employees, to 85% for the 300 largest French companies. Compared to other industries, financial activities use electronic commerce applications most intensively (with EDI as the main medium), followed by public administration, business services industries and agriculture, which used the Minitel as the main medium. The Internet (rather than EDI and the Minitel) is used as the main medium by business services and education (Figure 6).

Figure 1. **Share of the ICT sector in GDP and employment, 1993 and 1997**



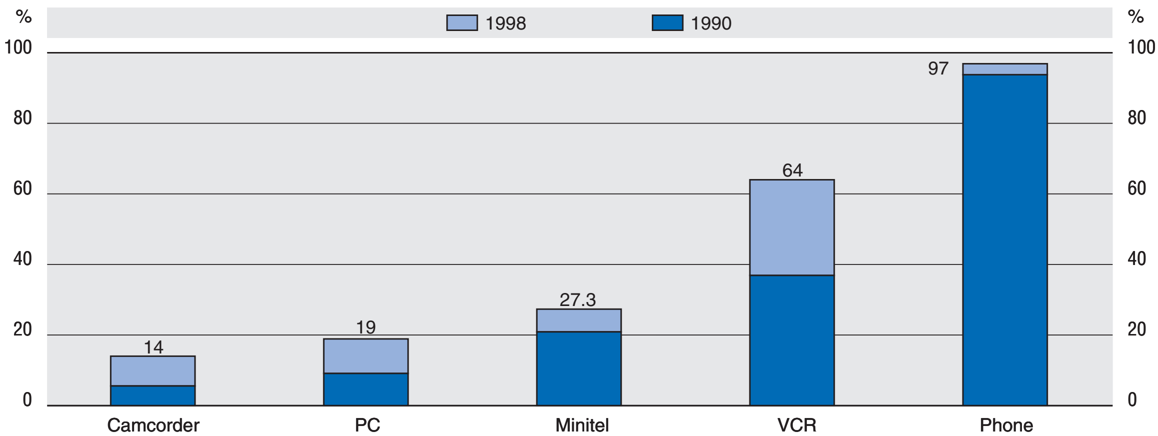
1. Includes public telecommunication operator (PTO) employment, estimated at around 150 000 at the end of 1996.
Source: OECD, based on data from INSEE.

Figure 2. **Employment in the ICT sector, 1989, 1993 and 1996**[1]



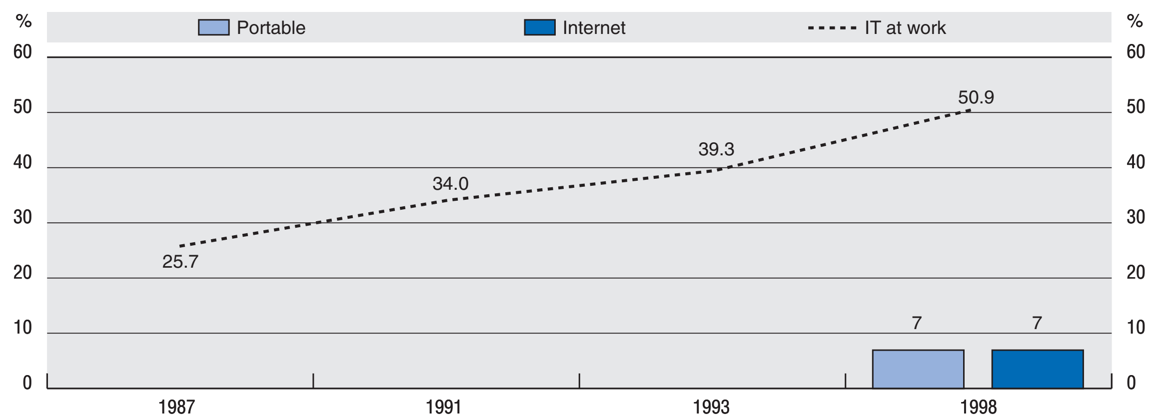
1. Excludes PTO employment.
Source: *Premières Synthèses* No. 33.1, 1998, DARES, Ministère de l'Emploi et de la Solidarité. Available online at: <www.travail.gouv.fr/publications/picts/titres/titre208/integral/331.pdf>

Figure 3. **ICT penetration in households, 1990 and 1998**



Source: INSEE and CREDOC.

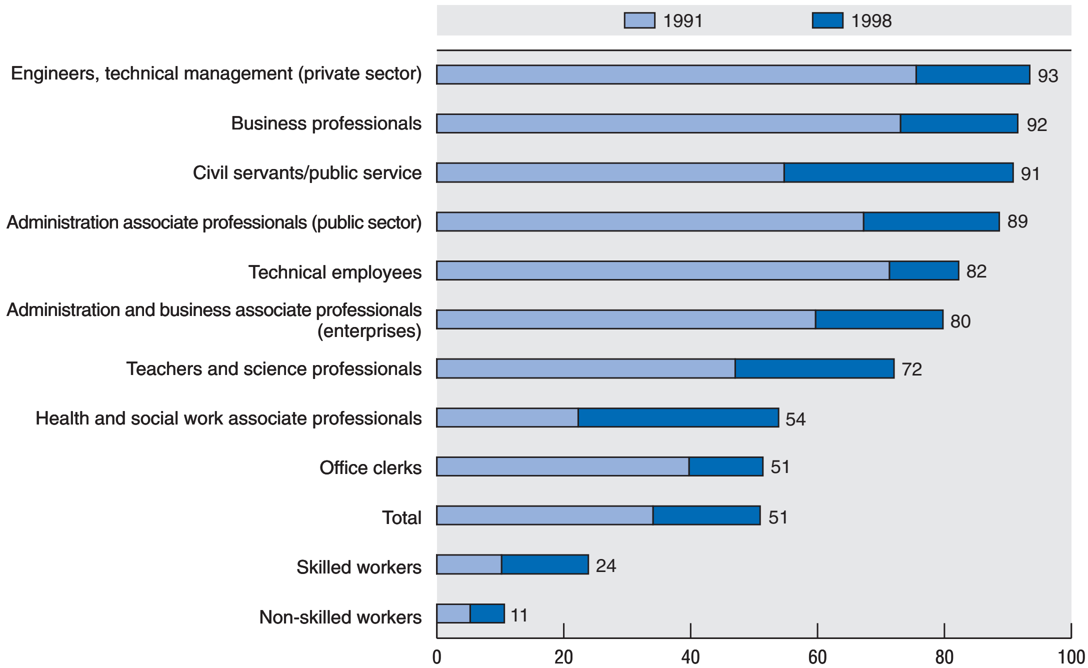
Figure 4. **Share of employees using IT at work, 1987-98**



Source: *Premières Synthèses* No. 53.2, December 1998, DARES, Ministère de l'Emploi et de la Solidarité. Available online at: <www.travail.gouv.fr/publications/picts/titres/titre208/integral/331.pdf>

Figure 5. **Share of employees using a computer at work, by occupational category, 1991 and 1998**

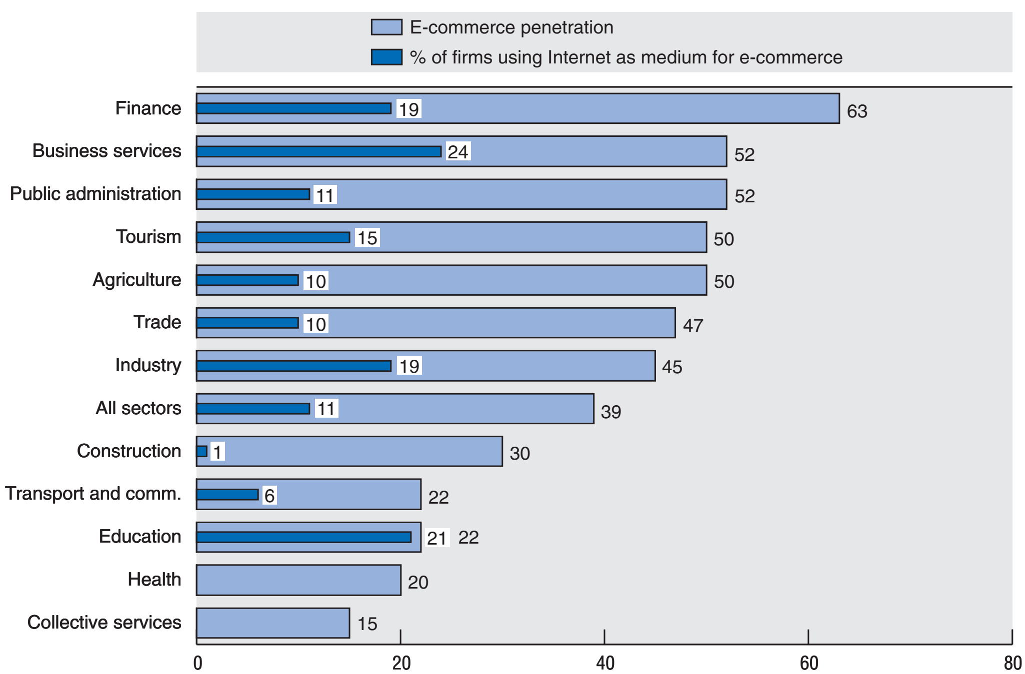
Percentages



Source: *Premières Synthèses* No. 53.2, December 1998, DARES, Ministère de l'Emploi et de la Solidarité. Available on line at: <www.travail.gouv.fr/publications/picts/titres/titre208/integral/53.2.pdf>

Figure 6. **E-commerce penetration and Internet usage, 1997**

Percentages



Source: Observatoire des échanges et du commerce électronique, 1998 survey, cited in Ministère de l'Économie, des Finances et de l'Industrie, *Technologies et société de l'information*, March 1999.

Italy

In 1996, only 1.9% of enterprises were in the ICT sector, but out of ITL 100 invested in Italy that year, almost ITL 8 were invested in the ICT sector. In that year, the ICT sector contributed 3.5% to GDP and 3.0% to employment, and it accounted for 2.4% of GDP growth between 1995 and 1996 (Figures 1 and 2).

Within the ICT sector, services activities account for more than 70% of employment. Almost one-third of the ICT sector's employees work in computers and related services, and more than one-fifth in the wholesale sector. Provisional data for 1996 show a very strong increase in employment in computer and related services and in wholesale (Figure 3).

R&D expenditures by firms in the ICT sector accounted for 29.3% of total business R&D expenditures in 1998, increasing from 24.5% in 1991 (Figure 2).

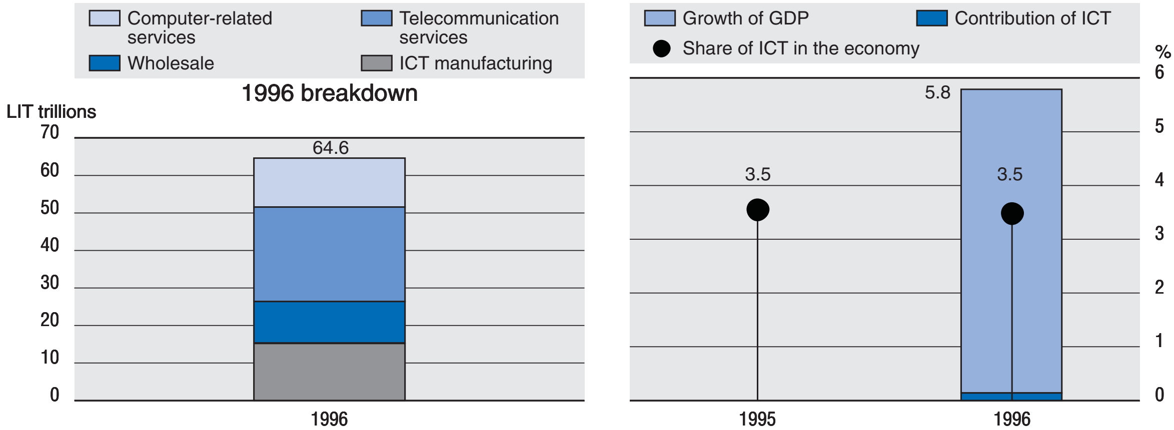
ICT use is spreading in firms, and in 1995, one-third of the smallest firms were equipped with PCs. Not surprisingly, the PC penetration rate increases with firm size. Modems lagged for all size categories (Figure 4).

Recent ISTAT estimates indicate that over half of the provinces have an Internet site as do nine out of ten main cities in the provinces. The share falls to less than 6% on average for other municipalities. Another recent survey mentioned "the risk of saturation in use of local government electronic services", and the "difficulty in extending use of the Internet to the majority of citizens", given that the characteristics of common users were that they were male, aged 25-44, highly educated and interested in technology.

ICTs are still little diffused in households. In 1997, 17.5% of households owned a home computer, and only 2.3% subscribed to an Internet provider (Figure 5). Mobile phones, on the other hand, have shown strong growth and were present at the end of 1998 in more than one-third of households. There were 25 million mobile subscribers by end July 1999, compared with 24.3 million fixed-line subscribers.

