

INFORMATION TECHNOLOGY OUTLOOK

1997



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**INFORMATION
TECHNOLOGY
OUTLOOK
1997**

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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FOREWORD

The *Information Technology Outlook 1997* has been prepared by the OECD Secretariat under the guidance of the OECD's Committee for Information, Computer and Communication Policy. It is the fourth in a biennial series designed to provide Member governments with analysis of the trends in the Information Technology industry and the impact of information technologies on the economy. A common theme throughout the 1997 edition is the shift towards networked computing and its implications for producers and users.

Building on the 1995 edition, the 1997 edition has further extended the economic and policy analysis. The description of the IT market and the role of IT in the broader economy in Part I has been enlarged to include more in-depth analyses of the economic impact of IT: the impact of IT networks on organisational structure, accounting for IT quality changes in productivity measurement, the globalisation of IT firms, and the use of IT in the home. The policy analysis of Part II looks at the use of electronic information systems by governments, with a special focus on the use of IT as a tool for lifelong learning. Part III is new. It attempts to provide a forward perspective by

analysing some key issues that are likely to shape the IT field in the near future: the development of the Internet (Internet congestion), recent developments in software (component software and data mining), and the business application of IT technologies (IT and the packaged consumer goods industry).

The *Information Technology Outlook* draws on official data sources, notably those of the OECD Member governments and the OECD itself, as well as other international organisations such as the International Telecommunication Union (ITU) and the International Organisation for Standardization (ISO). The collaboration of the European Commission is gratefully acknowledged. Several private sector sources kindly provided data and information unavailable elsewhere, notably the International Data Corporation (IDC), Dataquest, and the Software Publishers Association (SPA). The EITO (European IT Observatory) Task Force provided data; a number of press sources were also used. The Secretariat and the Committee acknowledge with gratitude the help received from these organisations.

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

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Part I

INFORMATION TECHNOLOGY SCOREBOARD

The Information Technology Scoreboard has four sections. The first analyses information technology (IT) markets at world level, as well as in OECD Member countries and non-member countries where IT production or consumption is important. The second and third examine two dynamic segments of the IT market: the semiconductor industry and network-based computing. The final part places the IT industry in the broader context of the economy as a whole.

1. IT MARKETS

The world market: an overview

In 1995, the world IT market, as measured by the revenues of primary vendors, was worth an estimated US\$527.9 billion.¹ Between 1987 and 1994, its growth rate averaged nearly twice that of gross domestic product (GDP) worldwide (Table 1.1), and in all but five of the countries considered, growth in the IT market outstripped growth in GDP. It was particularly high in Asia and some of the dynamic Asian economies (DAEs) but also in certain South American countries.

This strong growth did little to redress the geographical imbalance in the world IT market. In 1994, OECD countries still accounted for almost 92 per cent of the market, compared with 93.7 per cent in 1987. The slight decrease in the OECD share was captured by Asia (excluding Japan). Over the same period, the Asian market (including Japan) climbed from 17.5 to 20.9 per cent of the world market, with the share for Japan growing from 15.2 to 16.9 per cent (Table 1.1). Markets outside Asia and the OECD area remained at around 4 per cent of the world total (Figures 1.1 and 1.2).

From 1985 to 1995, the world IT market underwent a structural change involving two broad trends. The first was a downward trend in the relative importance of hardware and a corresponding rise in software/services, which climbed from 46.6 to 52.1 per cent of the world market over this period; most of the increase was attributable to software (from 13.5 to

18.4 per cent) (Annex Table 1). The second was the increasing popularity of personal computers (PCs) and workstations, up from 21 to almost 31 per cent of the world market. Computer-related communication equipment rose from 3.0 to 4.5 per cent. Other hardware (large-scale systems, mid-size systems and mini-computers) dropped from 30 to 13 per cent of the total IT market. Mainframes declined from 11 to just under 4 per cent (Figure 1.3, Annex Table 1).

OECD countries

In the OECD area since 1987, the IT market has remained concentrated within the G7 countries, at around 88 per cent. The United States still stands as the largest market with over 46 per cent; the slight decrease from 1987 has mainly benefited Japan, Germany, and Canada. Turkey, Hungary, Mexico, and New Zealand, Germany and Canada are the OECD countries with the strongest average growth in their IT markets since 1987 (Figure 1.4). In Japan, after the recession of the early 1990s, the market is growing again. It rose sharply in 1995 due to the growing popularity of PCs and the concurrent expansion in sales of packaged software. Europe, with its highly differentiated markets, is a region of contrasts, where factors such as significant government budget cuts in some countries or the implementation of national information-highway projects have a strong influence on IT sales.

Between 1987 and 1993, growth in OECD countries' IT markets was largely driven by services, and to a lesser extent by software. Several broad trends are evident: a marked increase in data communication equipment and a sharp increase in PCs and workstations; a relative decrease in systems software and utilities and a marked rise in applications tools; finally, a sharp rise in IT services. Mainframes are the only segment to have contributed negatively to market growth over the period studied (Figure 1.5 and Table 1.2).

Everywhere except in Hungary, the decline in multi-user systems has been greater than the

Table 1.1. **Worldwide information technology market and GDP**Percentage¹

	1987	1994	1987-94 IT market CAGR	1987-94 GDP CAGR	CAGR Difference (IT-GDP)	1994 IT/GDP
North America	47.4	45.1	9.1	5.9	3.2	2.7
United States	44.8	41.4	8.7	5.7	3.0	2.8
Canada	2.3	2.9	13.5	4.0	9.5	2.4
Mexico	0.3	0.7	25.3	15.0	10.3	0.9
Japan	15.2	16.9	11.5	9.0	1.7	1.7
Oceania	2.0	2.1	10.2	6.3	3.9	2.5
Australia	1.8	1.7	9.5	6.6	2.9	2.4
New Zealand	0.3	0.3	14.4	4.7	9.7	3.0
Europe	29.1	27.6	9.1	6.5	2.6	1.6
Austria	0.6	0.6	11.4	7.6	3.8	1.5
Belgium	1.0	0.9	8.9	7.2	1.7	1.8
Denmark	0.5	0.5	9.8	5.3	4.4	1.7
Finland	0.6	0.3	2.0	1.2	0.8	1.6
France	5.3	4.8	8.3	5.8	2.5	1.6
Germany	5.9	7.2	13.1	9.1	4.0	1.6
Greece	0.2	0.1	3.6	7.7	-4.1	0.6
Hungary	0.1	0.1	26.2	7.5	18.7	1.6
Ireland	0.2	0.1	9.1	7.5	1.6	1.3
Italy	3.4	2.5	5.0	4.3	0.7	1.1
Netherlands	1.3	1.5	11.8	6.1	5.8	2.1
Norway	0.5	0.4	8.4	3.9	4.5	1.8
Portugal	0.2	0.2	7.6	11.1	-3.5	1.0
Spain	1.4	1.1	6.5	7.3	-0.8	1.1
Sweden	1.3	0.9	4.7	2.7	2.0	2.2
Switzerland	1.2	1.3	11.1	6.2	5.0	2.3
Turkey	0.0	0.1	24.8	6.4	18.4	0.4
United Kingdom	5.5	4.7	7.6	5.7	1.9	2.1
OECD 24	93.7	91.6	9.5	6.9	2.6	2.0
DAEs	1.7	2.8	17.6	16.7	0.9	1.2
Chinese Taipei	0.4	0.4	11.7	13.1	-1.4	0.8
Hong Kong	0.2	0.4	23.6	15.1	8.5	1.2
Malaysia	0.1	0.2	16.8	12.2	4.6	1.3
Singapore	0.2	0.3	17.2	19.3	-2.1	1.9
Republic of Korea	0.8	1.4	19.0	15.6	3.3	1.6
Thailand	0.1	0.2	16.2	16.0	0.2	0.6
China	0.3	0.6	22.6	10.0	12.6	0.5
India	0.2	0.3	20.0	2.3	17.7	0.5
Indonesia	0.1	0.2	24.2	12.8	11.4	0.4
Philippines	0.0	0.1	25.5	9.0	15.6	0.5
Argentina	0.1	0.3	37.8	14.6	23.2	0.5
Brazil	1.1	1.1	10.0	9.5	0.5	0.9
Colombia	0.1	0.1	23.7	9.2	14.5	0.8
Venezuela	0.0	0.1	26.2	2.8	23.4	0.7
World	235 110	455 000	9.9	5.7	4.2	1.8

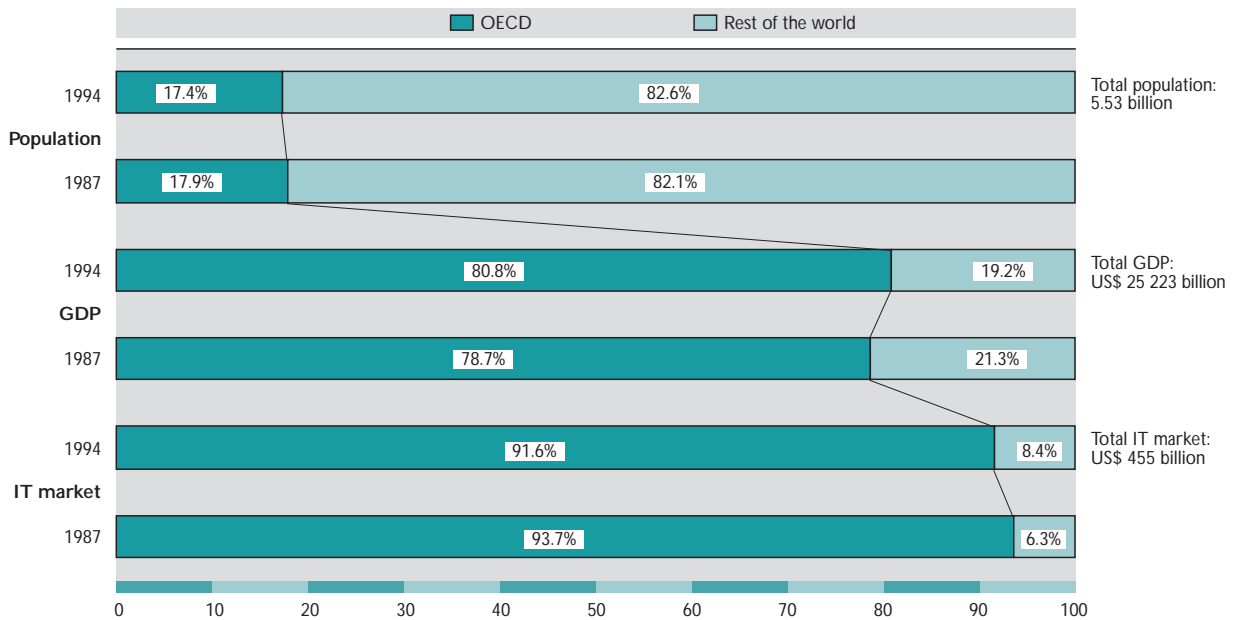
1. Except world total in million US\$.

Source: OECD Secretariat, based on IDC (1995b), World Bank (1995) and OECD (ANA Database) data.

increase in the combined share of PC/workstations and data communication equipment. The result has been a very clear decline in hardware expenditure, which now accounts for less than half of total IT spending in 14 of the 24 countries considered, against only six countries eight years earlier.