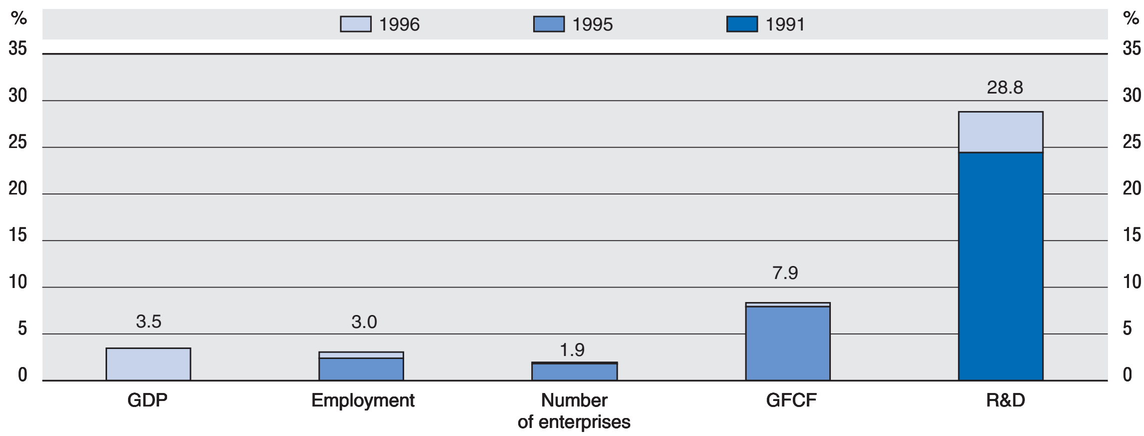
In a 1995 survey, 22.5% of respondants declared that they had a computer at home, but only 12.3% actually used it, for a usage rate of 54.6%. Students were both the most equipped and the most intensive users, followed by the employed. People seeking first employment also used computers intensively (Figure 6). On average, computer use at least once a week was mainly for work (60.2%), followed by play (31%) and study (22.6%).

Figure 1. **Contribution of the ICT sector to GDP, 1995-96**



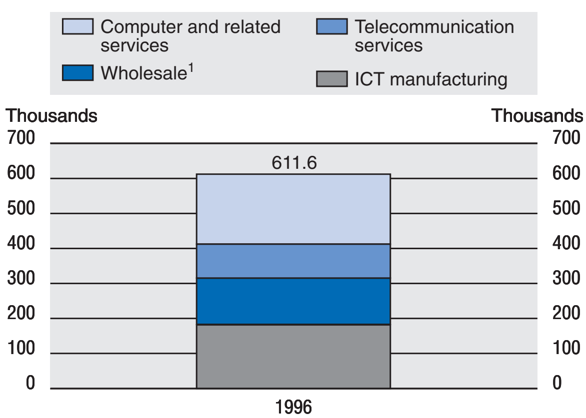
Source: ISTAT and OECD.

Figure 2. **Share of the ICT sector in GDP, employment, number of enterprises, GFCF and R&D, various years**



Source: ISTAT and OECD.

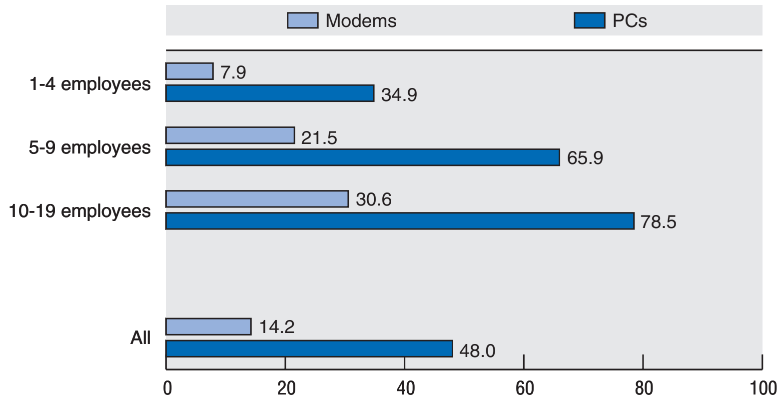
Figure 3. **ICT employment by industry, 1996**



1. Includes rental of office machines and equipment (including computers). Provisional data.

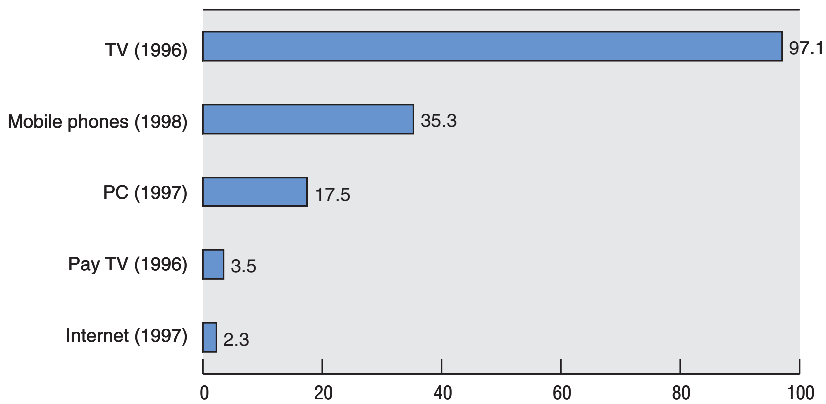
Source: ISTAT.

Figure 4. **Diffusion of modems and PCs in SMEs by size, 1996**
Percentage of all business



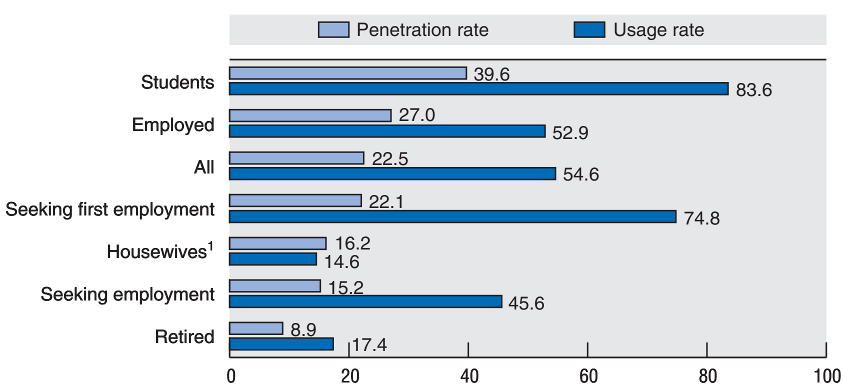
Source: ISTAT.

Figure 5. **Diffusion of ICT in households, various years**
Percentages



Source: ISTAT.

Figure 6. **Presence and use of computers at home, by professional status, 1995**
Percentage of the population



1. Not available for men.
Source: ISTAT.

Japan

The ICT industry is extremely important to the Japanese economy. It accounted for 7% of GDP as early as 1990, but the share increased only slightly to 7.3% in 1997, owing to the economic downturn of the first part of the decade. During the same period, the industry's share of employment decreased slightly from 4.7% to 4.3% of total employment. Average nominal productivity in the ICT sector has increased at an average annual rate of 3.6%, against only 1.7% for the economy as a whole (Figure 1).

The decline in employment between 1990 and 1997 is mainly due to the privatisation of NTT, which led to a staff reduction of more than 150 000 between 1985 and 1997 (100 000 between 1990 and 1997). If NTT is excluded, employment in the telecommunications sector is quite stable. The ICT equipment-leasing sector also contributed, but to a lesser extent, to the general decrease in ICT employment (Figure 2).

The ICT sector's R&D was estimated at 28.9% of total BERD in 1997, up from 26.6% in 1990.

Since 1990, Japan's trade balance has had a structural surplus for electronics goods. In 1998, both imports and exports contracted. Exports were affected by slow demand in Asian countries, and imports slowed, as the economic recession curbed demand for many electronics products, except for categories such as telecommunications systems and cellular phones (Figure 3). Between 1994 and 1997, software showed a trade deficit, but, in terms of value, this deficit corresponded to only around 6% of the trade surplus in electronics goods.

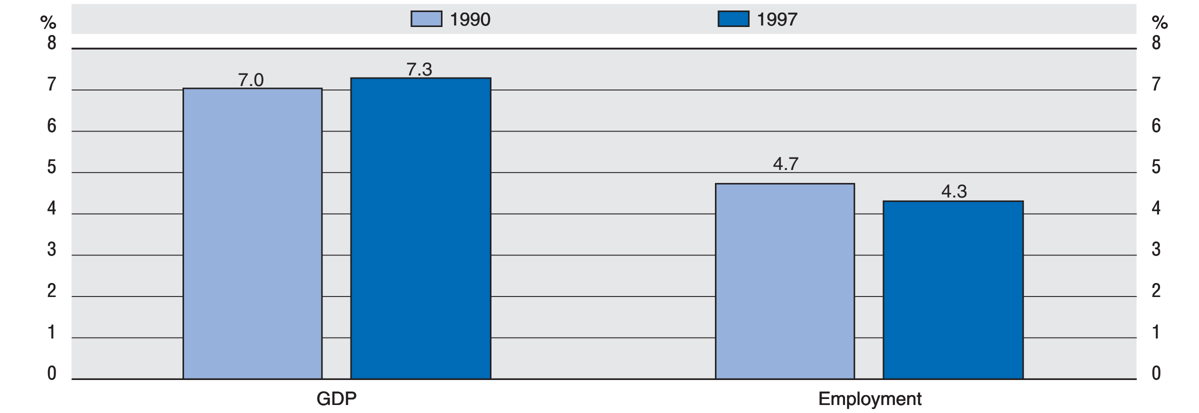
Since 1985, overseas electronics production facilities of Japanese corporations have quadrupled to reach 1 274 units in March 1998. Asia has been the main destination, with more than two-thirds of the units. One overseas electronics production facility out of five is now located in China.

The Internet is diffusing rapidly in all areas of the economy. The number of Internet service providers in Japan jumped from 1 260 in September 1996 to 3 782 in September 1999. In March 1999, 80% of big companies and 20% of the smallest had access to the Internet. Local governments have also used the Web, and more than 70% now offer Web sites for citizens. Almost 20% of schools have access to the Internet, the share reaching more than 63% for senior high schools (Figure 4).

The diffusion of ICT goods in the home is increasing. In 1998, almost 100% of households were equipped with colour TV, one-quarter had a PC, and more than one in ten had access to the Internet. A more recent Ministry of Post and Telecommunications survey indicates a clear trend towards a strong increase in household PCs, the share having reached one-third in March 1999. However, while 47.7% of men say they have a PC at home, only 32.3 actually use it. For women, the ratios are 39.7% and 17.7%, respectively. Another recent survey indicated that 29.5% of households used a PC at home and 11% accessed the Internet from home (Figure 5). Recent figures suggest that the consumer PC market, after zero growth in 1998, is expanding rapidly and, as this goes hand in hand with demand for Internet access at home, there may be a rapid increase in Internet usage by households.

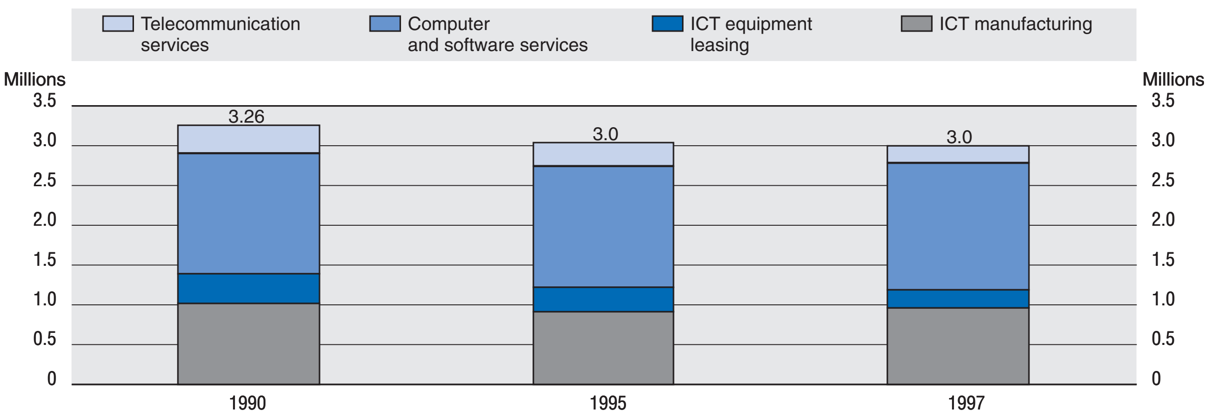
Electronic commerce is growing very rapidly in Japan. Between 1997 and 1998, the size of the market for products and services sold via the Internet more than doubled to reach an estimated JPY 166.5 billion for 1998. Internet stores offering transactions for final consumption have multiplied by twelve in less than three years (Figure 6).