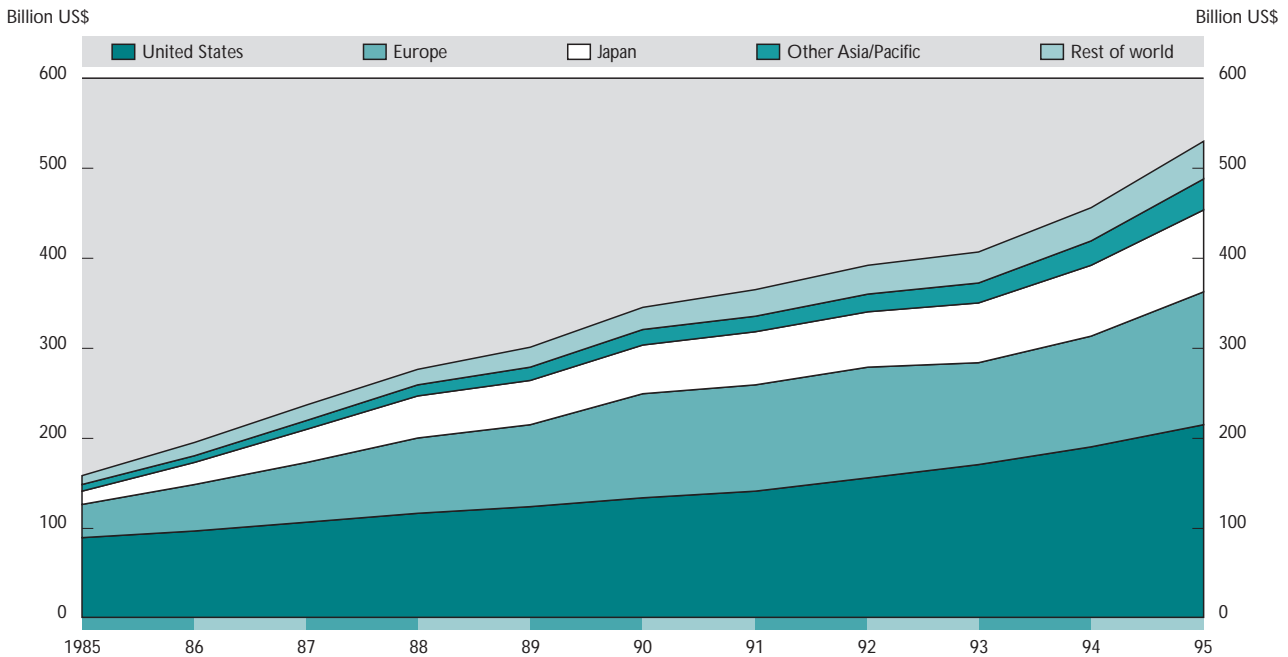
Growth in packaged software as a share of annual IT expenditures has been relatively high in Greece, the Netherlands, Spain and Turkey, but has been nil in Hungary and Mexico and very low in Japan. With respect to the increase in the share of services, Turkey and Greece head the list, along with

◆ Figure 1.1. *Share of OECD Member countries in world population, GDP and IT market, 1987 and 1994*
Percentage



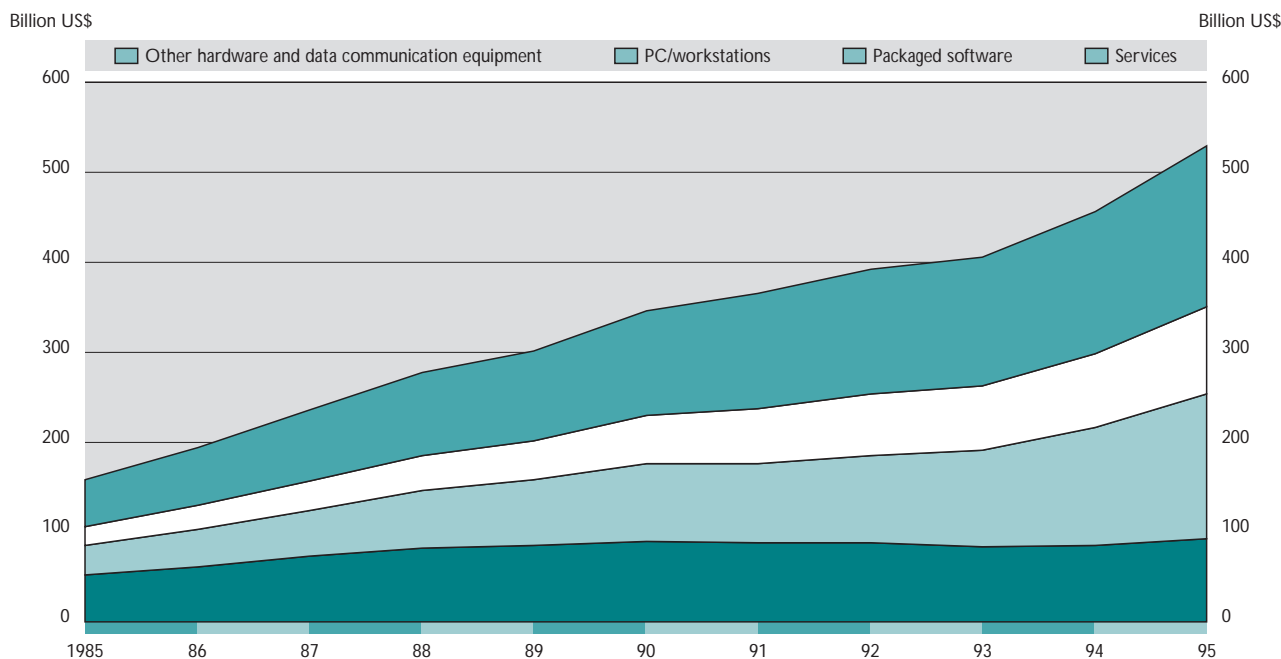
Source: OECD Secretariat, based on IDC (1995b), World Bank (1995) and OECD (ANA Database) data.

◆ Figure 1.2. *Worldwide IT market by region/country, 1985-95¹*



1. 1995 data are IDC estimates.

Source: OECD Secretariat, based on IDC (1995b) data.

◆ Figure 1.3. *Worldwide IT market by segment, 1985-95*¹

1. 1995 data are IDC estimates.

Source: OECD Secretariat, based on IDC (1995b) data.

Italy and Canada. The sharpest decrease was observed in Hungary and, to a lesser extent, in Germany and Sweden (Table 1.2).

Hardware market

Within the OECD area, growth in IT hardware markets over the past few years has been mainly driven by PCs and workstations (Figure 1.6), although mainframes are, despite their decline, still of prime importance in the IT field, if only in terms of computing power.² Worldwide, the market shrank steadily in value from 1992 to 1995, whereas there was considerable growth in annual deliveries expressed in computing power.

The price/performance ratio has been steadily declining, notably thanks to CMOS (complementary metal oxide semiconductor) processors. Even if downsizing continues to have a marked impact, mainframe systems are still irreplaceable for a number of applications involving large-scale data processing (e.g. on-line transaction processing – OLTP). Furthermore, in terms of total cost, these systems often have a greater comparative advantage over PC-based structures than purchase price alone would suggest.

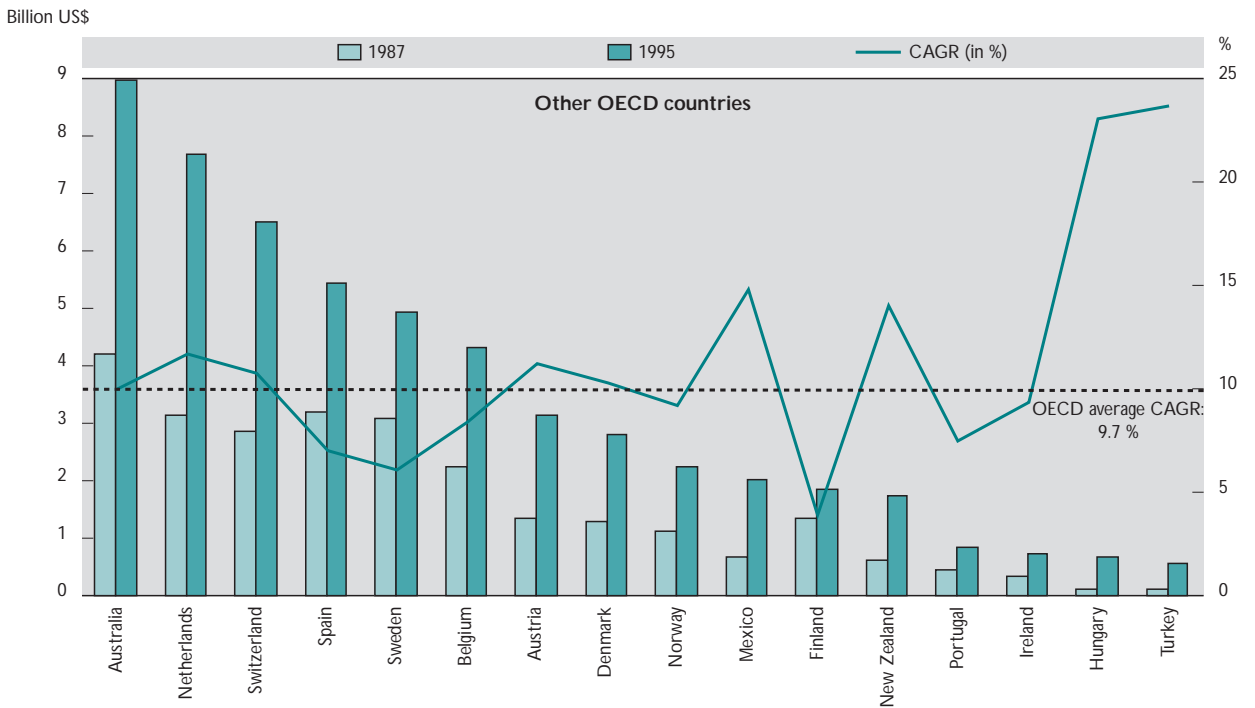
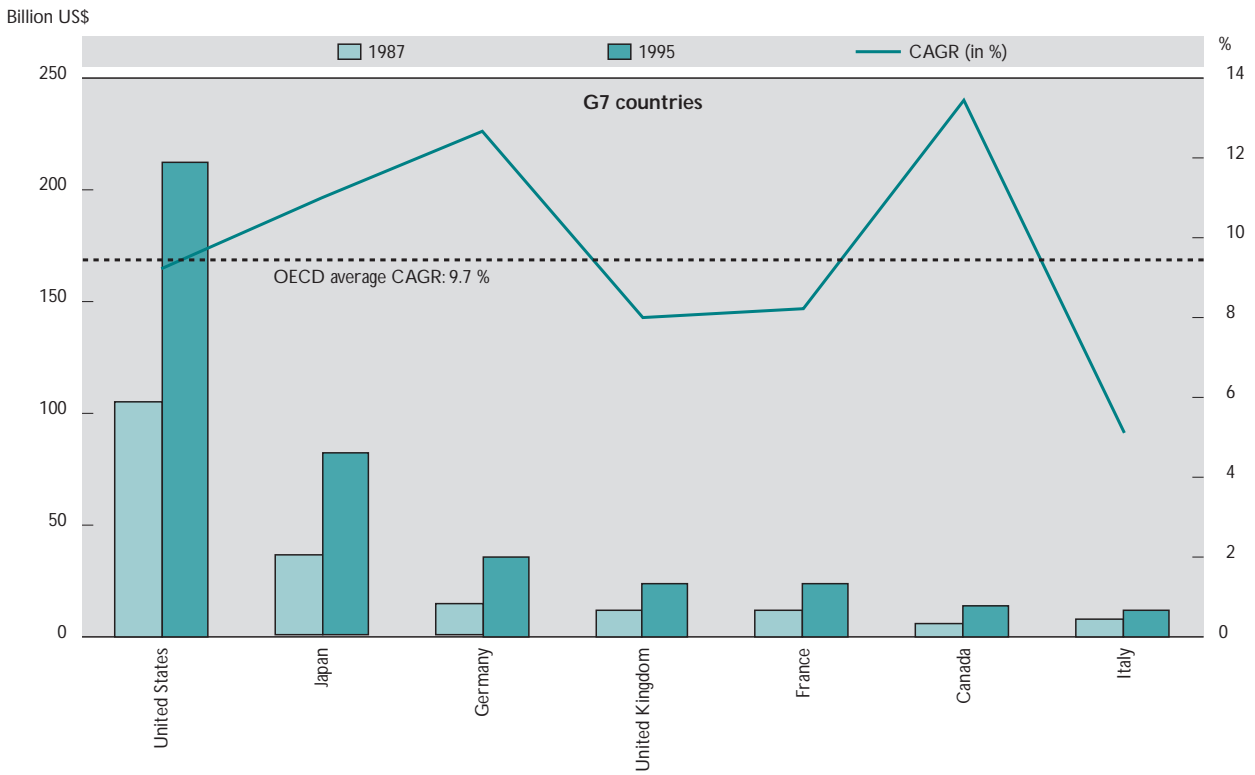
Small-scale and even medium-scale systems increasingly have to compete with workstations or even top-of-the-range PCs and local area network (LAN) servers. Software assistance is taking on greater importance as a differentiating factor now that price competition is growing keener.

Within the PC market, the pace of technological upgrading has quickened considerably. While it took earlier generations several years to take over the market, the Pentium-type microprocessor generation became widespread in less than a year. This is corroborated by the fact that PC models now have a shorter life cycle. In every OECD country, PCs and workstations are gradually taking over the market (Figure 1.7).