Figure 1. **Share of the ICT sector in GDP and employment,[1] 1990 and 1997**



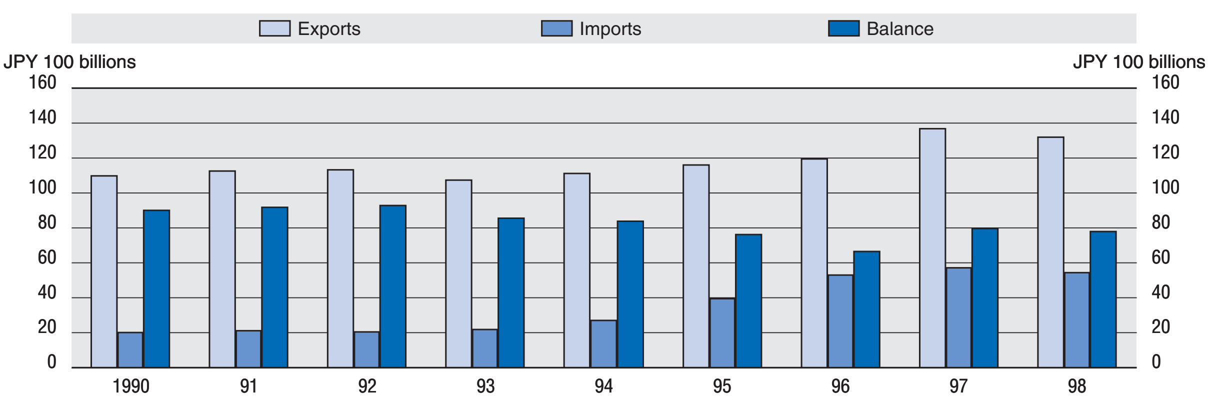
1. Including NTT group employment (153 000 at the end of 1997).
Source: OECD, compiled from various official sources.

Figure 2. **ICT employment by industry,[1] 1990, 1995 and 1997**



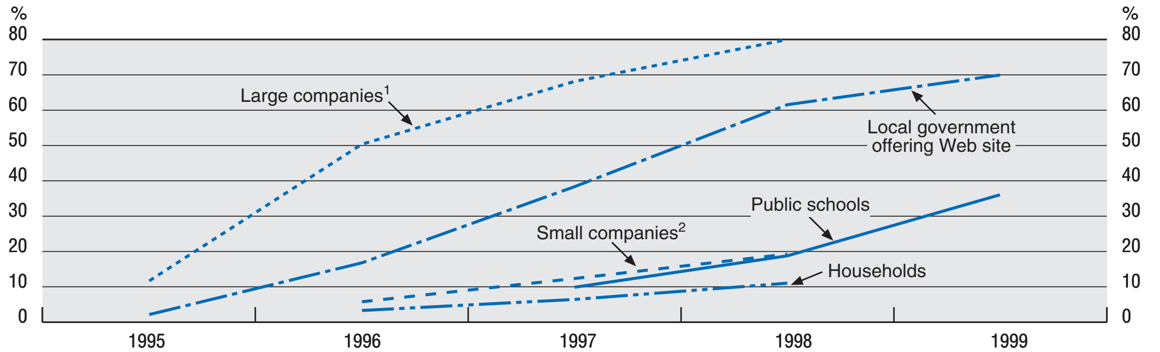
1. Including NTT group employment, of 153 000 at the end of 1997.
Source: OECD, compiled from various official sources.

Figure 3. **Trade in electronics goods, 1990-98[1]**



1. Fiscal year, ending in March. Electronic goods include consumer electronic equipment, industrial electronic equipment, and electronic components and devices.
Source: Electronic Industries Association of Japan, *Facts and Figures on the Japanese Electronics Industry*, 1999 edition.

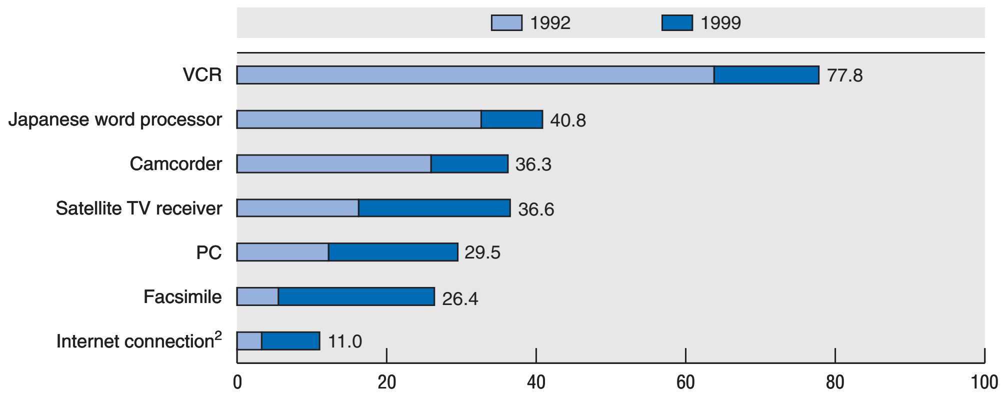
Figure 4. **Internet penetration in Japan, 1995-99**



1. 300 employees and more.
2. Fewer than six employees.

Source: Compiled by OECD from MPT, *Telecommunications Services Usage Survey and Communications Equipment Usage Survey*; Economic Planning Agency; Ministry of Education, Sciences, Sport and Culture survey on the status of IT in public schools.

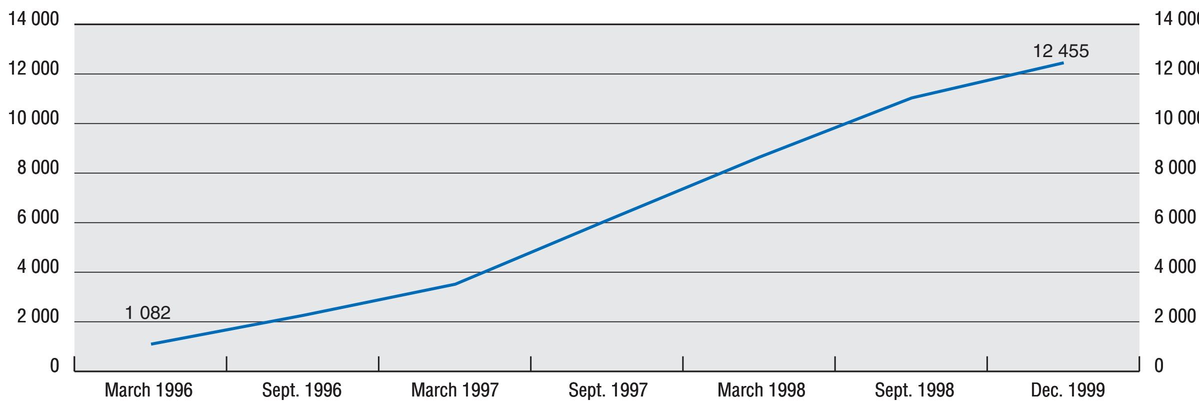
Figure 5. **ICT penetration in households, 1992 and 1999**[1]



1. Fiscal year, ending in March.
2. 1996 instead of 1992 and 1998 instead of 1999.

Source: Economic Planning Agency.

Figure 6. **Number of Internet stores in Japan offering goods and services**[1]



1. For business-to-consumer transactions and business-to-business transactions leading to final consumption.

Source: Nomura Research Institute, cited in MPT, *Communication White Paper*, 1999.

Norway

The ICT sector provided a modest but increasing contribution to the growth of the Norwegian economy between 1993 and 1995. During this period, its average annual growth of 8.4% was more than 2% higher than that of the economy as a whole (6.2%) (Figure 1).

The slight increase of 3.6% in employment in the ICT sector between 1993 and 1996 (Figure 2) was mainly due to the computer and related services sector and, to a lesser extent, to the telecommunications sector. Wholesale of ICT-related goods remains the main provider of employment in the ICT sector (around 40%), but at the end of 1996, more than one ICT sector employee in four worked in computer and related services (Figure 3).

Employees in the ICT manufacturing sector are slightly younger than in manufacturing employment as a whole, with employees between 25 and 44 years of age accounting for 59% (against 53%); the share of employees with tertiary education is 38% (against 13%). The pattern is similar for ICT services compared with total services; employees in the 25-44 age group account for 64% and 51%, respectively, and employees with tertiary education represent 36% and 21%, respectively.

Although there are no recent figures on IT diffusion in the workplace, it was already widely used in 1994, when more than one employee out of two used a PC. This share was only 15% in agriculture, but climbed to around 43% in manufacturing and construction and almost 60% in trade and financial services. Education and research employees were the most intensive PC users, as three out of four used a PC at work.

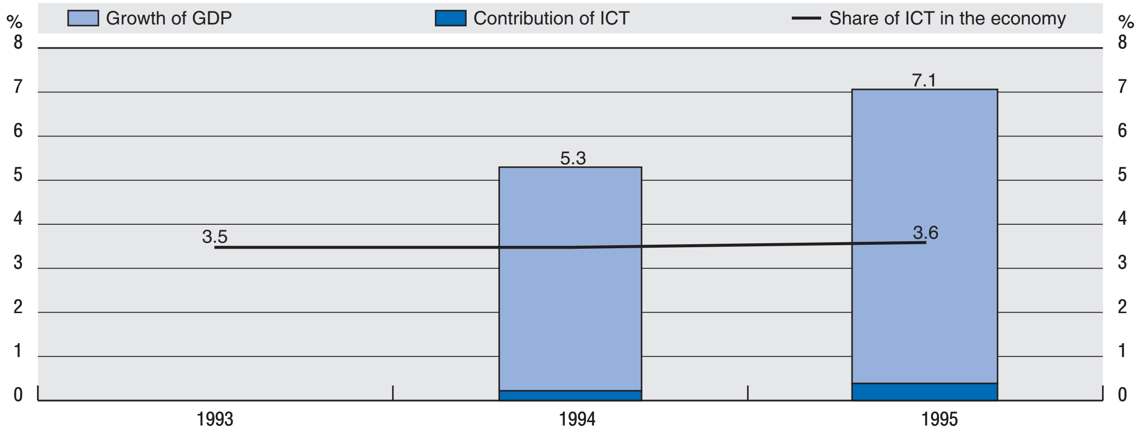
ICT is diffusing rapidly in the home; in 1998, more than one person in two had access to a PC at home, more than two out of five had a CD-ROM player, and more than one out of five had Internet access (Figure 4). More recent data from private sources suggest that home Internet access has grown strongly in the last few years, with the number of people accessing the Internet from home jumping from around 200 000 in September 1996 to more than 1 million in July 1999.

The youngest age group (9-15 years old) are also the most intensive users. More than 80% had access to a PC at home in 1998 (*vs.* 60% in 1996), against only 57% for the average population (*vs.* 43% in 1996).

Average daily time spent reading printed newspapers fell from 39 to 34 minutes between 1991 and 1998. However, there are few indications that use of electronic media has replaced reading. Even though home computers with a CD-ROM player and an Internet connection are increasing, time spent on line has not increased significantly. Home computers accounted for less than 5% of the time spent on mass media on an average day in 1996 (Figure 5). In spring 1999, less than 2% of the time spent on the media on an average day was devoted to the Internet.

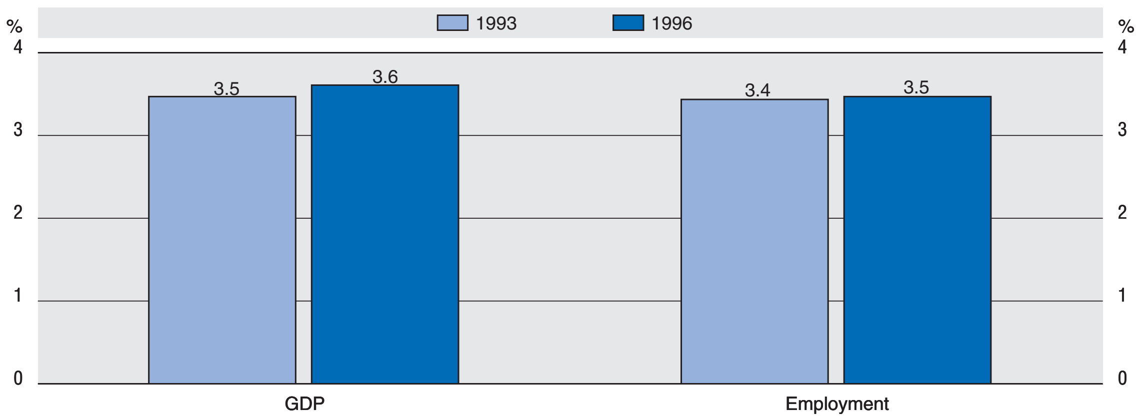
According to a 1998 survey, more than 14% of Norwegian companies had adopted electronic commerce in 1998, and around 28% of companies that were not users had plans to do so. Compared with other Nordic countries, these figures put Norway ahead of Denmark and Sweden, but behind Finland and Iceland.

Figure 1. **Contribution of the ICT sector to GDP, 1993-95**



Source: Statistics Norway and OECD.

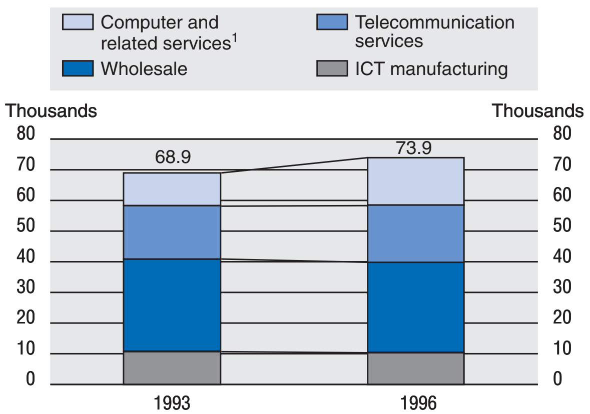
Figure 2. **Share of the ICT sector in GDP[1] and employment, 1993 and 1996**



1. 1995 instead of 1996.