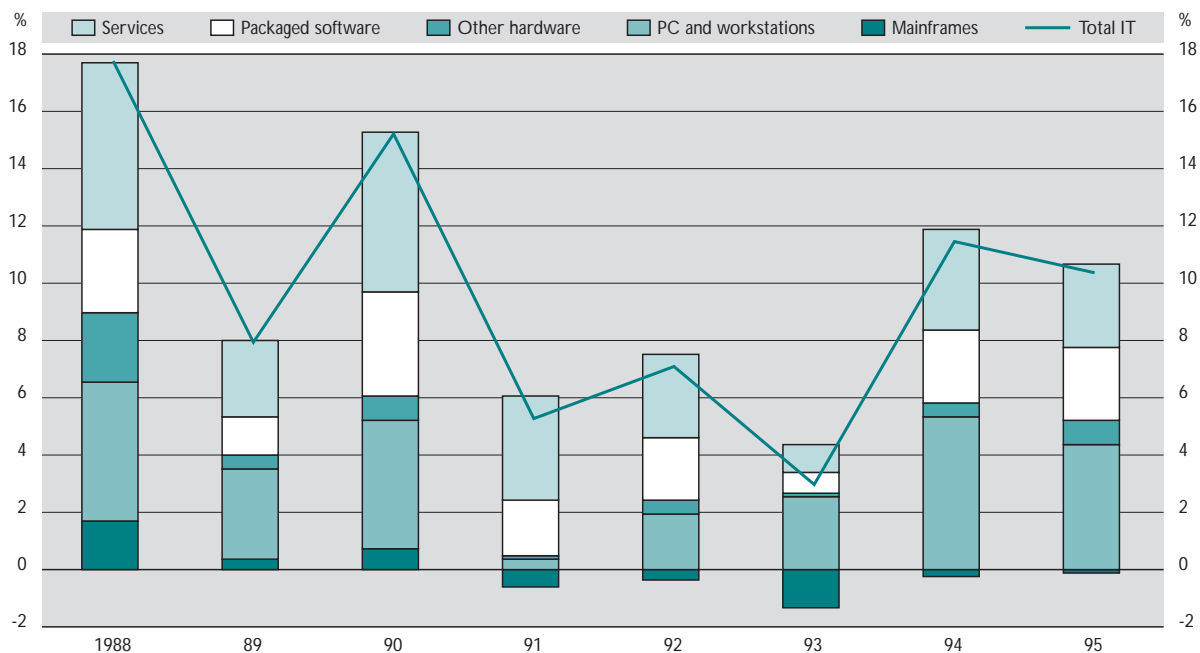
The buoyancy of the world PC market in recent years, carried along by a general trend towards downsizing and networked computing, has moved from the United States to the Asia-Pacific region, and more specifically to Japan. In terms of both production and consumption, the Asia-Pacific area is currently the most dynamic region in the world for the PC industry (Table 1.3).

Another feature, in Japan and the United States, is the increasing convergence of PCs and consumer

◆ Figure 1.4. *IT markets, 1987-95*



Source: OECD Secretariat, based on IDC (1995b) data.

◆ Figure 1.5. *Contributions to OECD IT market growth by segment, 1988-95*

Source: OECD Secretariat, based on IDC (1995b) data.

electronics, through joint development of hardware and specific software for use on the Internet.³

The US market remains by far the largest in terms of size, but growth is expected to decline as the installed base expands, particularly if replacement purchases stabilise. In Japan, growth in PC sales in 1995 was unprecedented, with the last quarter of 1995 up 93 per cent over the same period in 1994. To some extent this was a cyclical trend, following several years of low or negative growth, but there were also structural factors. For a long time NEC (with over 50 per cent) led the market with an architecture that was incompatible with IBM/DOS standards. In 1993, Microsoft began producing a Japanese-language version of its Windows operating system (OS), with versions that were compatible with NEC and IBM. The hardware price war, launched suddenly by the US manufacturers in 1992-93, also revived the Japanese market, and the "open price" system spread rapidly.⁴ IBM-compatibles saw their share climb from 16 to 30 per cent of the market between 1993 and 1994. Japanese PC manufacturers changed their strategy: Fujitsu began producing IBM compatibles at the end of 1993, while the sole manufacturer of NEC compa-

tibles, Seiko Epson, began producing IBM compatibles in September 1994 and announced in January 1995 that it would stop producing NEC compatible PC-98s. Finally, in late November 1995, the Japanese version of Windows 95 was launched.⁵

In Europe, three countries (France, Germany, the United Kingdom) accounted for almost 60 per cent of all unit sales in 1995 (as they did in 1990). The market is growing moderately, and a slowdown or even a decline is expected, even if household ownership is relatively low in most countries, the Nordic ones being an exception. The business market, which accounts for most sales, has now reached maturity (apart from the small office/home office category), and replacement purchases are expected to have a substantial impact on growth.

In terms of the installed PC base,⁶ the United States was by far the world leader in 1995 (some 86.3 million units), well ahead of Japan (some 19.1 million), Germany (13.5 million), the United Kingdom (10.9 million), and France (7.8 million). Until 1995, PC base growth traced steady curves in the United States (around 10 per cent annual growth between 1988 and 1995) and Europe (between

Table 1.2. **IT market segments in selected OECD countries, 1987 and 1995**

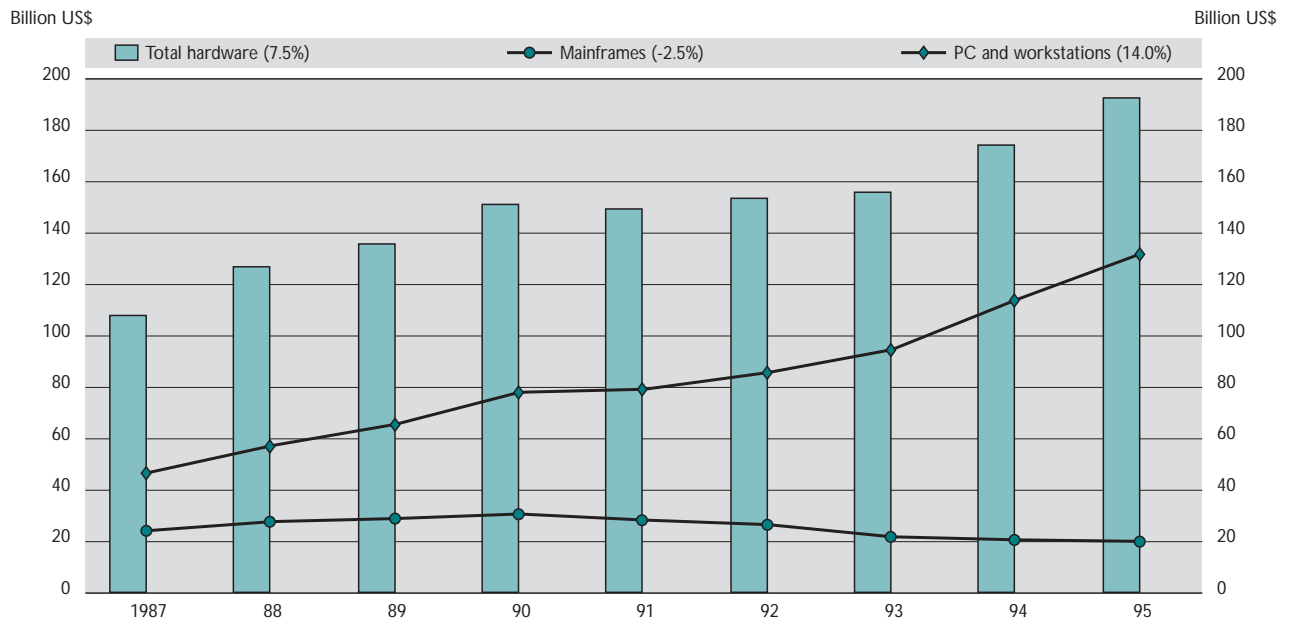
Percentage

		1987										
Level	Million US\$	Hardware				Packaged				Software		
		Multi-user systems	Data comm. equip.	PCs and workst.	Total hardware	System softw. and utilities	Applic. tools	Applic. solutions	Total pack. soft.	Profess.	Support	Total services
United States	105 255	23.6	3.5	23.4	50.4	5.3	4.1	6.4	15.8	13.5	20.3	33.8
Canada	5 428	25.8	3.0	28.3	57.1	3.6	2.6	4.5	10.7	17.0	15.2	32.1
Mexico	676	31.5	1.9	28.4	61.8	5.3	3.8	3.6	12.7	12.7	12.7	25.5
Japan	35 794	40.0	2.4	12.9	55.3	3.4	1.6	3.2	8.2	23.2	13.3	36.5
Australia	4 211	32.1	5.3	25.6	63.0	4.2	3.2	5.7	13.1	8.3	15.6	23.9
New Zealand	596	37.8	5.3	16.1	59.2	3.0	2.8	7.0	12.8	9.5	18.4	28.0
Austria	1 344	29.3	1.4	20.7	51.4	5.3	4.7	6.4	16.5	16.4	15.7	32.1
Belgium	2 278	27.9	1.2	14.5	43.6	8.4	6.2	10.4	25.0	14.5	16.1	30.6
Denmark	1 283	30.5	1.9	20.4	52.8	3.8	4.3	6.4	14.6	22.6	10.1	32.7
Finland	1 372	23.2	1.5	34.9	59.6	3.6	3.9	6.2	13.7	17.7	9.0	26.7
France	12 352	25.0	1.7	20.3	47.0	4.2	2.7	4.8	11.7	24.2	17.2	41.3
Germany	13 923	27.4	1.2	20.5	49.1	4.1	3.9	6.2	14.3	18.4	18.3	36.7
Greece	365	41.1	2.7	33.0	76.8	2.2	0.6	5.3	8.1	6.3	8.8	15.0
Hungary	131	10.3	1.9	34.7	46.9	5.9	2.9	7.7	16.5	20.7	15.8	36.5
Ireland	355	30.7	1.9	28.7	61.3	4.3	3.7	5.5	13.5	12.0	13.1	25.2
Italy	8 027	35.7	0.9	17.5	54.0	4.3	5.0	6.2	15.4	15.4	15.1	30.6
Netherlands	3 169	25.0	2.3	27.3	54.6	4.1	4.9	6.9	16.0	16.5	12.9	29.4
Norway	1 118	26.8	2.1	23.5	52.4	4.3	3.6	5.8	13.7	20.8	13.1	33.9
Portugal	478	49.4	1.9	22.1	73.4	4.1	2.3	3.4	9.9	6.9	9.8	16.7
Spain	3 181	32.5	1.0	26.8	60.3	3.2	3.1	6.1	12.4	11.9	15.4	27.3
Sweden	3 115	21.8	1.4	21.7	44.9	3.7	3.2	5.7	12.5	30.0	12.6	42.6
Switzerland	2 878	27.4	0.8	18.8	47.0	5.7	5.1	8.5	19.2	17.2	16.7	33.8
United Kingdom	12 826	27.4	3.2	20.7	51.3	5.0	4.2	8.9	18.1	13.7	16.9	30.6
Turkey	106	59.7	2.1	25.5	87.3	1.5	0.4	2.7	4.5	4.6	3.6	8.2
OECD 24	220 261	27.9	2.8	21.1	51.8	4.7	3.6	5.9	14.1	16.5	17.6	34.1
		1995 ¹										
United States	212 745	9.6	4.5	30.4	44.5	4.7	6.0	9.8	20.5	21.2	13.8	35.0
Canada	14 861	9.6	3.6	30.1	43.3	4.6	3.9	8.0	16.5	29.8	10.3	40.1
Mexico	2 045	11.0	5.5	38.4	54.9	2.5	4.5	5.6	12.6	21.2	11.3	32.5
Japan	82 296	22.8	3.2	27.2	53.2	2.5	2.6	6.0	11.1	24.4	11.4	35.8
Australia	8 987	11.2	9.9	38.2	59.4	4.0	5.1	7.5	16.6	16.4	7.6	24.0
New Zealand	1 717	10.7	7.2	36.1	54.1	3.2	4.4	10.7	18.3	20.5	7.1	27.6
Austria	3 169	14.1	2.8	29.2	46.1	4.9	7.0	11.3	23.3	17.2	13.5	30.6
Belgium	4 342	14.0	3.2	21.9	39.2	6.9	9.6	14.6	31.1	14.7	15.0	29.7
Denmark	2 810	11.4	5.5	31.2	48.1	3.9	6.4	8.9	19.2	22.7	10.0	32.7
Finland	1 861	8.7	7.1	34.3	50.1	3.5	6.1	8.6	18.1	22.0	9.8	31.8
France	23 155	12.6	3.7	22.7	38.9	4.3	6.3	8.7	19.4	26.8	14.9	41.7
Germany	36 236	12.7	2.7	26.7	42.1	3.8	8.1	11.0	22.9	21.8	13.2	35.0
Greece	538	13.5	4.7	39.2	57.4	3.6	1.7	13.7	19.0	15.3	8.3	23.6
Hungary	696	10.7	2.4	46.6	59.7	4.6	2.8	9.1	16.6	16.3	7.5	23.8
Ireland	724	14.8	3.6	35.2	53.6	5.1	6.3	9.4	20.8	13.9	11.8	25.7
Italy	11 980	17.1	2.5	18.8	38.3	4.7	7.5	9.9	22.0	24.4	15.3	39.6
Netherlands	7 686	10.9	4.3	26.5	41.7	3.8	8.8	14.0	26.5	19.3	12.5	31.7
Norway	2 258	8.2	6.2	33.1	47.5	3.8	6.0	9.1	18.9	22.6	10.9	33.6
Portugal	852	27.0	3.7	31.0	61.7	4.9	4.6	8.2	17.6	10.2	10.4	20.7
Spain	5 457	17.6	3.8	27.8	49.2	3.6	5.7	13.0	22.4	14.1	14.4	28.4
Sweden	4 977	8.1	5.1	29.6	42.9	3.2	4.8	8.1	16.1	31.0	10.0	41.0
Switzerland	6 530	10.3	2.7	27.5	40.6	5.3	7.2	14.2	26.7	19.1	13.6	32.7
United Kingdom	23 798	12.9	6.2	27.4	46.5	4.7	5.8	12.3	22.9	18.2	12.4	30.6
Turkey	586	18.2	9.1	38.3	65.6	2.7	1.2	10.2	14.1	13.2	7.1	20.3
OECD 24	460 305	13.0	4.2	28.7	45.9	4.1	5.6	9.4	19.1	22.0	13.0	35.0

1. IDC estimates.

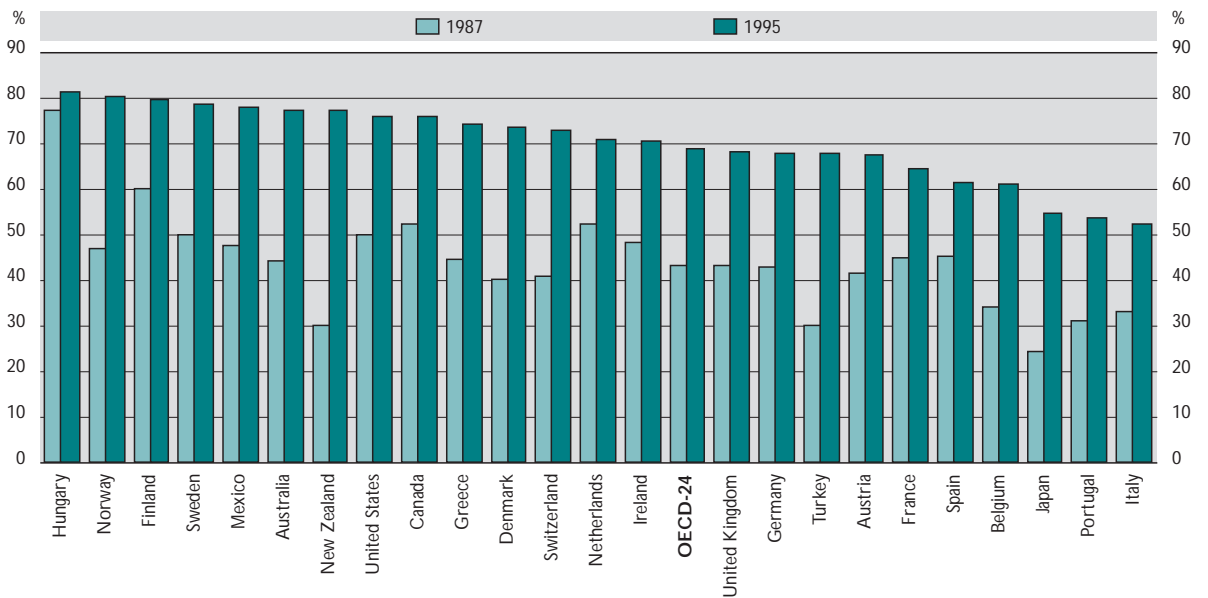
Source: OECD Secretariat compiled from IDC (1995b) data.

◆ Figure 1.6. *Contribution of mainframe and PC/workstations to total OECD area hardware spending, 1987-95*
1987-95 CAGR



Source: OECD Secretariat, based on IDC (1995b) data.

◆ Figure 1.7. *Relative importance of PCs and workstations in hardware in selected Member countries, 1987 and 1995*
Percentage of total hardware market



Source: OECD Secretariat, based on IDC (1995b) data.

Table 1.3. **Worldwide PC shipments by destination, 1993-96¹**

	Million units				
	1993	1994	1995	1996	CAGR 1993-96
United States	15.05	18.70	23.00	26.51	15.2%
Western Europe ²	10.60	12.50	14.38	16.30	11.3%
Japan	2.50	3.50	5.82	8.39	35.3%
Rest of Asia-Pacific ³	3.23	5.06	6.45	8.13	26.0%
Rest of World	7.62	7.26	8.52	9.89	6.7%
Total	39.00	47.02	58.17	69.22	15.4%

1. 1996 estimated.
2. Austria, Belgium, Denmark, Finland, France, Germany, Italy, Netherlands, Norway, Spain, Sweden, Switzerland, United Kingdom.
3. Australia, China, Chinese Taipei, Hong Kong, India, Indonesia, Malaysia, New Zealand, Philippines, Republic of Korea, Singapore, Thailand.

Source: OECD Secretariat, based on IDC (1995b) data.

15 and 18 per cent between 1991 and 1995). In Japan, the spectacular growth rates of 1989-90 (more than 30 per cent annual growth) declined progressively during the early 1990s (11.9 per cent in 1994).

In terms of average number of PCs per inhabitant, the United States is also the world leader, averaging 32.8 PCs per 100 inhabitants in 1995, more than twice the rate of either Japan or Europe (Figure 1.8).

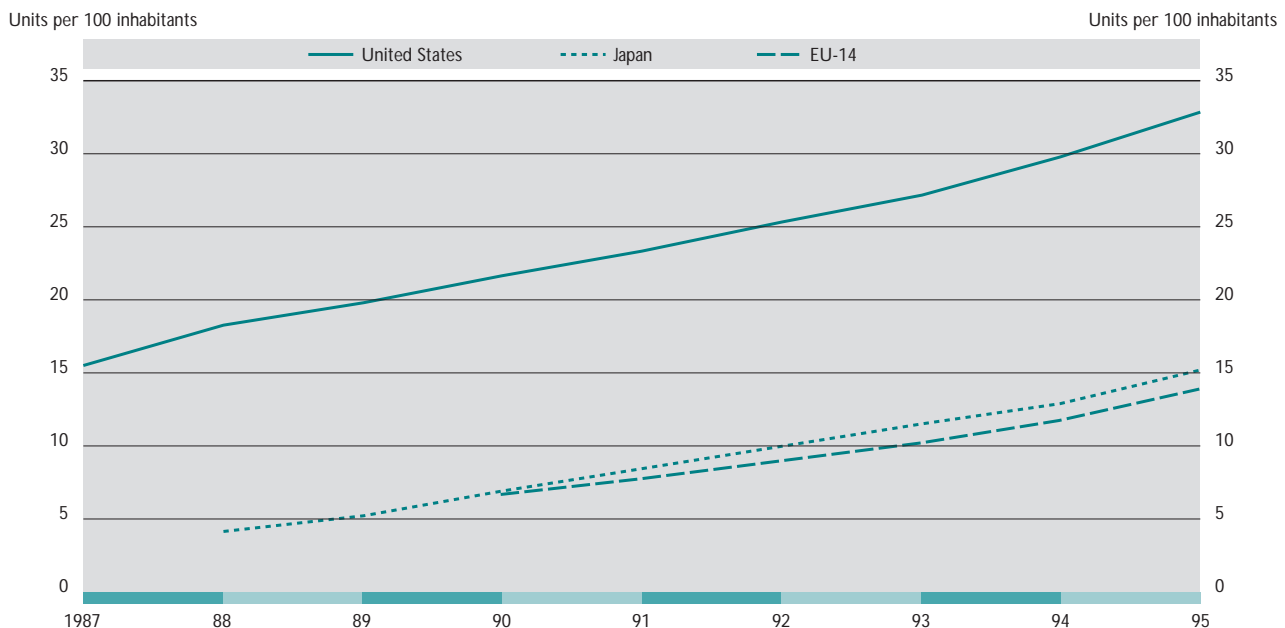
Packaged software

In 1995 the packaged software market in OECD countries was worth US\$88 billion, or 94 per cent of the world market. In relation to total IT expenditure, the OECD area spent more on packaged software than non-member countries (19 and 11 per cent, respectively, of total IT spending in 1995). Packaged software was one of the main contributors to growth in IT markets within the OECD area from 1987 to 1995 (Figure 1.9 and Annex Table 3).

The United States is the leading world market, accounting for almost half the OECD market in 1995, against 53.3 per cent in 1987. The Japanese market follows, its relative growth slightly higher than the OECD average owing to an acceleration in 1994-95, following the sustained demand for PCs and the increasing popularity of multimedia. In 1995, however, packaged software accounted for only 15 per cent of the overall software market, a share that has varied little since 1990 (MITI, 1995a), and the 1994-95 boom generated a demand for packaged software that has mainly benefited US firms.⁷