Source: Statistics Norway and OECD.

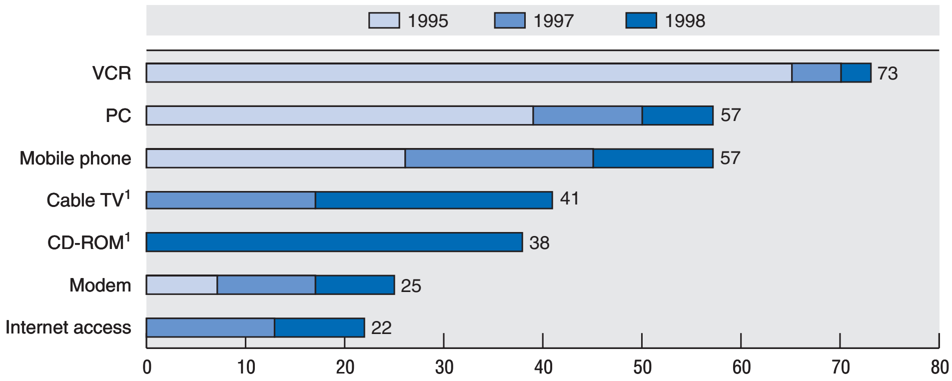
Figure 3. **ICT employment by industry, 1993 and 1996**



1. Includes rental and leasing of office machinery and equipment.

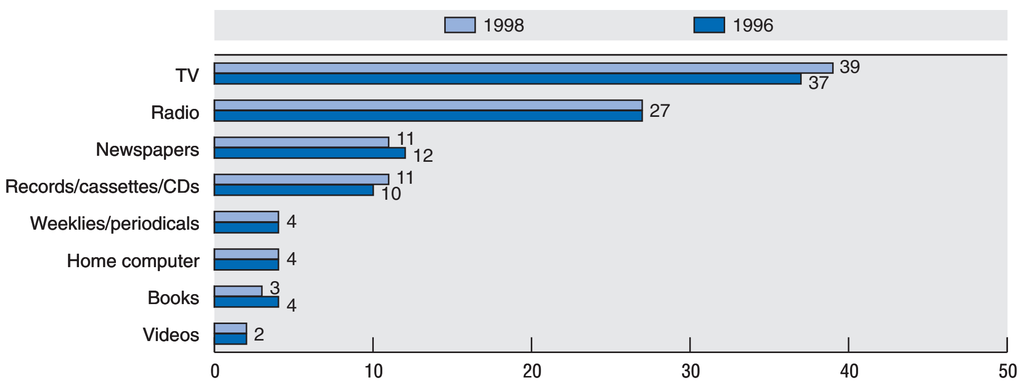
Source: Statistics Norway.

Figure 4. **Diffusion of ICT in households, 1995-98**
Percentage of the population



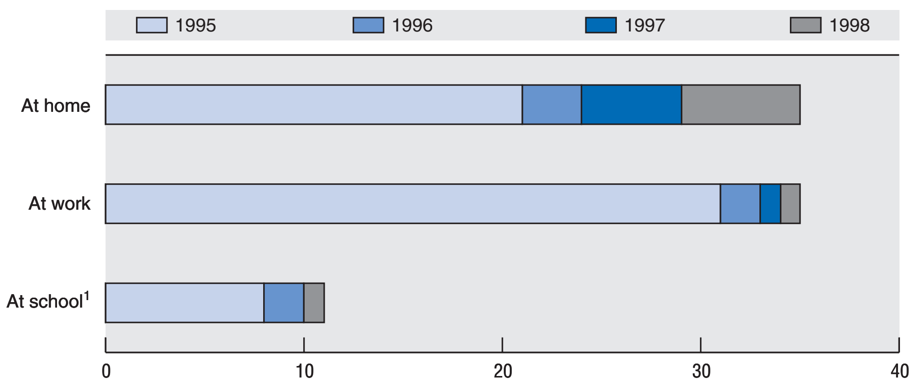
1. 1996 instead of 1997.
Source: Statistics Norway.

Figure 5. **Breakdown of the time spent[1] on mass media on an average day, 1996 and 1998**
Percentages



1. Some uses of media overlap, *e.g.* reading newspapers while listening to music.
Source: Statistics Norway.

Figure 6. **Use of PC an average week, by place of usage, 1995-98**
Percentage of population aged between 9 and 79 years



1. 1996 and 1997 at the same level.
Source: Statistics Norway.

Portugal

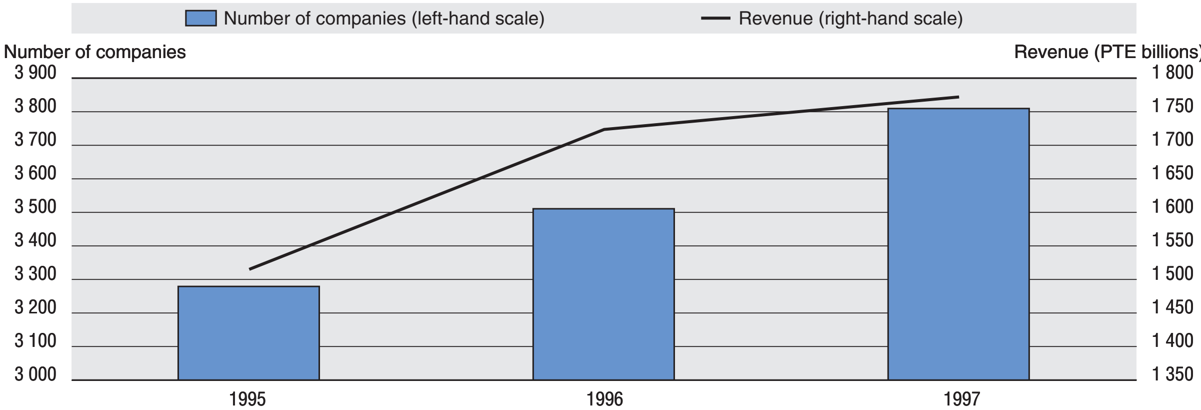
There were approximately 4 000 companies in the ICT sector in Portugal in 1997. Between 1995 and 1997, the average annual growth rate was about 8%. Comparing this figure with the corresponding figure for companies as a whole (5.4%), overall growth was clearly faster in the ICT sector (Figure 1).

The dynamism of the sector can also be seen in the overall sales figures for ICT companies. In 1997, total turnover was approximately PTE 1.8 trillion, with an average annual growth of 8.1%, higher than that recorded for companies as a whole (7.1%) (Figure 1).

In the most recent year studied, the ICT sector accounted for some 76 000 workers. Annual growth between 1995 and 1997 was 1.3%. Employment figures show an increase in the wholesale and computer-related services and a slight decrease in the telecommunications sector. Decreases are concentrated in ICT manufacturing (Figures 2 and 3).

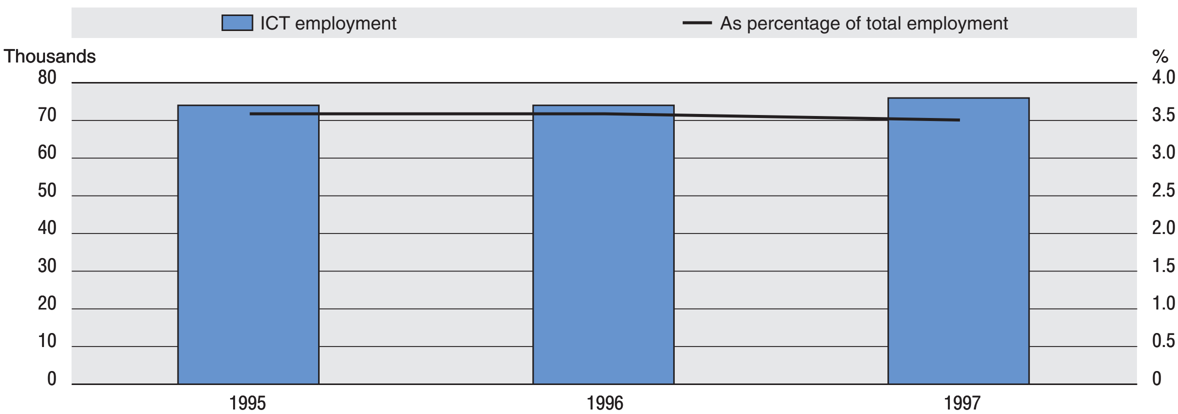
In the ICT sector, jobs generally require higher qualifications. In 1997, the sector had some 9 000 workers with university degree level studies. In the ICT sector, the share of degree-holders as a percentage of the overall workforce was 12.2%. In all other sectors combined, the percentage of graduates in relation to total employment was only 3.6%. Between 1995 and 1997, the annual growth rate in graduate employment in the ICT sector was 14.1%, compared with 10.6% for workers in all companies. In computer-related services demand for graduates is increasing, growing by 24.1% annually between 1995 and 1997. Other segments are quite stable.

Figure 1. **ICT sector companies, 1995-97**



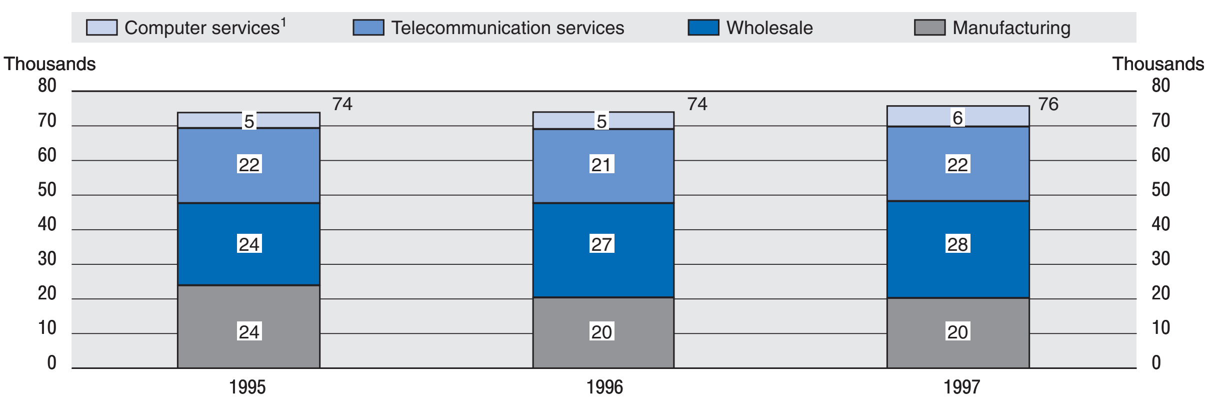
Source: Quadros de Pessoal, Departamento de Estatísticas do Trabalho, Emprego e Formação Profissional do Ministério do Trabalho e da Solidariedade, 1997 and Observatório das Ciências e das Tecnologias, 1999.

Figure 2. **ICT employment, 1995-97**



Source: Quadros de Pessoal, Departamento de Estatísticas do Trabalho, Emprego e Formação Profissional do Ministério do Trabalho e da Solidariedade, 1997 and Observatório das Ciências e das Tecnologias, 1999.

Figure 3. **ICT employment by industry, 1995-97**



1. Includes rental and leasing of office machinery and equipment.
Source: Quadros de Pessoal, Departamento de Estatísticas do Trabalho, Emprego e Formação Profissional do Ministério do Trabalho e da Solidariedade, 1997 and Observatório das Ciências e das Tecnologias, 1999.

Sweden

Between 1994 and 1996, the ICT sector contributed significantly to GDP growth. In 1996, it accounted for almost one-third, and its share in GDP was 6.2%, against 4.9% three years earlier (Figure 1).

In 1996, more than one employee in ten worked in the ICT sector, and eight businesses out of a hundred were engaged in ICT activities (Figure 2). Employment in the ICT sector increased at a compound annual growth rate (CAGR) of more than 8.5% between 1993 and 1996. Computer and related services was the most dynamic sector (CAGR of 18.8%), followed by the wholesale sector. Employment in the telecommunications sector increased only slightly (CAGR of 2.2%). As a result, computer and related services accounted for almost one-quarter of ICT sector employment in 1996, compared to less than one-fifth in 1993 (Figure 3).

In 1996, employees in the ICT sector were younger and had a higher level of education than those in the economy as a whole. In ICT manufacturing, more than 57% of employees were between 25 and 44 years of age (compared to 49% for the economy as a whole), and 36% had tertiary education (compared to 20%). Similar patterns are observed for ICT services, where the share of employees aged 25-44 years and of those with tertiary education were 58% and 40%, respectively.

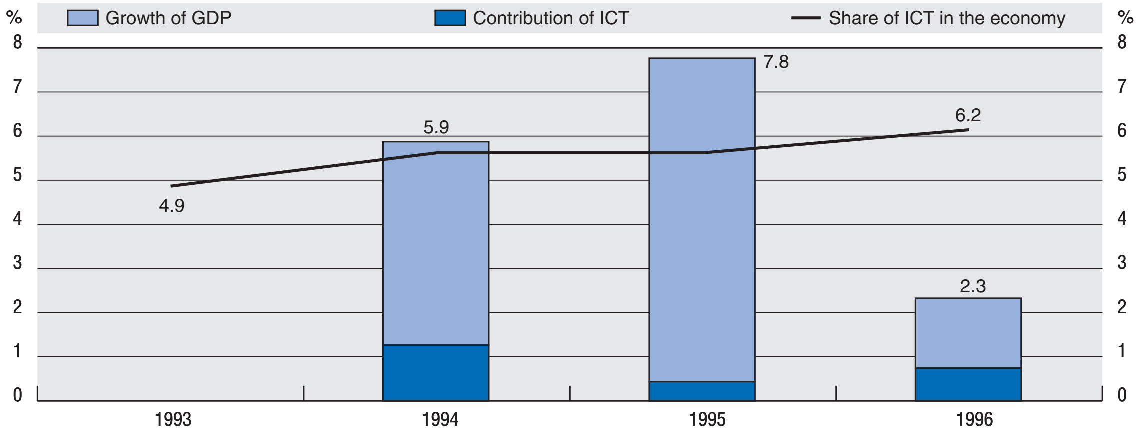
The ICT sector's business enterprise R&D expenditures (BERD) accounted for more than 20% of total BERD in 1993, a share that has probably increased slightly since.

Access to PCs in Sweden (all locations) has increased regularly from 42% in 1989 to 68% in 1997. At work, access to PCs jumped from 32% to 59% between 1989 and 1997. Access rates are quite similar at home and at work for telephone, mobile phone and answering machines, and not very far apart for PCs. Fax is the only medium which has clearly penetrated the workplace much more than the home (Figure 4).

Access to computers at home has increased strongly since spring 1996. At that time, 32% of individuals said that they had access to a computer at home, but the share reached 47% in 1997. Computer access has increased most among the unemployed between 1996 and 1997, from 28% to 55% (Figure 5). Home PCs are used frequently. Already in 1995, almost one in four of the 1.4 million people who used a computer at home used it daily, and one in two at least a few times a week.

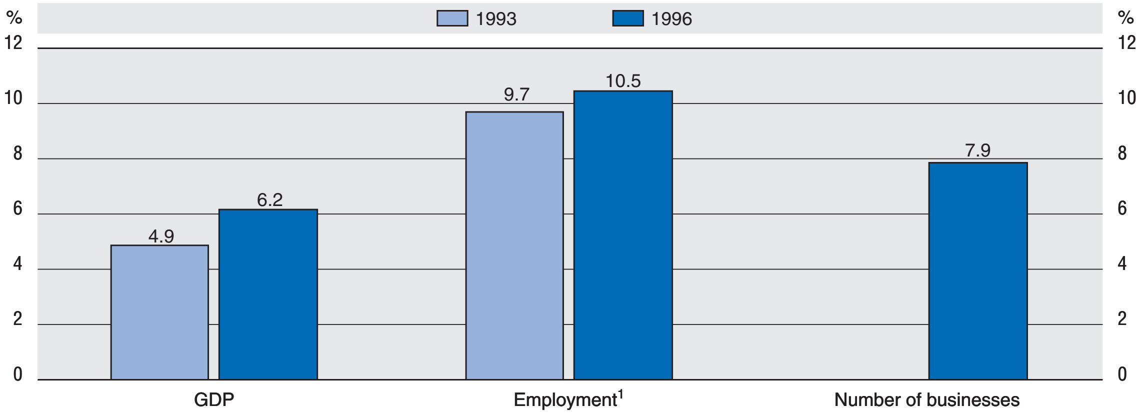
On average, each person has two contacts a day via phone, mobile phone, e-mail, Internet, fax or letter. However, Internet and e-mail are used for less than 8% of these. The youngest age categories have a higher propensity to use Internet and e-mail, as they use them for more than 10% of their daily contacts (Figure 6). Several indicators show that Internet use is spreading quickly throughout the population. The number of Internet users was estimated at 2.6 million in June 1998 and reached 3.6 million in May 1999, or more than 50% of the population. In Stockholm, the share was higher (57%) than in the rest of Sweden (46%).

Figure 1. **Contribution of the ICT sector to GDP, 1993-96**



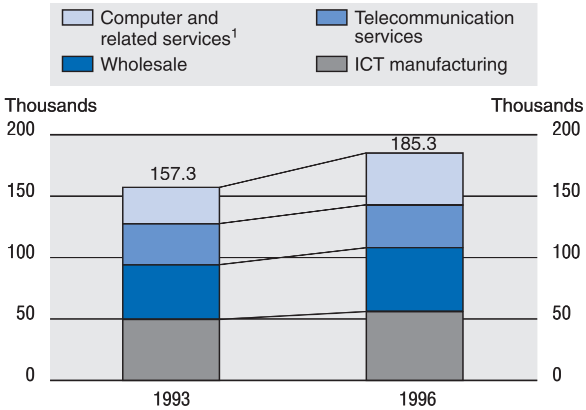
Source: Statistics Sweden and OECD.

Figure 2. **Share of the ICT sector in GDP, employment and number of businesses, 1993 and 1996**



1. Private sector only.
Source: Statistics Sweden and OECD.

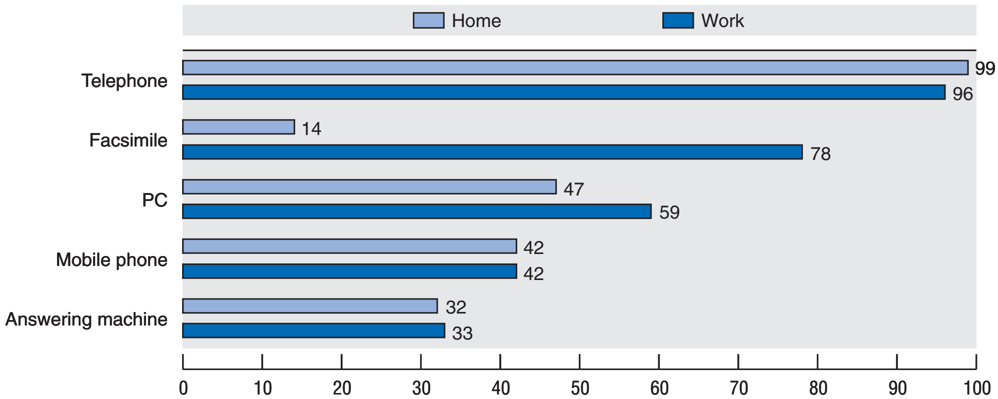
Figure 3. **ICT employment by industry, 1993 and 1996**



1. Includes rental and leasing of office machinery and equipment.
Source: Statistics Sweden.

Figure 4. **Access to ICT at work and home, 1997**

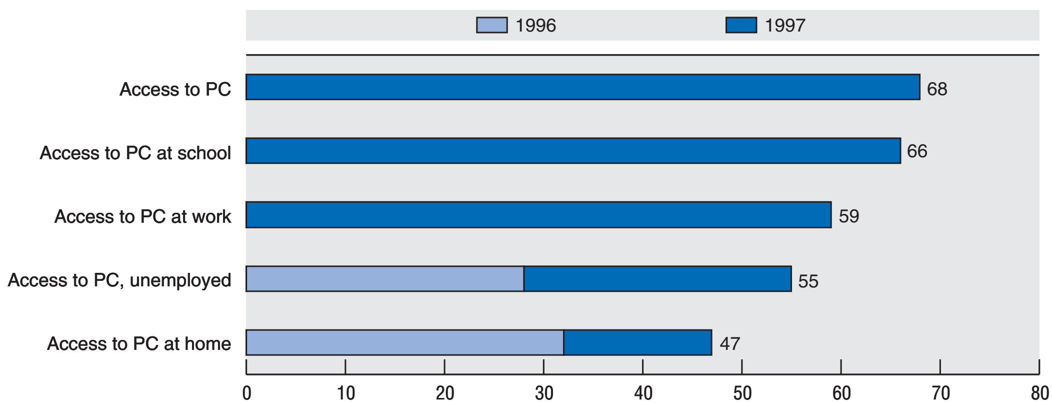
Percentage of the population



Source: Swedish Institute for Transport and Communication Analysis (SIKA).

Figure 5. **Computer access, 1996-97**

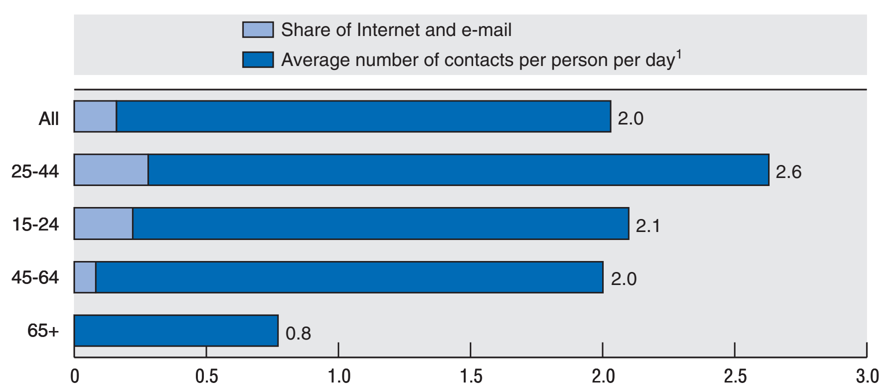
Percentage of the population



Source: SIKA.

Figure 6. **Importance of Internet and e-mail in communication,[1] by age group, 1997**

Percentage of the population



1. For phone, mobile phone, facsimile, letter, e-mail and Internet.

Source: SIKA.

United Kingdom

The relative importance of the ICT sector in the economy is increasing regularly and reached almost 7% of GDP in 1997 (from around 5% in 1993) and about 4% of total employment in 1996 (up from 3.6% in 1995). In 1998, seven firms out of a hundred were doing business in the ICT sector, which is dominated by services. ICT manufacturing activities generated less than one-quarter of total ICT revenue in 1997. Wholesale of ICT products generated the major part of ICT services revenues and was the main driver of growth between 1993 and 1997 (Figure 1).

Employment was highest in the ICT manufacturing sector and in software and computer services (around 30% each), followed by wholesale and telecommunication services (around 20% each). However, the main driver of employment has been software and computer services, with an increase of 15% between 1995 and 1996; this contrasted with a slight decrease in telecommunication services (Figure 2).

In 1997, the ICT sector accounted for almost one-quarter of total business R&D expenditures (Figure 3).

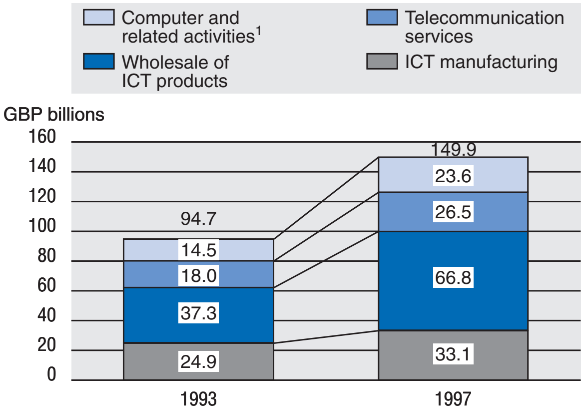
UK trade has been almost in equilibrium in 1996 and 1997. There was a trade deficit in goods, particularly for computers and electronic components, but a trade surplus in telecommunication equipment and instrumentation as well as in services, particularly computer and software services (Figure 4).

The United Kingdom was the first country in Europe where Internet service providers offered free Internet access to households and businesses; other countries (France, Italy) have followed since. Home Internet users in the United Kingdom, who do not pay a fee for accessing the Internet but pay a local call charge, were recently estimated at more than 65% of all Internet users.

Use of ICT grew quite significantly between 1996 and 1998, especially for CD-ROM, Internet and mobile phones. In 1998, while 42% of the population saw the Internet as useful, only 28% had used it; this suggests the potential for significant growth in the coming years. Home ownership of PCs increased from 34% to 44% of the population, but 12% said they never used it. In 1998, 16% had Internet access from home, up from only 4% in 1996, but only 32% of the home PC owners mentioned the Internet as an activity, far behind games and educational activities (73% and 72%, respectively) (Figure 5).

Households' share of expenditures on final consumption devoted to communication services was stable between 1989 and 1997, at slightly less than 2% of the total. For audio-visual, photographic and information-processing equipment, the share declined from 2% to 1.6% during the same period.