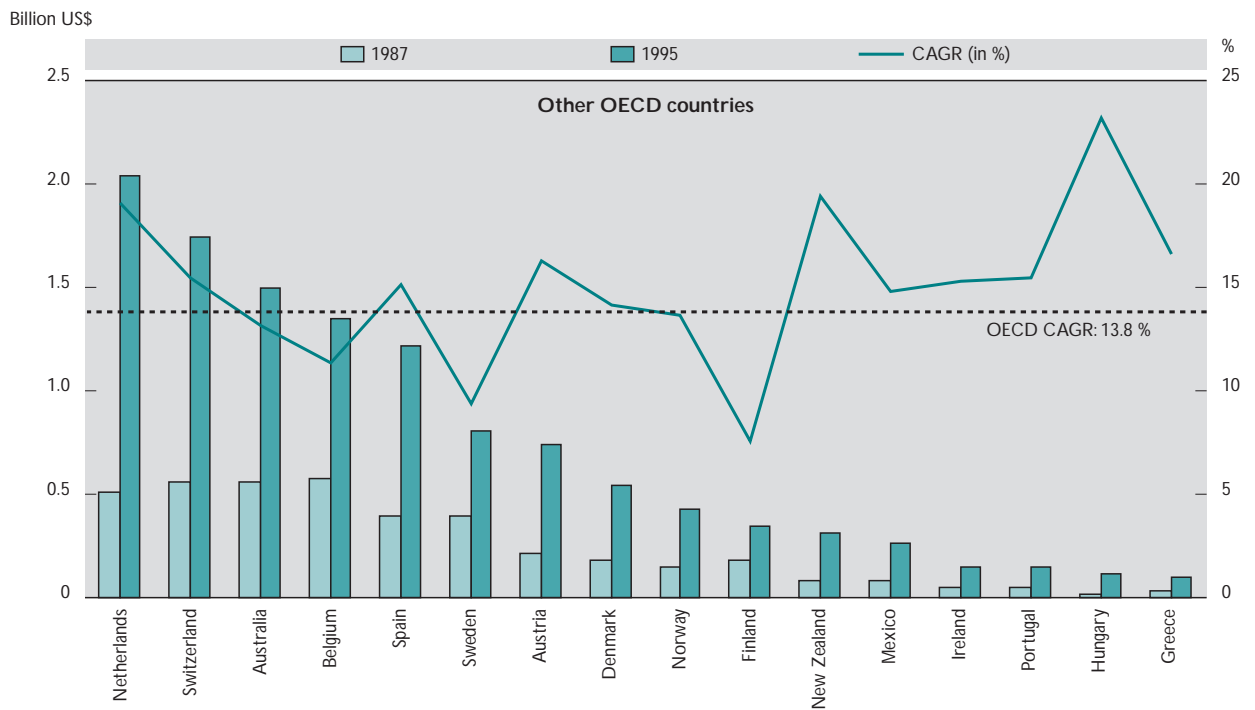
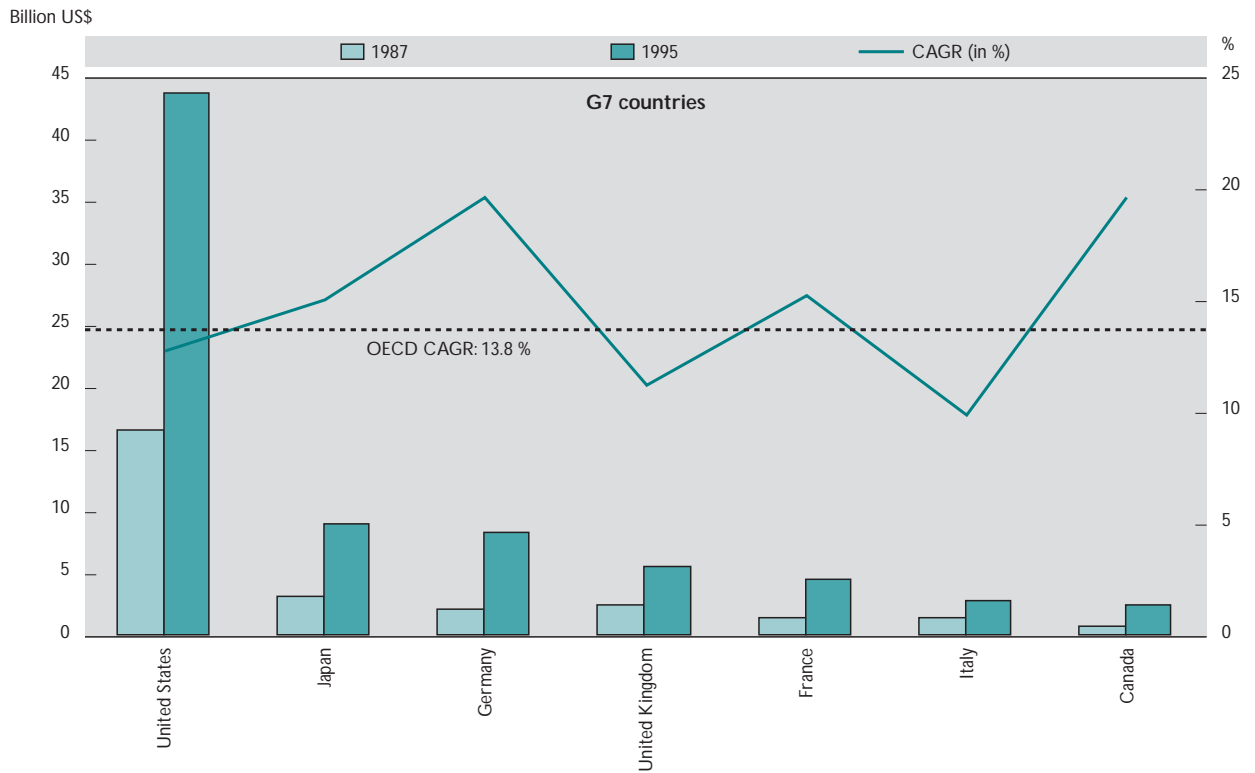
Europe recorded contrasting trends from 1987 to 1995. Some markets were in full growth (Netherlands, Germany, Greece), while others developed much

◆ Figure 1.8. **PC installed base for selected OECD countries or regions, 1987-95**
Average number of units per 100 inhabitants



1. EU-14 includes Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain, Sweden, United Kingdom.
Source: OECD Secretariat, based on ITU (1995) data.

◆ Figure 1.9. **Packaged software markets, 1987-95**



more slowly (United Kingdom, Italy, Belgium). Germany, ahead of the United Kingdom, is now the largest market, owing to the development of client/server applications. Greece and Portugal recorded relatively high growth. Sweden and Finland, emerging from a serious economic recession in the early 1990s, have had the lowest market growth in packaged software since 1987 for the entire OECD area.

It is difficult to establish a correlation between market size and pace of growth, and size differentials do not seem to be decreasing. Even if markets have been growing very rapidly in countries such as Hungary and Greece, they are still relatively small (less than 0.1 per cent of the OECD total). Conversely, market growth rates in countries such as Germany and Canada, which already had a considerable share, are among the highest in the OECD area (Figure 1.9).

Another point worth noting is that the average unit price of applications software is still dropping sharply, regardless of area. The ever keener price competition stems from a decrease in PC prices, which is bringing down software prices, but also from the high price elasticity of demand, which has made firms cut prices to increase sales volume and gain market share. Consequently, innovation and marketing now represent a greater share of the total cost of software products.⁸

Services

The services market in the OECD area was worth US\$161 billion in 1995 and, with an annual growth rate averaging 10 per cent since 1987, it is the second largest contributor, after PCs and workstations, to overall IT market growth in OECD Member countries since 1994.

The market has remained extremely concentrated since 1987, some 90 per cent of it in the G7 countries. The United States, by far the largest market in terms of size, saw a slight decrease in its share (from 46.2 to 45.5 per cent of the total for the area), while other major countries like Canada and Germany have seen their market grow faster than the OECD average. Japan's share also rose slightly, but this is partly due to currency appreciation. Mexico, Canada, and Hungary have seen remarkable growth over the same period (Figure 1.10).

Divergence from average annual OECD growth rates is quite similar to what is observed for packaged software markets, as the two types of expenditure are relatively closely linked ($R^2 = 0.87$ for average growth).

The broad increase in the services market has been accompanied by structural changes in the industry. First, as firms move to microcomputers and packaged software, the relative importance of customised software has declined, while use of system integration services, many of which have become less standardised, has grown.

Second, as the pace of internal reorganisation continues to quicken, firms are increasingly turning to IT services, in particular for business process re-engineering. The increased use of consultancy services is a sign that firms are making major structural changes as they adapt to new technologies that entail changes in organisational structures, working arrangements and the relations between them (Henkof, 1993).

Finally, in an effort to control costs, firms have made outsourcing of information systems a central aspect of changes in corporate strategy (Crane, 1996). Originally used for large-scale computing, outsourcing has kept pace with the expansion and growing penetration of microcomputers in firms, adding new vigour to this segment of the industry in many countries.

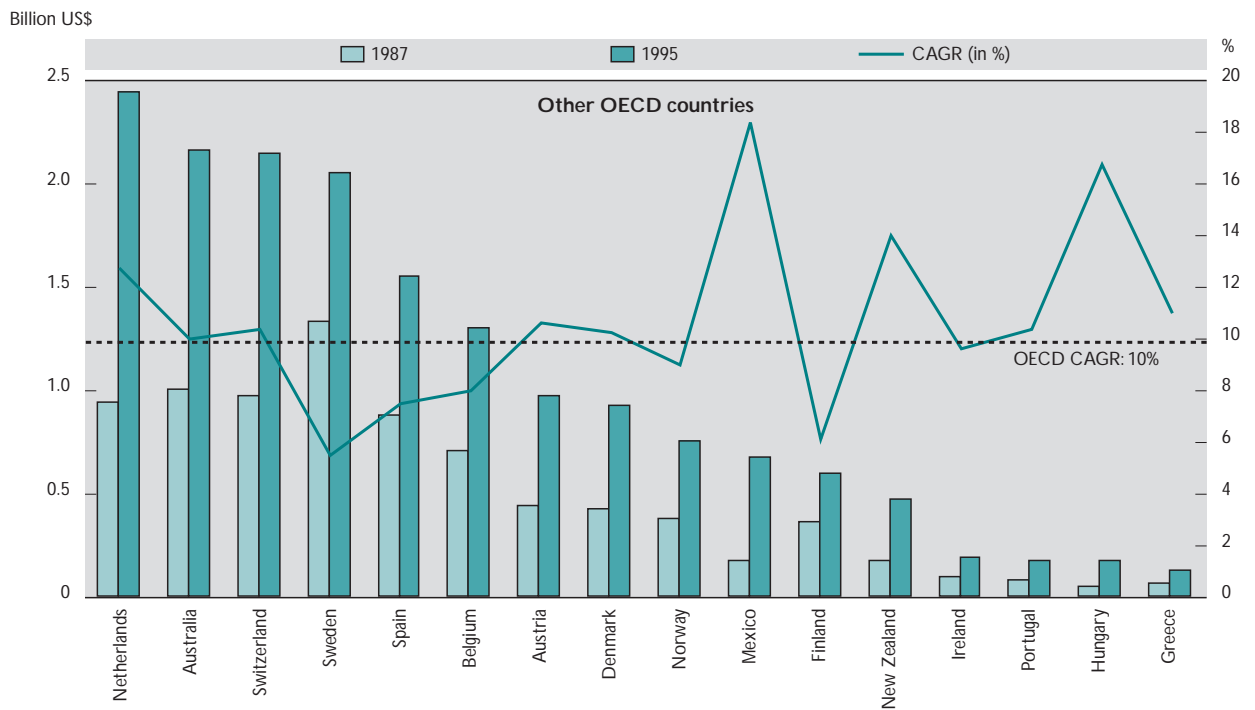
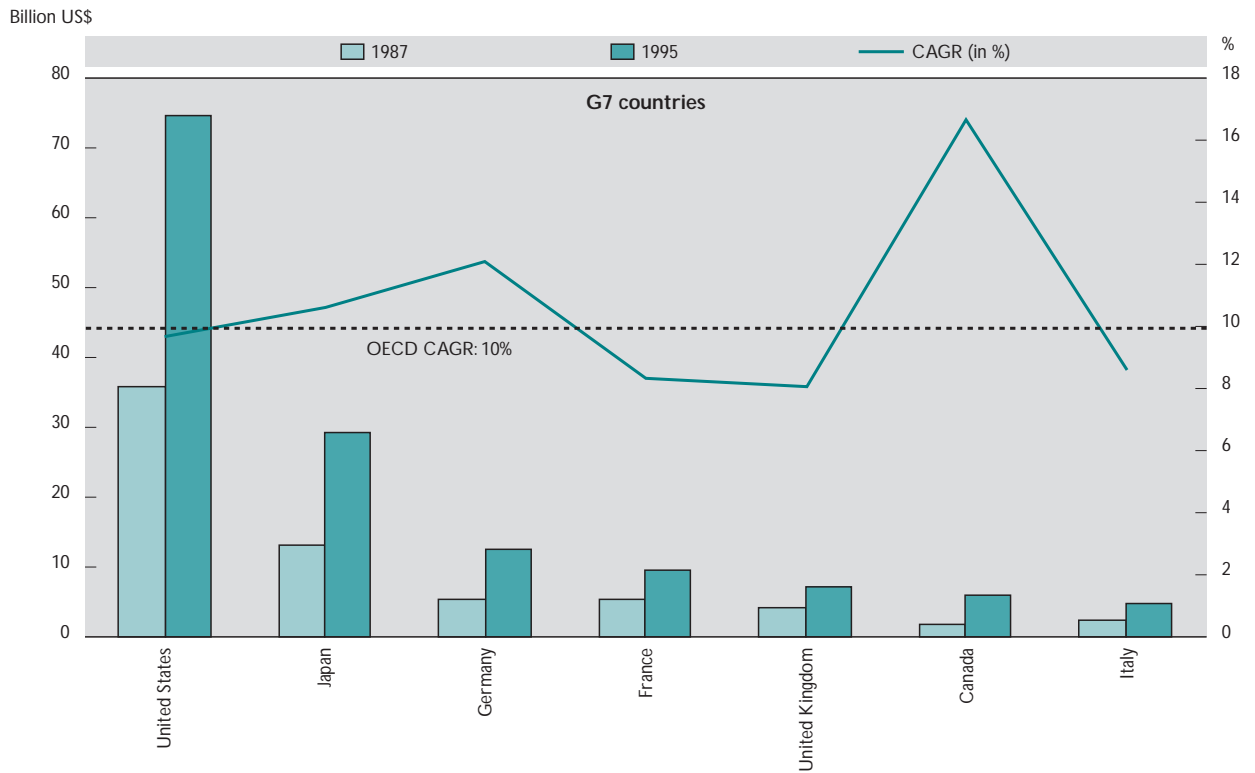
Non-member countries