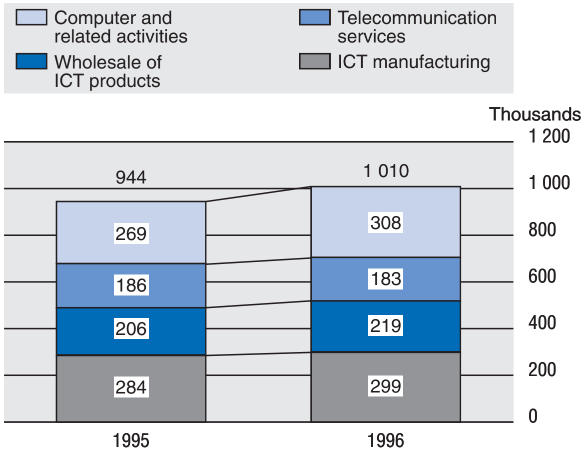
Figure 1. **ICT revenue by industry, 1993-97**



1. Includes rental of office machinery and equipment, including computers.

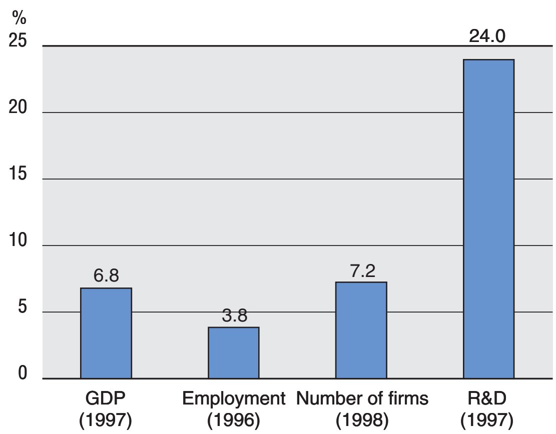
Source: Department of Trade and Industry.

Figure 2. **ICT employment by industry, 1995-96**



Source: Department of Trade and Industry.

Figure 3. **Share of the ICT sector in GDP, employment, number of businesses and R&D, various years**



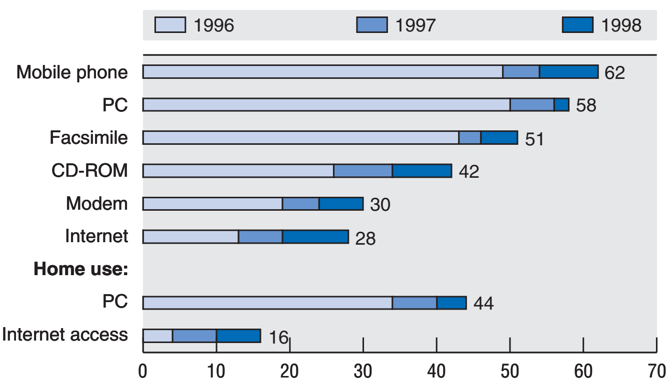
Source: Department of Trade and Industry and OECD.

Figure 4. **Trade in ICT manufacturing and services, 1996-97**

Source: Department of Trade and Industry.

Figure 5. **Use[1] of selected ICTs, 1996-98**

Percentage of people over 15 years of age



1. Percentage of people having used at least once.

Source: Department of Trade and Industry.

United States

Information technology (IT) is increasingly regarded as one of the most significant sources of growth for the US economy. ICT investment has also become the main component of private investment in equipment, and IT equipment contributed to more than half of the annual growth in real capital equipment spending between 1995 and 1998. The relative importance of ICT industries output to GDP appears, in nominal term, modest, even though the share is increasing. However, because prices in these industries are falling rapidly, it is worth noting that over the last four years combined, ICT industries' output has contributed more than one-third of the growth of *real* output in the United States.* Similarly, although employment in ICT industries represents a modest share of total US employment, forecasts indicate that by 2006 almost half of the US workforce will be working in industries that are either major producers or intensive users of ICT (Figures 1 and 2).

Since 1990, ICT industries have made a positive and increasing contribution to the growth of overall private sector employment. Between 1990 and 1998, they created over 1.1 million jobs (compared with around 14.8 million for total private sector employment). The software and computer services sectors are the main drivers, with over 836 000 jobs created during that period; together, they represented a combined share of 1.5% of all US employment at the end of 1998. If IT-related occupations in non-ICT sectors are added, the share of direct and indirect ICT employment reached 7.3% of total employment in 1996 (Figure 3).

The ICT industries' trade deficit increased between 1993 and 1997, owing to the trade deficit in ICT goods. The ICT services trade balance has been in equilibrium, as computer-related services, which accounted for 41% of US global trade in IT services in 1997, generated trade surpluses between 1993 and 1997 which were compensated by the deficit in telecommunication services (Figure 4).

The use of computers is widespread in the workplace, where more than 50% of all workers used computers on the job in October 1997, 5% more than four years previously. Technicians and administrative support workers are among the highest users, before executive and managerial workers. Sales occupations have also significantly increased their computer usage (Figure 5).

Since 1994, diffusion of computers and Internet access have increased in public schools and libraries. In public schools, the average number of students per computer has been divided by ten in less than 15 years, falling from 63.5 to 6.3 between 1984/85 and 1997/98. The Internet access rate has more than doubled in four years, and nine out of ten public schools had access to the Internet at the end of 1998 (Figure 6). In these schools, one instruction room in two was connected to the Internet. Four-fifths of college and university teachers use a computer on the job (compared with 72.5% in October 1993). For other teachers, the share has grown from 49% to 60% over the same period. The share of students using a computer has risen regularly and strongly since 1984. Only 27 out of 100 students used a computer in 1984, compared with 69 out of 100 in 1997.

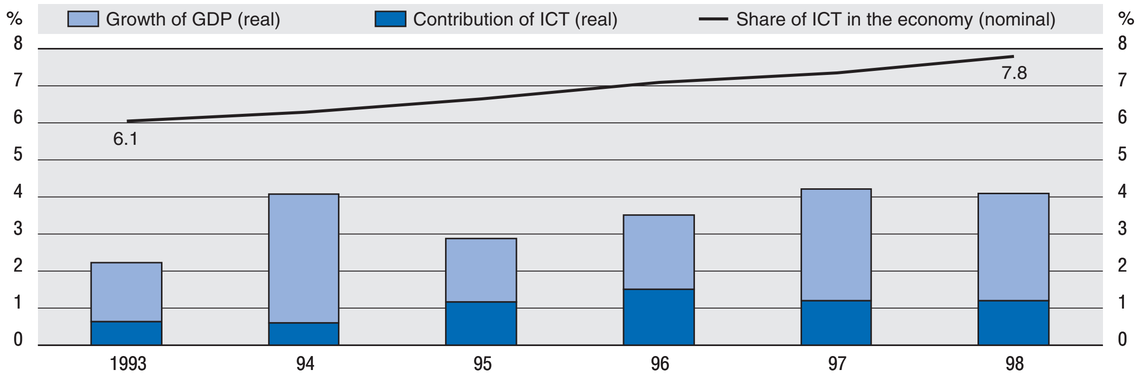
The number of households with Internet access increased very significantly between 1994 and 1998. At the end of 1998, 33.3 million households were connected (24.9 million at the end of 1997), and 10 million did some kind of shopping on line (5 million at the end of 1997). This indicates that around one out of three households with home Internet access is purchasing on line. In the first quarter of 1999, 83 million persons over 16 years of age accessed the Internet, against 66 million one year earlier.

The IT manufacturing industry is a leading industry using electronic commerce to sell final products to consumers and businesses and intermediates (e.g. components) to businesses. According to Forrester Research, the IT industry represented the largest share of total US Internet commerce revenue in 1998 and should remain predominant until 2001 at least. This revenue represented only 5% of the IT market in 1998 but is projected to reach around 30% in 2000.

* Note that these data are not directly comparable with data in nominal prices for other countries. There are major differences among countries in methods of measuring real output in ICT industries. The United States has adopted hedonic pricing for quality adjustment in computers and peripherals, semiconductors, software, cellular phones, telecommunications equipment and televisions. In addition, the United States uses chain-weighting (weighting based on the current year or quarter rather than a fixed base year) for the output of all goods and services. International comparability is being improved between those countries that employ chain-weighted indices in these rapidly changing industries.

Figure 1. **Contribution of the ICT sector to growth in real GDP, 1993-98**[1]

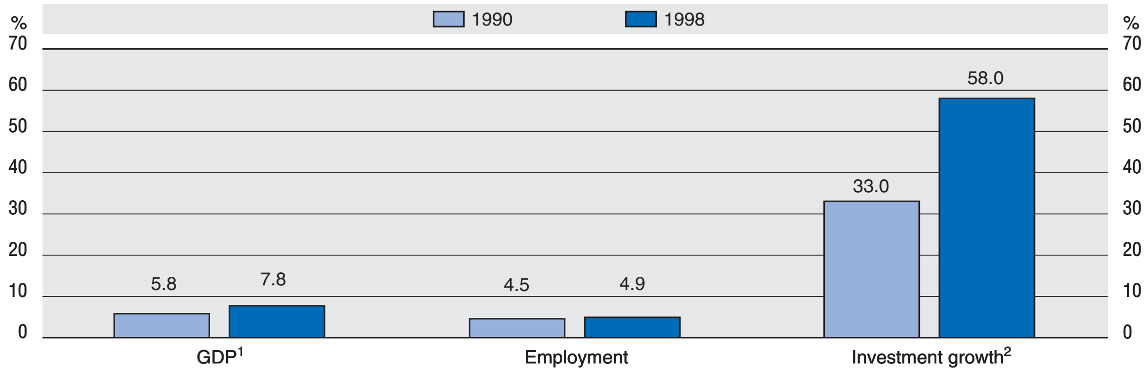
Constant 1992 USD



1. Estimates for 1997-98.

Source: US Department of Commerce, *The Emerging Digital Economy II*, Tables 2.3 and A-2.2, June 1999.

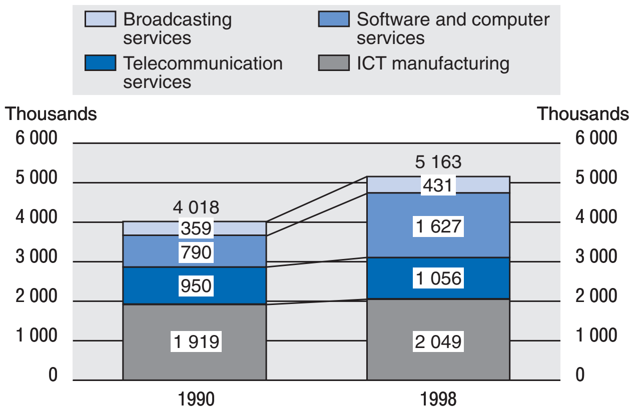
Figure 2. **Share of the ICT sector in GDP, employment, and growth of investment, 1990 and 1998**



1. 1998 estimated.
2. 1993 instead of 1990. Contribution of real growth in investment in IT equipment to real growth in capital equipment investment.

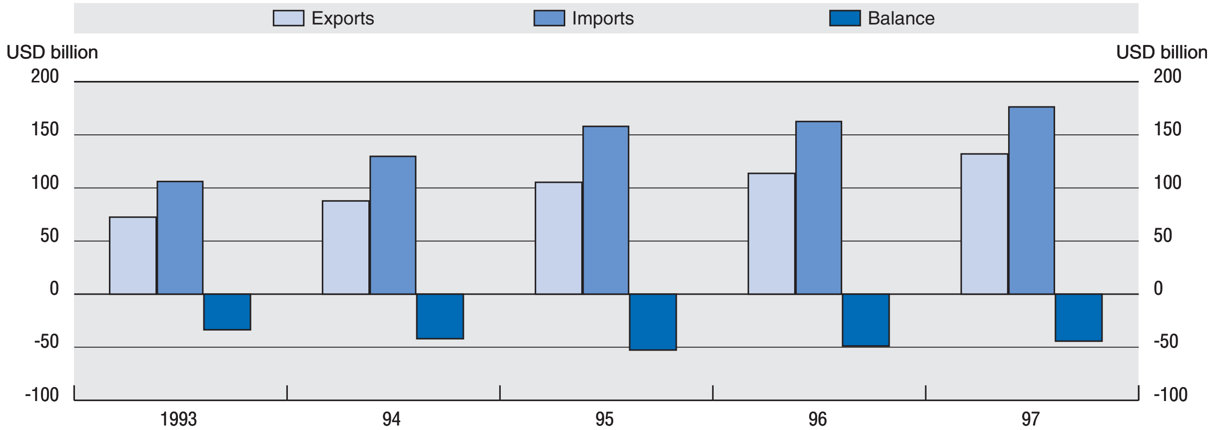
Source: OECD, compiled from US Department of Commerce, *The Emerging Digital Economy II*, Tables 2.5, A-2.2 and A-4.1, June 1999.

Figure 3. **ICT employment by industry, 1990 and 1998**



Source: OECD, based on data from the US Bureau of Labor Statistics, and the methology provided in US Department of Commerce, *The Emerging Digital Economy II*, June 1999.