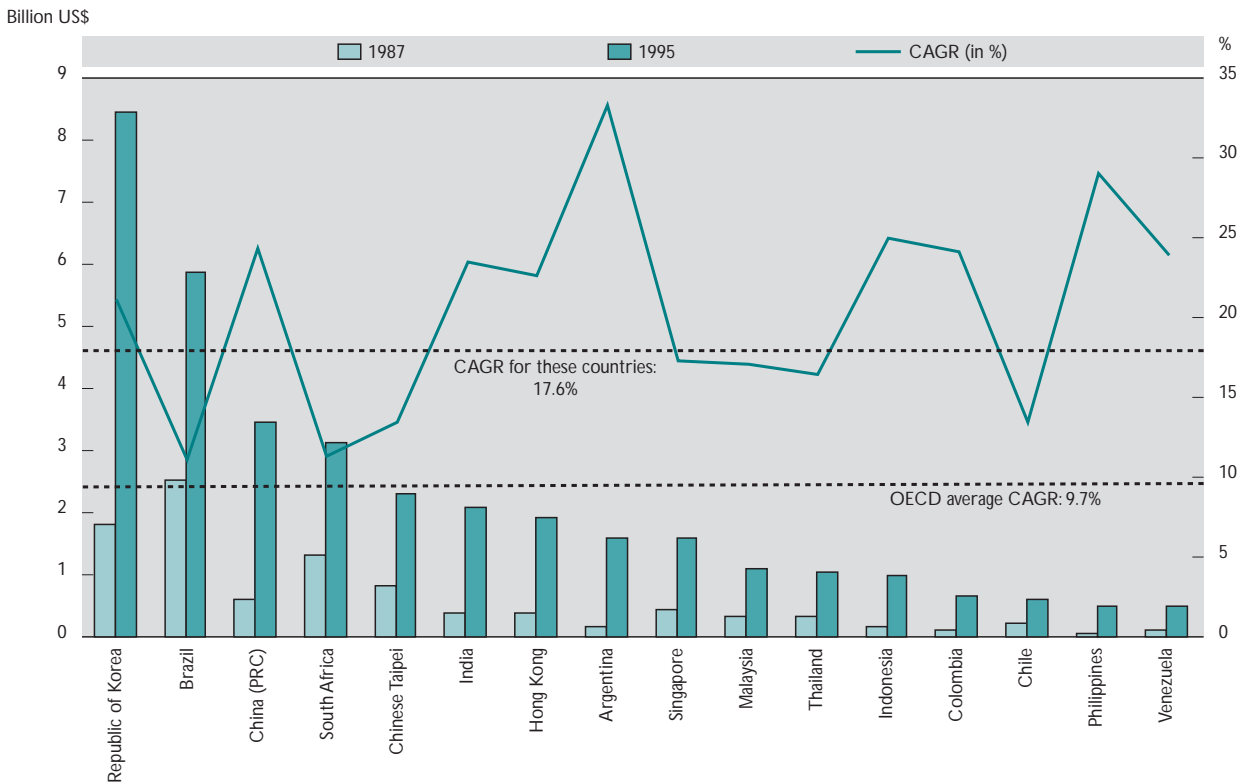
The world IT market has remained predominantly concentrated in the G7 countries, but in 1995 some non-member countries (Republic of Korea, which subsequently became a Member country, Brazil and China) had markets that were comparable to or larger than those of some European countries. (Figure 1.11). On average, market growth in non-member countries is almost double that in Member countries.

Taking as a benchmark the IT penetration ratio (as measured by market size as a percentage of GDP), certain non-member countries such as Singapore are at levels similar to those of some OECD countries. However, there is great potential for growth in parts of Asia (e.g. China, India, Indonesia) and South America (e.g. Argentina), where the IT-to-GDP ratio is significantly below the OECD average (Table 1.1).

The steadiest and highest growth is to be found in the DAEs. Markets there are expanding very rapidly, at an average of almost 18 per cent over the period 1987-94, thereby continuously increasing their share of the world market (from 1.7 to 2.8 per cent). In these countries, successive multi-annual plans and information-highway projects,⁹ together with the development of national science/technology parks

◆ Figure 1.10. IT services markets, 1987-95



◆ Figure 1.11. *IT markets in non-member countries, 1987-95*

Source: OECD Secretariat, based on IDC (1995b) data.

and large new industrial estates with an IT focus,¹⁰ are contributing to market expansion.

While most South American countries were affected by the Mexican crisis of 1995, some are beginning to see their IT markets expand again, but they are still small in relation to GDP. For countries like Argentina and Venezuela, the growth differential since 1987 between IT markets and GDP is among the highest in the world.

Annual IT expenditure patterns in non-member countries differ from those of OECD countries over the relevant period (Annex Table 2). As a share of total IT spending, PCs and workstations grew at more than double the rate recorded in OECD countries, even though their share was already higher in 1987. This would suggest that some non-member countries have in effect “by-passed” large mainframes and invested almost exclusively in PCs and workstations. Conversely, their expenditure on packaged software remained virtually flat (at around 10 per cent),

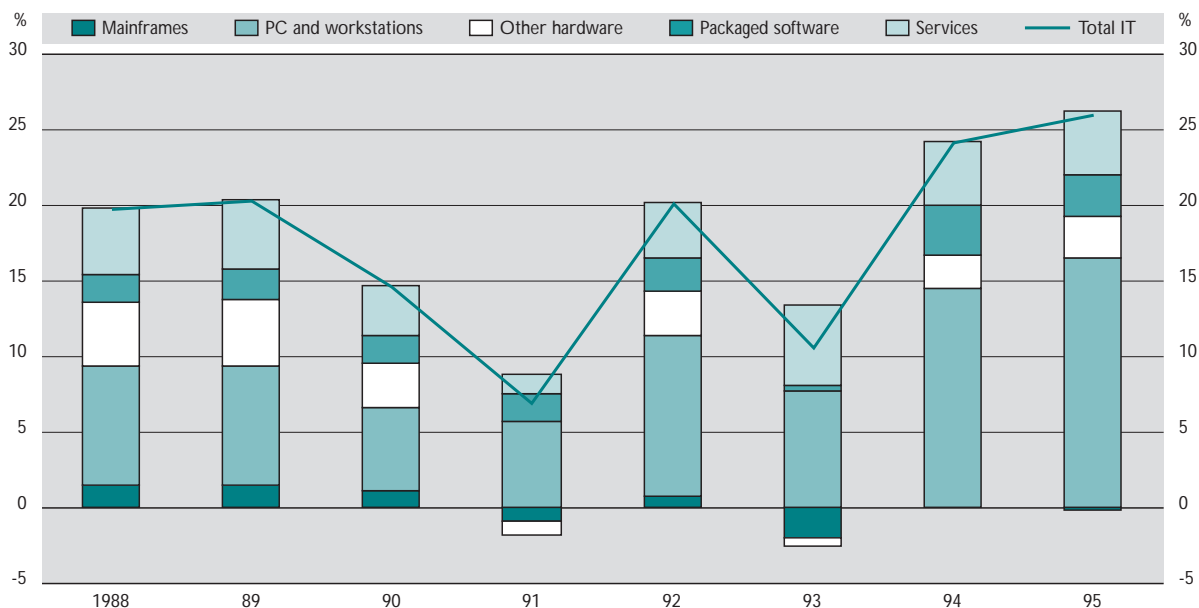
whereas the OECD area saw considerable growth in this area, with almost one dollar in every five spent on IT in 1995 going to packaged software purchases.

The particularly high hardware-to-software ratio in some countries (China, Hong Kong) may be partly due to widespread illegal copying of software, which reduces distributor/vendor turnover. Despite this, when it comes to total IT market expansion in absolute terms, Asia ranks first in value and in units¹¹ (see Annex Tables 2 and 3).

PCs and workstations also figure prominently in the IT market's contribution to growth in all the non-member countries studied, whereas software and services play a lesser role and the impact of mainframes on growth is virtually non-existent or even negative (Figure 1.12).

With respect to services, the market in non-member countries is generally less well developed than that of other IT segments, the exception being countries like Singapore, India, Brazil, Chile and

◆ Figure 1.12. *Contributions to IT market growth in non-member countries,¹ 1988-95*



1. Includes Argentina, Brazil, Chile, China (PRC), Chinese Taipei, Colombia, Hong Kong, India, Indonesia, Malaysia, Singapore, the Republic of Korea, Thailand, South Africa and Venezuela.
 Source: OECD Secretariat, based on IDC (1995b) data.

South Africa where the industrial or service sectors are sufficiently developed to require such services.

2. SEMICONDUCTORS

Introduction

The semiconductor industry has experienced an unprecedented rate of growth in recent years. World demand is now driven by South-East Asia which, together with Japan, accounted for almost half of world consumption in 1995. Investments during the past few years have followed a similar trend, as the structure of world production has been reorganised, with the Republic of Korea emerging as a leading player in the market for dynamic random access memories (DRAMs), a sector dominated by Japanese firms in the 1980s.¹²

Market

The value of the world semiconductor market grew at a rate of 37 per cent in 1995, following growth rates of around 30 per cent in the two previous years. Estimates for 1996, however, indicate a more modest

increase of around 7 per cent,¹³ primarily due to the drop in DRAM prices.¹⁴ By the end of 1995, sales of PCs, which are a major outlet for semiconductors, had failed to reach projected levels; this, combined with higher levels of DRAM stocks, continuing construction, and the start-up of large numbers of new manufacturing plants, has put continuing downward pressure on prices (Table 1.4).

Since the mid-1980s (with the exception of 1990, which marked the bottom of a cycle), there has been sustained growth in semiconductor demand in all major regions. The Japanese market, which had contracted in 1992 owing to the recession, began to grow again by the following year. Since 1990, the highest rate of growth has been in South-East Asia (excluding Japan), which has become, since 1993, the third largest market in the world behind the United States and Japan. The region's current vitality does not appear to be a transitory phenomenon and may lead, in the medium term, to substantial changes in the geographical division of world production. The Asian market may even outgrow Japan's to take second place behind the North American market by as early

Table 1.4. **Worldwide semiconductor sales by region, 1985,1990-96**

Million US\$ and percentage

	1985	1990	1991	1992	1993	1994	1995	1996 ¹
North America ²	9 418	16 540	16 990	20 430	27 998	35 939	48 281	52 478
(% of total)	38.7	30.3	28.5	31.3	32.7	32.6	31.9	32.3
(% change from previous year)		-3.1	2.7	20.2	37.0	28.4	34.3	8.7
Japan	8 149	20 257	22 496	20 579	24 652	30 682	42 192	41 244
(% of total)	33.5	37.1	37.7	31.5	28.8	27.8	27.9	25.4
(% change from previous year)		-5.7	11.1	-8.5	19.8	24.5	37.5	-2.2
Europe ³	4 795	10 415	11 014	12 218	15 450	20 819	28 360	31 479
(% of total)	19.7	19.1	18.5	18.7	18.0	18.9	18.7	19.4
(% change from previous year)		9.7	5.8	10.9	26.5	34.8	36.2	11.0
Asia/Rest of world ⁴	1 979	7 333	9 194	12 034	17 505	22 812	32 439	37 411
(% of total)	8.1	13.4	15.4	18.4	20.4	20.7	21.4	23.0
(% change from previous year)		16.8	25.4	30.9	45.5	30.3	42.2	15.3
Total	24 341	54 545	59 694	65 261	85 605	110 252	151 272	162 612
(% change from previous year)		0.4	9.4	9.3	31.2	28.8	37.2	7.5

1. Estimates.

2. Includes the United States, Canada and Mexico.

3. Includes both Western and Eastern Europe, including the former Yugoslavia and the former USSR.

4. Does not include Japan.

Source: OECD Secretariat, based on Dataquest (1996a).

as 1999 (EIAJ in *Electronique Internationale Hebdo*, 25 January 1996). In 1994, China already accounted for over 9.2 per cent of the region's market, compared with less than 8.5 per cent in 1991.¹⁵ If the Hong Kong market is also included, the Chinese share of the Asian market (excluding Japan) could grow from 18 per cent to over 24 per cent by 1999.¹⁶

This high growth rate is driven by sustained demand from workstation and PC manufacturers. In 1995, sales to these sectors accounted for over 50 per cent of the world market in terms of value, compared with less than 40 per cent five years earlier. It is worth noting that the computer industry accounts for a substantially larger share of semiconductor consumption in North America and South-East Asia than in Europe or Japan. Indeed, semiconductor manufacturers are currently trying to secure their sales outlets, and thus protect themselves against fluctuations in DRAM prices, by buying shares in, or entering into agreements with, micro-computer manufacturers (Samsung, for example, has a 40 per cent stake in AST Research). Europe's use of semiconductors is relatively more specialised in telecommunications and the automobile industry than in consumer electronics, while the opposite is true for Japan. The rapid decline in consumption by the North American defence sector reflects general declines in military budgets associated with the end of the cold war (Figure 1.13).