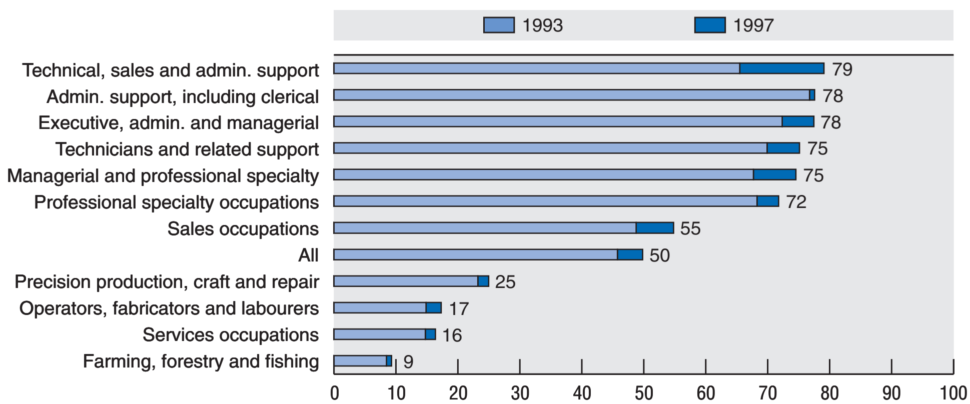
Figure 4. **ICT sector trade, 1993-97**



Source: US Department of Commerce, *The Emerging Digital Economy II*, Appendix, Tables A2-4 et A2-5, June 1999.

Figure 5. **Use of IT at work, 1993 and 1997**

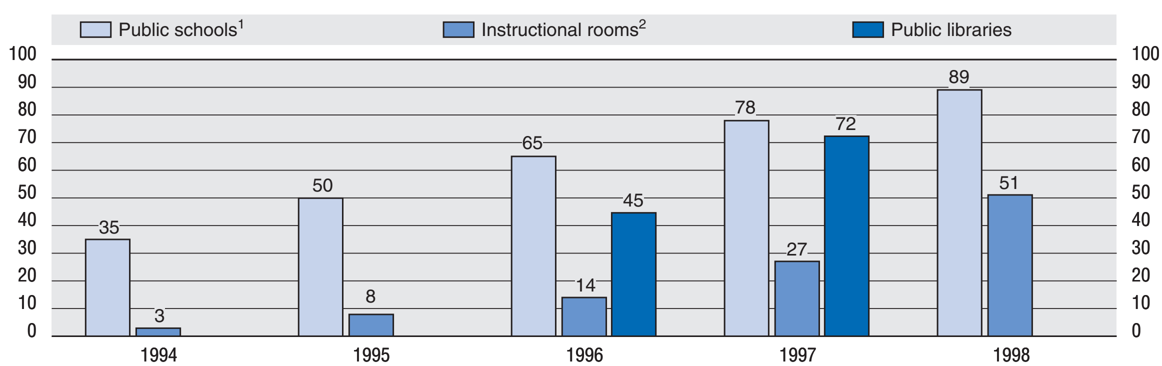
Percentage of employees



Source: US Census Bureau, October 1998, *Statistical Abstract of the United States: 1998*, Table 424.

Figure 6. **Schools, instructional rooms and libraries connected to the Internet at the end of the year, 1994-98**

Percentage

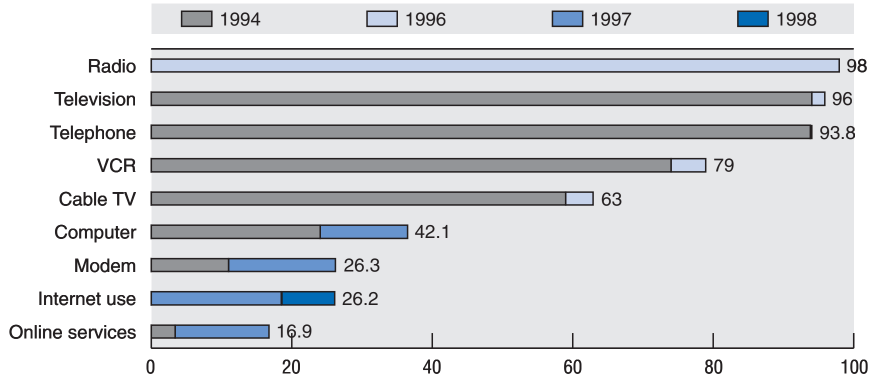


1. Includes all classrooms, computer labs, and library/media centres.
2. At least one outlet in the system connected or offering services.

Source: US Census Bureau, October 1998, *Statistical Abstract of the United States: 1998*, Tables 282 and 333.

Figure 7. **Overall ICT penetration in US households, 1994 and 1996-98**

Percentages



Source: For online services, modem, computer and phone, NTIA, *Falling Through the Net*, July 1998 and July 1999; for other items, US Census Bureau, *Statistical Abstract of the United States: 1998*, Section 18, Table 915, October 1998.

Annex 2

DEFINITIONS AND METHODOLOGY

Over the years, the IT sector has been defined in various ways. Existing standard statistical classifications and systems (both national and international) have been unable to keep up with the rapidly changing character of IT goods and services and IT firms. Now, with convergence of computing and telecommunication technologies, these sectors are often classified into a combined information and communication technology (ICT) sector. This Annex describes definitions and classifications adopted in this rapidly moving area for the purposes of this edition of the *Information Technology Outlook*. Definitions and classifications used, and the data derived from them, will draw to the maximum extent from the work of the OECD Working Party on Indicators for the Information Society (WPIIS) which is working to improve the international comparability of statistics and data on the Information Economy and Information Society.

A sector-based definition of ICT

The agreed OECD definition of the ICT sector is presented below in terms of the International Standard Industrial Classification (ISIC), Revision 3. OECD Member countries are working towards collecting and providing the OECD with a set of data initially based on the industry/activity-based definition of the ICT sector. Work in this area is planned to be presented in a separate statistical publication (see below). However, the work on developing harmonised internationally comparable data sets is in its first stage and data have not yet been fully assessed. As a result, the data in this report are based on disparate sources, depending on the availability of data within individual countries.

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: *goods related*

5150	Wholesale of machinery, equipment and supplies[1]
7123	Renting of office machinery and equipment (including computers)

Services: *intangible*

6420	Telecommunications[2]
7200	Computer and related activities

A commodity-based definition of ICT

The industry-based sector definition, as recorded in international and national industrial classifications, only approximates the ICT sector, which ideally must be based on ICT commodities. As part of its work, the OECD through the WPIIS is developing a commodity-based definition of the ICT sector based on the CPC (Central Product Classification) and the Harmonised System (HS). It is hoped to complete this work in 2000 so as to create an improved database of information about the ICT sector and its outputs.

Statistical compilation methodology

In the first half of 2000, the OECD intends to prepare a statistical publication that brings together available comparable national statistical data about the ICT sector in Member countries. To the extent possible, the publication will use the definition described above. Until then, it is necessary to continue to use other sources for data about the ICT sector. For this report, statistics have been compiled using all available sources, primarily those listed below.

Chapter 1

ICT *production*

Data on production were compiled from Reed Electronics Research, *Yearbook of World Electronics Data* 1999. The six main groups that comprise ICT, followed by their Standard Industrial Trade Classification (SITC Rev. 3) codes, are:

– Electronic data processing (EDP) equipment: 752.1, 752.2, 752.3, 752.6, 752.7, 752.9, 759.9.

– Office equipment: 751.1, 751.2, 763.3 (P), 763.8 (P), 751.3, 759.1.

– Radio communications (including mobiles) and radar: 764.3, 764.8 (P), 764.9 (P), 874.1.

– Telecommunications: 764.1, 764.9 (P), 763.8 (P).

– Consumer equipment: 763.8 (P), 764.8 (P), 761.1, 761.2, 763.3 (P), 763.8 (P), 762.1, 762.2, 762.8, 881.1, 885.3, 885.4, 885.7, 898.2.

– Components: 776.2, 776.3, 776.8, 776.4, 771.1, 771.2, 778.6, 772.3, 772.2, 772.4, 772.5, 764.2, 764.9 (P), 898.4, 761.1, 764.9.

Note: (P) denotes partial coverage.

ICT *trade*

Trade data were extracted from the OECD Foreign Trade Statistics Database (FTS). Four main product groups were retained: computer equipment, electronic components, communication equipment and software. The first three groups were defined using the following SITC Rev. 3 codes:

– Computer equipment: 752, 759.97.

– Electronic components: 772.2, 772.3, 776.1+776.27, 776.3, 776.4, 776.8, 778.6, 776.29.

– Communication equipment: 764.1, 764.3, 764.81, 764.91.

Software goods were defined using the Harmonised System (HS, Rev. 2) and include product groups 852431, 852440, 852491, and 852499.

Chapters 1 and 2

ICT *markets*

Data on markets were compiled from the 1998 World Information Technology and Services Alliance (WITSA) report, *Digital Planet: The Global Information Economy*, and from data provided directly by International Data Corporation (IDC). As the WITSA study uses data from IDC, IDC is the only original source of data on ICT markets. IDC defines information technology markets as revenue paid to vendors for the following main ICT segments:

– IT hardware: computer system central units, storage devices, printers, bundled operating systems and data communications equipment. More specifically, hardware can be broken down into:

  • Multi-user systems make up a classification used to group all computer systems except personal computers and workstations. Multi-user systems include: high-end servers, which are any servers priced at USD 1 000 000 or more; mid-range servers, which are everything above an entry (low-end) server and below a high-end server. The definition is based strictly on the price of the server, which must be between USD 100 000 and USD 999 999. Low-end servers are those priced below USD 100 000.

  • Single-user systems are workstations, personal computers, and PC add-ons.

  • Data communications includes LAN hardware (restricted to the equipment for multi-user systems, PCs, or workstations required to implement a local area network, but excluding software) and other data communication equipment (such as modems, multiplexers, digital switching equipment, communication processors, cluster controllers and channel extenders).

– IT services and software:

  • IT software: purchases of software products and external customisation of computer programmes. This includes systems software and utilities, application tools and application solutions.

  - IT services: IT consulting, implementation services, operations management, IT training and education, processing services and IT support services.
  - For Chapter 1 only, internal IT spending was added to IT services and software. Internal IT spending includes the internal portion of the information system operating budgets, internally customised software, capital depreciation and any other expense related to IT that cannot be tied to a vendor.
- Telecommunications: expenditure on public network equipment (such as switching, transmission, and mobile communications infrastructure), private network equipment (such as telephone sets, PBXs and key systems, mobile and other equipment) and telecommunications services (such as fixed and mobile telephony, switched data, leased lines and cable TV services).

In Chapter 1, the whole ICT sector is included in order to provide a more accurate measurement of the broader impact of these technologies economy-wide. In Chapter 2, which analyses trends in IT markets, a narrower definition is used, which excludes telecommunication markets and includes only IT hardware, software and services without internal IT spending.

Chapter 2

Semiconductors

Data are provided by the World Semiconductor Trade Statistics (WSTS), an industrial association of about 70 semiconductor manufacturers representing about 90% of the market in terms of value of production. WSTS produces detailed statistics for its members. The figures provided cover only the "commercial" (merchant) semiconductor market and not internal or "captive" consumption.

Appendix 1.* ICT *statistical profiles

Statistical profiles have been based, as much as possible, on official statistical sources. On the supply side (ICT-producing sector), while the profiles may appear similar in terms of the indicators selected, they differ slightly owing to differences in national sources and definitions, which are not always fully compatible with international classifications and the OECD sector-based definition (see above). On the demand side (ICT-use indicators) and on electronic commerce, work is currently under way to achieve harmonised indicators. Those presented in the profiles are quite heterogeneous and differ from one country to another. Sources and major characteristics are indicated below.

Australia

The statistical profile of Australia is based on the following references:

- Australian Department of Communications, Information Technology and the Arts (1999), *Australia's e-commerce report card*, <http://www.dcita.gov.au/nsapi-text/?MIval=dca_dispdoc&ID=3789>.
- ABS (1999), *Year Book Australia* 1999, Chapter 24, Communications.
- ABS (1995), *Information Technology Australia* 1992-93, Cat. N.8126.0, 25 May.
- ABS (1997), *Information Technology Australia* 1995-96, Cat. N.8126.0, 5 December.
- ABS (1998), *Small and Medium Enterprises, Business Growth and Performance Survey* 1996-97, Cat. N.8141.0, 11 September.
- ABS (1999), *Small and Medium Enterprises, Business Growth and Performance Survey* 1997-98, Cat. N.8141.0, 10 September.
- ABS (1999), *Business Use of Information Technology*, Cat. N.8129.0, 9 May 1999 and Cat. N.8133.0, 30 April.
- Centre for Strategic Economic Studies, Victoria University (1999), *Information Technology Trade Update* 1999, John Houghton, Australia.
- J. Houghton, M. Pucar and C. Knox (1996), *Mapping the Information Industries*, July.
- ABS (1999), *Use of Internet by Householders*, May 1999, Cat. N.8147.0, 6 September.
- ABS (1999), *Telecommunication Services*, 1996-97, Cat. N.8145.0, 3 January.

The ICT sector is based on the Australian and New Zealand Standard Industrial Classification (ANZSIC). It includes, for the profile, the following sectors (see ABS, *Information Technology Australia* 1995-96, Table 2, ABS Cat. N.8126.0, December 1997):

2841	Computer and business machines
2842	Telecommunication, broadcasting and transceiving equipment
2849	Electronic equipment n.e.c.
2852	Electric cable and wire
4613	Wholesale trade of computers

4614 and 4615	Wholesale trade of business machines; electrical and electronic equipment n.e.c.
7120	Telecommunication services
7831 to 7834	Computer services

ICT BERD includes, for the statistical profile, the R&D expenditure of businesses in the following industries:

2430	Recorded media manufacturing and publishing
2839	Professional and scientific equipment manufacturing n.e.c.
284	Electronic equipment manufacturing
2852	Electric cable and wire manufacturing
4613	Computer wholesaling
4614	Business machine wholesaling n.e.c.
4615	Electrical and electronic equipment wholesaling n.e.c.
7120	Telecommunication services
783	Computer services

Canada

Canada's statistical profile is based on the following references:

- Industry Canada (Spectrum, Information Technologies and Communication Sector) (1999), *Information and Communication Technologies* (ICT) *Statistical Review* 1990-1997, May, <http://strategis.ic.gc.ca/SSI/it/ictsr.pdf>.
- Statistics Canada (1996), *Survey of Technology Diffusion in Service Industries*, <http://strategis.ic.gc.ca/SSI/it/survey.pdf>.
- Statistics Canada (1999), *Technology Adoption in Canadian Manufacturing*, 1998, August.
- Task Force on Electronic Commerce (1999), News Release, 19 August, <http://e-com.ic.gc.ca/english/41.html#>.
- Industry Canada (1999), *Canadian Internet Commerce Statistics Summary Sheet*, 4 June, <http://e-com.ic.gc.ca/using/en/e-comstats.pdf.>.

The ICT sector is based on the Canadian Standard Industrial Classification (CANSIC), but approximates the OECD definition. For more detail, see ICT *Statistical Review* 1990-1997, p. 82.

Denmark

Denmark's statistical profile is based on the following sources:

- Statistics Denmark (1999), *Danish IT-pictures, Status Report, Digital Denmark*, Ministry of Research and Information Technology, April.
- Statistics Denmark (1999), *Danske virksomheders brug af informtionsteknologi* 1998 [use of information technology by Danish businesses], Danish only, April.
- Nordic Council of Ministers (1998), *The Information and Communication Technology Sector in the Nordic Countries – A First Statistical Description*, TemaNord, 587.
- Eurostat (1998) *Communication de Statistics Denmark*, Actes de la 83^{e} conférence des DGINS, Helsinki, May 1997.

The ICT sector is based on NACE Rev. 1 and approximates the OECD definition.

Finland

Finland's statistical profile is based on the following reference:

- Statistics Finland (1999), *On the Road to the Finnish Information Society* II. An Executive Summary can be found at <http://www.stat.fi/tk/yr/tttietoti_en.html>.

The ICT sector is based on NACE Rev. 1 and approximates the OECD definition.

For R&D by product group, ICT products include: electronics and telecommunication equipment, instrument and precision mechanics, data processing and programming services, computer and office machinery, and radio and television receivers, sound and image recording. Publishing and printing were not taken into account in order to respect the OECD definition.

Use of IT at work is defined as employees spending at least some working time using the following IT equipment: PC or computer terminal, cash register, word processor, programmable machine, computer device used to control production processes, or any other computer-aided control, measurement or supervision device.

Information society expenditures are defined as the sum of seven expenditure items, which include telecommunications cost, computer costs, electronic entertainment, etc. For further details see Statistics Finland (1999), *On the Road to the Finnish Information Society* II, Table 8.1.3, p. 183.

Data on Internet connections at home are from Member State Study II, *Usage of Electronic Services in Private Households, at Work or at School* (in Finnish). Cited in Statistics Finland (1999), *On the Road to the Finnish Information Society* II, pp. 187-196.

France

The statistical profile of France is based on the following references:

- INSEE (1999), "Les comptes de la nation en 1998, forte consommation et très faible inflation", INSEE *Première*, No. 645, May, <ftp://ftp.insee.fr/vf/produits/pub/prem/ip645.pdf>.
- INSEE (1999), "Les technologies de l'information et de la communication: 5% du PIB", INSEE *Première*, No. 648, May, <ftp://ftp.insee.fr/vf/produits/pub/prem/ip648.pdf>.
- Ministère de l'Économie, des Finances et de l'Industrie (1999), *Technologies et société de l'information*, édition 1999, March.
- INSEE (1999), *Les entreprises de services en* 1997, Tome 1, July.
- Ministère de l'Emploi et de la Solidarité, DARES (1998), "En 1998, plus d'un salarié sur deux utilise l'informatique dans son travail", *Premières synthèses*, No. 53.2, <http://www.travail.gouv.fr/publications/picts/titres/titre316/integral/texte53_2.pdf>.
- Dominique Strauss-Kahn (1999), Statement at the meeting of the OECD Council at Ministerial level, Item 3, Growth, Employment and Social Cohesion – Policy Priorities for OECD Governments, 27 May.
- UFB *Locabail*, *Enquête* PME-PMI *informatique et bureautique*, et *Enquête* PME-PMI *Internet*, différentes années, <http://www.ufb-locabail.fr/IndEnq.htm>.
- Médiangles (1999), Press release, April, <http://www.mediangles.fr>.
- Ministère de l'Éducation nationale (1998), cité dans *Les Echos*, 2 September.

The ICT sector is based on NAFE but approximates the OECD definition.

Italy

Italy's statistical profile is based on the following references:

- L. Fenga, G. Perani, F. Riccardini and G. Trovato (1998), "ICT Supply Side: An Analysis of Some Statistical Sources for Italy", paper presented at the 13th Voorburg Group Meeting, Rome, September.
- L. Fenga, F. Riccardini and G. Trovato (1998), "ICT Demand Side: An Analysis of Some Statistical Sources for Italy", paper presented at the 13th Voorburg Group Meeting, Rome, September.
- F. Riccardini and A. Nurra (1999), "E-commerce in Italy", draft, 30 January.
- *Financial Times* (1999), "Italians Fall in Love with Mobile Phones", 13 August.

The ICT sector is in line with the OECD definition.

Japan

Japan's statistical profile is based on the following references:

- Japan Information Services Association (JISA) (1998), *Statistical Survey on Software Trade*, 26 October.
- Ministry of Post and Telecommunication (MPT) (1999), *Communication White Paper.*
- Electronic Industries Association of Japan (EIAJ) (1999), *Facts and Figures on the Japanese Electronics Industry.*
- MPT, *Telecommunications Services Usage Survey* and *Communications Equipment Usage Survey*, various years.
- Economic Planning Agency (EPA), "Households with Selected Consumer Durables", <http://www.stat.go.jp/1616.htm#jf16-04>.
- EPA and Ministry of Education, Sciences, Sport and Culture, *Survey on the Status of* IT *in Public Schools*, various years.
- *Nikkei Weekly* (1999), "PC Sales Hit Record Levels amid Demand for Email, Internet Access", 30 August.
- Nikkei Research (1999), *Informatisation at Home Survey*, March.
- Info-Com Research Inc. <http://www.icr.co.jp/index_j.html>.

The ICT sector, as published in the MPT *Communication White Paper* (1999), approximates the OECD ICT definition and includes the following sectors: ICT equipment production, telecommunication infrastructure construction, ICT equipment leasing, telecommunication services, information software, information-related services.

Estimates of the ICT sector's R&D as a share of the total BERD is taken from the *Communication White Paper.* On the OECD definition, the share should clearly be smaller, as the info-communication sector includes content-related sectors which are not included in the OECD definition.

The number of Internet stores offering transactions for final consumption was estimated by Nomura Research Institute (NRI), and is cited in the *Communication White Paper* 1999. NRI defines final consumption transactions as involving business-to-consumer transactions and business-to-business transactions for final consumption.

Norway

The statistical profile of Norway is based on the following references:

– Statistics Norway (1998), "Statistikk om informasjonsteknologi, status, behov og utviklingsmuligheter", 98:1.
– Nordic Council of Ministers (1998), "The Information and Communication Technology Sector in the Nordic Countries – A First Statistical Description", *TemaNord*, 587.
– S. Longva, General Director, Statistics Norway (1997), "Quelle connaissance les statisticiens ont-ils de la société de l'information et des besoins nouveaux des utilisateurs de statistiques", in Eurostat, Actes de la 83e conférence des DGINS, Helsinki, May.
– Norsk Gallup Institut (1999), "The Internet in Norway: Methods, the Market, Electronic Newspapers: An Update", <http://www.gallup.no/menu/media/internett/resultater/annet/Emro_98_kaf.ppt>.
– Statistics Norway (1999), *Weekly Bulletin*, Issue No. 13-14, "Norwegians Spend Less Time Reading", Online summary, <http://www.ssb.no/english/weekly_bulletin/editions/9913-14/2.html>.
– Norsk Gallup Institut (1999), "A Time Budget Study with New Qualitative Media Data", <http://www.gallup.no/menu/media/english/GTM_EMRO_99/sld001.htm>.
– IDC for the Nordic Council of Ministers (1998), "The Nordic ICT-O Survey: Preliminary Results", May, Room Document No. 6, 5th meeting of the Working Party on the Information Economy, October, OECD, Paris.

The ICT sector is based on NACE Rev. 1 and approximates the OECD definition.

Portugal

Portugal's statistical profile is based on the following sources:

– Quadros de Pessoal (1997), Departamento de Estatísticas do Trabalho, Emprego e Formação Profissional do Ministério do Trabalho e da Solidariedade.
– Observatório das Ciências e das Tecnologias (1999).

The ICT sector is based on NACE Rev. 1 and approximates the OECD definition.

Sweden

The statistical profile of Sweden is based on the following references:

– Swedish Institute for Transport and Communication Analysis (SIKA) (1998), "IT-Utvecklingen och Transporterna 2", Swedish only.
– TELDOK (1998), TELDOK *Yearbook* 1997.
– Statistics Sweden (1996), *Data om informationstekniken i Sverige*, Swedish only.
– Statistics Sweden (1995), *Dator Vanor* 1995, Swedish only.
– Nordic Council of Ministers (1998), *The Information and Communication Technology Sector in the Nordic Countries – A First Statistical Description*, *TemaNord*, 587.
– Business Arena Stockholm (1999), "Internet and New Media", <http://www.bas.stockholm.se>.
– SIFO Interactive, <http://www.sifointeractive.com/e_index2.html>.

The ICT sector is based on NACE Rev. 1 and approximates the OECD definition.

As the ICT sector's business enterprise R&D expenditures (BERD) accounted for more than 20% of total BERD in 1993, it should be noted that the BERD of Sectors 30, 32 and 72 of SITC Rev. 3, which are only part of the total ICT sector according to the OECD definition, accounted for more than 22% of total BERD in 1995 (OECD ANBERD database, 1999).

United Kingdom

The United Kingdom's statistical profile is based on data provided to the OECD by the Department of Trade and Industry (DTI). For households' share of expenditures on final consumption devoted to communication services, see:

– National Statistical Office, *United Kingdom National Accounts* 1998.

The ICT sector is based on NACE Rev. 1 and approximates the OECD definition.

Home Internet use in the United Kingdom has been estimated by Goldman Sachs. See *Freeserve*, Goldman Sachs, 24 August 1999.

United States

The statistical profile of the United States is based on the following references:

– US Department of Commerce (1999), *The Emerging Digital Economy* II, June, <http://www.ecommerce.gov/ede/ede2.pdf and http://www.ecommerce.gov/ede/APPEND.PDF>.

– National Telecommunication and Information Administration (NTIA), *Falling through the Net* II, <http://www.ntia.doc.gov/ntiahome/net2/>.

– National Telecommunication and Information Administration (NTIA), *Falling through the Net* III, <http://www.ntia.doc.gov/ntiahome/fttn99/contents.html>.

– US Bureau of the Census (1998), *Statistical Abstract of the United States*: 1998, October, Tables 281, 282, 333, 424 and 915.

– National Center for Education Statistics (1999), *Digest of Education Statistics*, 1998 *Edition*, March. See Table 428, p. 484, <http://nces.ed.gov/pubs99/1999036.pdf>.

The ICT sector is based on the US Standard Industrial Classification (SIC) and approximates the OECD definition, but also includes the following sectors:

5734 (part)	Retail trade of computer equipment
4832	Radio broadcasting
4833	Television broadcasting
4841	Cable and other pay-TV services

The complete list of the US industries is listed in the appendices of *Digital Economy* II, Table A-2.1.

Data on the number of households connected to the Internet at the end of 1998 and on shopping on line are from Forrester Research, <http://www.Forrester.com>.

In 1998, the IT industry represented 45% of total US Internet commerce revenue. This was only 5% of the IT market, its share is projected to reach around 30% in 2000. These ratios should be interpreted as order of magnitude: they were calculated by the OECD from data from Forrester Research (*Resizing Online Business Trade*, Forrester Research, 1998) and the European Information Technology Observatory (EITO) (EITO, 1999).

The share of electronic shopping and mail-order firms in total retail trade was provided by the US Bureau of the Census, Press Release, 20 May 1999. The Boston Consulting Group, a consultancy, estimated (July 1999) that the top 50 US e-commerce Web sites accounted for around three-quarters of the revenue, and the top ten for about 43%.

NOTES

1. Where available, countries should only include those subsectors of this industry that directly provide ICT wholesaling services. This will avoid the inclusion of extraneous wholesaling activity. For example, using the NACE nomenclature, only NACE categories 5143, 5164 and 5165 should be included.
2. In those instances where countries include telecommunication activities as part of radio and television activities (ISIC 9213), then radio and television activities should be included in the definition of the ICT sector. Otherwise, they should not be included.

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