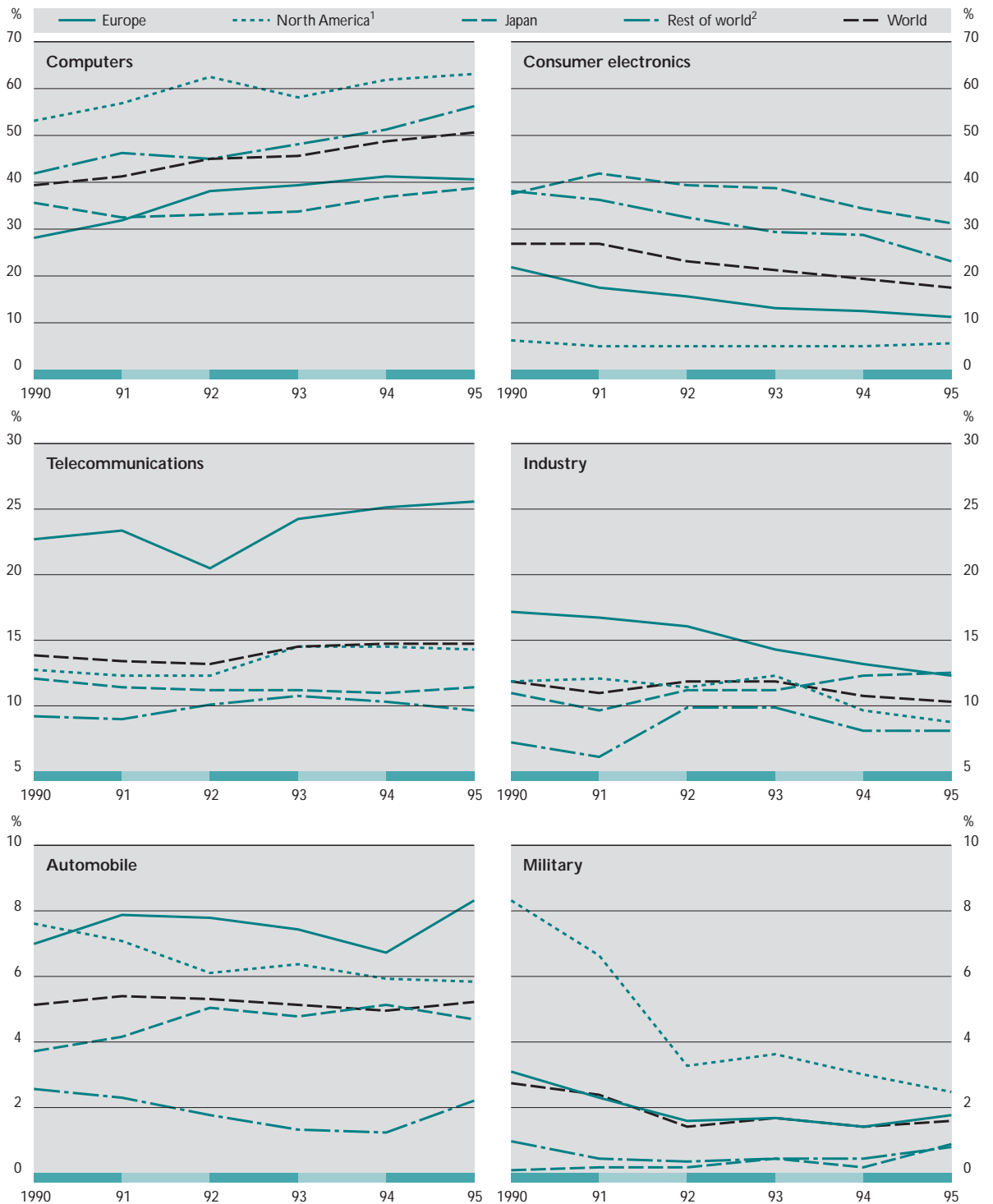
Sales by ownership

The general trends in the geographical pattern of consumption are echoed in the data on sales by country of ownership. Between 1985 and 1995, US firms suffered the largest fall in total semiconductor market share (approximately 5.8 per cent) compared with European (down 3.2 per cent) and Japanese firms (down 1.6 per cent). Firms from the rest of the world – primarily the Republic of Korea – gained almost 10.6 per cent. 1995 brought confirmation, after 1994, that the balance of power in the world market had shifted to South-East Asia. Sales by North American and European firms rose at a pace well below the rate of growth in the world market, and these firms therefore suffered some erosion of market share. Japanese firms maintained their market share, but market growth was primarily driven by Asian – and particularly Korean – firms, whose turnover has practically doubled within a year (Tables 1.5 and 1.6).

Semiconductor product categories

The semiconductor market is dominated by the category of products generally referred to as integrated circuits (IC), which accounted for over 87 per cent of the market in 1995. The remainder was made up by discrete semiconductors and opto-electronic devices (Table 1.7). In value terms, the main types of integrated circuit are memory devices, microproces-

◆ Figure 1.13. *Final use of semiconductor production, 1990-95*
Percentage of regional market



1. From 1994, includes South and Central America.

2. To 1994, includes South and Central America.

Source: OECD Secretariat, based on WSTS data.

Table 1.5. **Worldwide semiconductor sales by manufacture base (ownership basis), selected years**

Million US\$ and percentages

	1985		1990		1992		1994		1995	
	Sales	Market share (%)	Sales	Market share (%)	Sales	Market share (%)	Sales	Market share (%)	Sales	Market share (%)
US companies	11 051	45.4	21 047	38.6	27 105	41.5	45 791	41.5	59 956	39.6
Japanese companies	10 144	41.7	25 278	46.3	27 576	42.3	44 778	40.6	60 612	40.1
European companies	2 851	11.7	6 108	11.2	6 666	10.2	9 834	8.9	12 903	8.5
ROW companies	295	1.2	2 112	3.9	3 914	6.0	9 849	8.9	17 802	11.8
Total world	24 341	100.0	54 545	100.0	65 261	100.0	110 252	100.0	151 272	100.0

Source: Dataquest.

Table 1.6. **Semiconductor sales growth by ownership of companies, 1990-94**

Percentage change from previous year

	1990	1991	1992	1993	1994	1995
US companies	13.2	9.0	18.2	37.1	23.2	30.9
Japanese companies	-2.9	10.0	-0.4	25.4	29.5	35.4
European companies	24.2	3.7	5.2	14.9	28.4	31.2
Asian companies	49.4	29.5	43.2	58.7	58.5	80.7
Total world market	7.1	9.6	9.3	31.2	28.8	37.2

Source: Dataquest.

Table 1.7. **Semiconductor product categories**

Percentage of worldwide market

	1995 share	1988 share	Sales CAGR 1988-95 (%)
Integrated circuits	87.3	79.8	19.7
Memories	37.0	24.2	25.5
DRAM	28.3	14.0	30.6
Bipolar/digit.	1.9	10.6	-7.4
Micro-components	23.1	15.0	25.6
Microprocessors	11.0 ¹	3.0 ²	46.0 ³
RISC microprocessors	1.1	0.0	28.5 ⁴
ASICS and dedicated MOS logic	12.1	11.4	19.2
Linear/analog	11.5	16.1	12.7
Discrete semiconductors/opto-electronic components	12.7	20.2	10.5
Total semiconductors	100.0	100.0	18.1

1. 1994 instead of 1995. Dataquest figure.

2. 1989 instead of 1988. Dataquest figure.

3. 1989-94 CAGR.

4. 1992-95 CAGR. RISC microprocessors did not appear on the market until 1992.

Source: OECD Secretariat, based on WSTS and Dataquest data.

Table 1.8. **Worldwide microprocessor market by region, 1995**

Region	1995	1995 market share (%)	Sales CAGR 1994-95 (%)	1994-95 change of average unit value (%)
North and South America				
Value (million US\$)	6.1	48.0	23.0	-5.4
Units sold (millions)	36.2	45.3	30.0	
Europe				
Value (million US\$)	3.3	26.2	26.0	-13.9
Units sold (millions)	20.5	25.7	46.4	
Japan				
Value (million US\$)	1.4	10.8	92.6	-6.0
Units delivered (millions)	8.2	10.2	105.0	
Asia/Pacific-Rest of world				
Value (million US\$)	1.9	15.0	13.8	-2.1
Units sold (millions)	15.0	18.8	16.3	
World				
Value (million US\$)	12.7	100.0	27.0	-6.5
Units sold (millions)	79.9	100.0	35.9	

Source: OECD Secretariat estimations based on data from the Semiconductor Industry Association, 1996.

sors, application-specific integrated circuits (ASICs) and analog and linear circuits. In 1995, three-quarters of the market for memories was accounted for by DRAMs, whose growth in market share since 1988 has been second only to that of microprocessors.

In 1994 and 1995, sales of DRAMs, a key component of PCs (which account for over 80 per cent of DRAM consumption) grew at rates of 78 and 74 per cent, respectively. However, the market is likely to have contracted slightly in 1996 (down 2.3 per cent). This will probably have a major impact on the average memory capacity of PCs, as memories are becoming more widely available and lower in price.¹⁷

Microprocessors, the central component in PCs, have been the fastest-growing market segment since 1988, at a rate well over twice that of the market as a whole. This growth is due to two factors: first, the increase in unit value with each new product generation; and second, the extremely high growth in the volume of deliveries, mainly to PC and workstation manufacturers. In 1995, the strongest growth in sales was observed in Japan, probably owing to robust growth in the domestic market for PCs (Table 1.8). RISC chips, which can process information at higher speeds for a given clock time, are starting to be used more widely; although their market share is still very small, sales growth has been remarkable since 1992, when they first became commercially available.

While ASICs represent a relatively small share of the market (12 per cent in 1995), they have main-

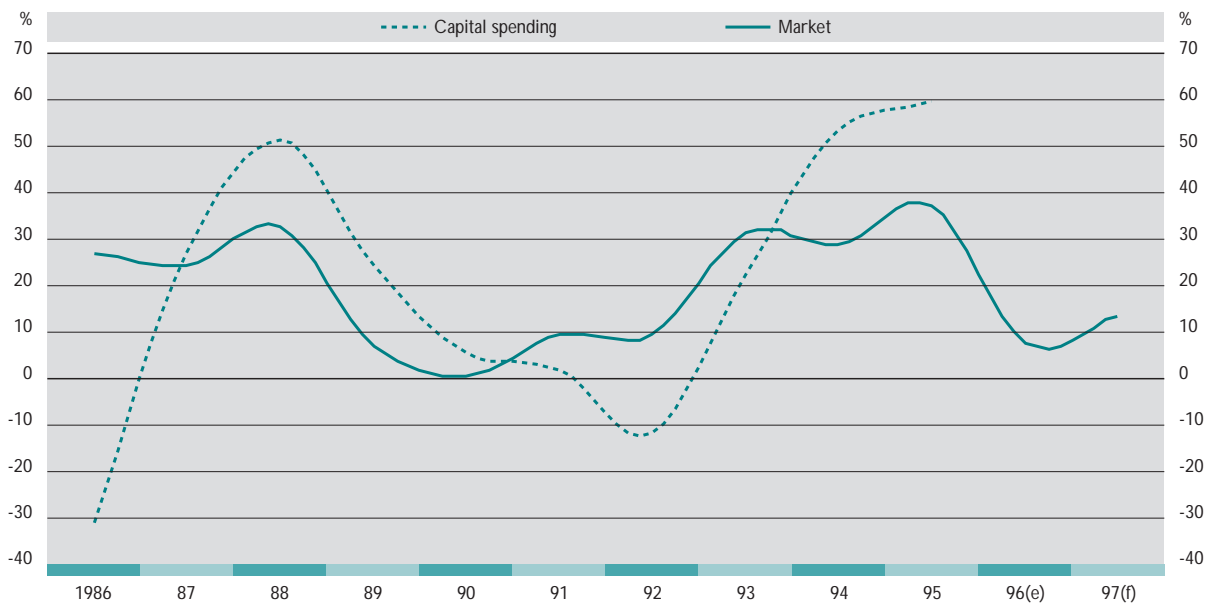
tained their market share at more or less the same level over the past seven years. This probably illustrates the pervasive nature of microelectronics and users' increasingly varied requirements for dedicated or specific circuits. Despite an increase in the cost of fabrication facilities, the semiconductor industry is producing a greater variety of products. Intel, for example, now offers over 30 different versions of its 486 microprocessor, whereas in the early 1980s it offered just three versions of its 8086 microprocessor and only two versions of its 8088 microprocessor. Likewise, Toshiba currently has 15 times as many four megabyte DRAM configurations as it had 64 kilobyte ones in 1984 (Hutcheson and Hutcheson, 1996).

Investment

Semiconductor manufacturing has always been a relatively cyclical activity. Product cycles have been shortening and massive pro-cyclical investment has been required (Figure 1.14). Heavy capital investment generally takes place during periods of strong market growth, whereas troughs in the cycle tend to be characterised by significant under-investment. However, any delay in undertaking investments leads to slippage in the medium term, and, in the past, under-investment has usually resulted in loss of market share.

Investment has risen at a rate that is strongly correlated with market growth. Total capital with

◆ Figure 1.14. *Worldwide semiconductor sales and investment, 1985-97¹*
Variation from previous year



1. Estimates for 1996, forecasts for 1997.

Source: OECD Secretariat, based on Dataquest data.

investment in 1995 has been estimated at almost 35 billion dollars, a 60 per cent increase from 1994 levels, with the corresponding production capacity coming on stream in 1997. All the major regional markets have been affected by rising levels of investment, but South-East Asia (excluding Japan) is the source of much new investment (Figure 1.15). A large part will have been devoted to the production of 16 megabyte, or larger, DRAMs; 55 per cent of the US\$80 billion invested in the semiconductor industry between 1993 and 1995 was for DRAM production. A kind of virtuous circle appears to be establishing itself, with the marketing of software programmes requiring greater memory capacity (Windows 95, for example) fuelling demand for more powerful memory chips.

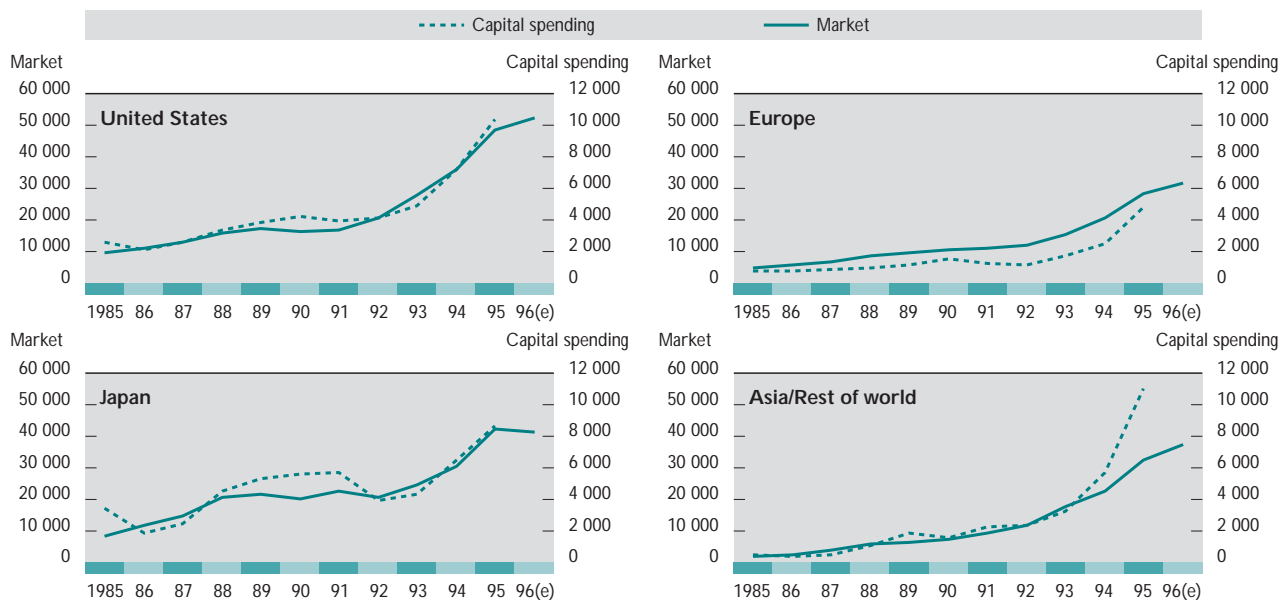
A major share of investment is also devoted to microprocessors, which in recent years have become key components and the “driver” for semiconductor technology in terms of both circuit design and etching density.

Thus, expectations of growing demand for PCs have prompted heavy capital investment in new pro-

duction plants, primarily for DRAMs and microprocessors. The risk of failing to obtain a return on this investment as a result of a downturn in demand has led to the formation of many partnerships between semiconductor and computer firms in a bid to secure captive sales. Texas Instruments, for example, has a stake of over 26 per cent in the Taiwanese firm Acer. The Korean LG Group, the world’s sixteenth largest semiconductor manufacturer, has formed a partnership with Hitachi to build a production plant in Penang, Malaysia. Samsung has signed a series of five-year contracts with some of the world’s largest computer manufacturers (*The Economist*, 20 January 1996).

Examples of the increased cost of building new manufacturing plants abound. Samsung, for instance, has recently invested over US\$1.3 billion in a DRAM factory in the United States (in Austin, Texas). Hitachi plans to invest US\$2.2 billion in new DRAM factories in Malaysia and Singapore, and should begin production in the first half of 1998. Siemens and Motorola are planning to build a joint 64-megabyte memory plant in Richmond (Virginia), at an estimated cost of US\$1.5 billion (*Nikkei Electronics Asia*, June 1996).

◆ Figure 1.15. *Semiconductor market and investment by region*¹
 Million US\$



1. Estimates for 1996.
 Source: OECD Secretariat, based on Dataquest data.

Top 20 firms

Concentration within the sector continued to increase during 1995. In 1987, the nine top-ranked firms accounted for 48.9 per cent of the market, and by 1995, while the value of the market had increased four-fold in current terms, their share had risen to 52.5 per cent. This trend was borne out for the top 20 firms, whose market share rose from 73 per cent in 1987 to 75.4 per cent in 1995. A key reason is the industry’s growing capital intensity. It cost around US\$4 million to build a new factory in 1970, but by 1995, the average cost had risen to over US\$1.2 billion (Hutcheson and Hutcheson, 1996). In view of its leading position as a manufacturer of fast-growing products (microprocessors), Intel has ranked first in terms of market share among the firms in OECD Member countries (Table 1.9), and second in terms of rate of growth, behind Samsung.

The gradual rise of Korean firms among the top 20 can be explained by specialisation in DRAMs, a product for which demand is growing rapidly [over 80 per cent of Korean semiconductor production in 1994 consisted of DRAMs (*Electronique Internationale*

Hebdo, 25 January 1996)] and the region’s general growth rate, which was higher than that of other regions. However, excessive specialisation in this type of product also increases exposure to the volatility of prices in the international market. Thus, in the first half of 1996, a number of these firms announced that they would cancel or suspend investment in DRAM facilities, and in some cases have even temporarily halted production.¹⁸

3. NETWORKED COMPUTING AND SERVERS

Until the early 1980s, the IT environment was a “mainframe” environment. Then, in the 1980s, it shifted radically to a “desktop” environment. At the beginning of the 1990s, it shifted again, to a “network” architecture, which includes client-server computing and open networks like the Internet.¹⁹ Servers are at the heart of the networked environment, and their use is growing rapidly to connect desktop computers to networks with sophisticated applications. Like any computer architecture, the network requires not only hardware but also software and firms that provide computing services.

Table 1.9. **Top 20 semiconductor companies, 1994-95**

Million US\$ and percentage

Company	Country	1995	1994	Growth (%)	Market share (%)	CAGR 1987/95 (%)	1987
1 Intel	United States	13 172	10 099	30.4	8.7	31.3	1 491
2 NEC	Japan	11 314	7 961	42.1	7.5	16.4	3 368
3 Toshiba	Japan	10 077	7 556	33.4	6.7	16.2	3 029
4 Hitachi	Japan	9 137	6 644	37.5	6.0	16.9	2 618
5 Motorola	United States	8 732	7 238	20.6	5.8	17.3	2 434
6 Samsung	Rep. of Korea	8 329	4 832	72.4	5.5	49.8	328
7 Texas Instruments	United States	7 831	5 552	41.0	5.2	17.7	2 127
8 Fujitsu	Japan	5 538	3 869	43.1	3.7	15.1	1 801
9 Mitsubishi	Japan	5 272	3 772	39.8	3.5	17.1	1 492
10 Hyundai	Rep. of Korea	4 132	1 521	171.7	2.7	n.a.	n.a.
11 Philips	Netherlands	3 901	2 920	33.6	2.6	11.8	1 602
12 SGS-Thomson	France	3 554	2 640	34.6	2.3	19.4	859
13 IBM	United States	3 522	3 035	16.0	2.3	n.a.	n.a.
14 Matsushita	Japan	3 476	2 896	20.0	2.3	11.5	1 457
15 Siemens	Germany	3 062	2 090	46.5	2.0	21.2	657
16 LG Semicon	Rep. of Korea	2 863	1 697	68.7	1.9	n.a.	n.a.
17 Sanyo	Japan	2 714	2 321	16.9	1.8	15.6	851
18 Micron Technology	Rep. of Korea	2 601	1 492	74.3	1.7	n.a.	n.a.
19 Sharp	Japan	2 592	2 188	18.5	1.7	20.3	590
20 Nat Semicond.	United States	2 408	2 023	19.0	1.6	6.0	1 506
Other		37 045	27 906	32.7	24.5	n.a.	n.a.
Total		151 272	110 252	37.2	100.0	18.8	38 251

Source: Dataquest.

Networked computing in the OECD countries

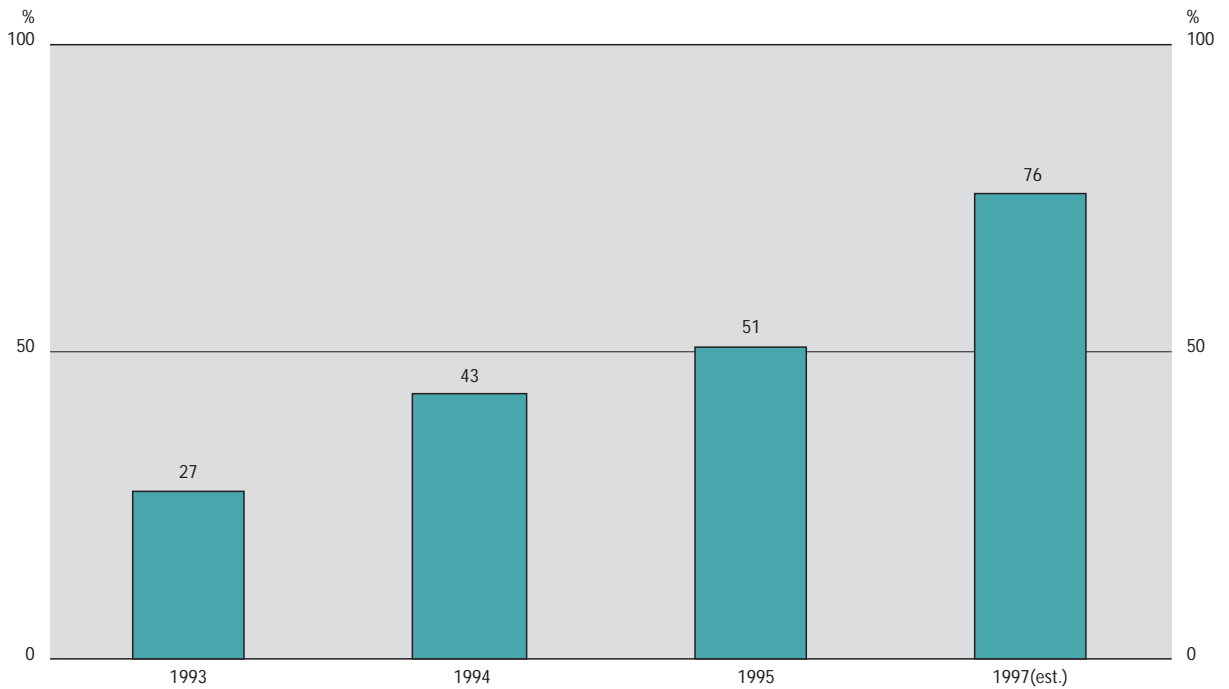
While it is difficult to compare client-server implementation across countries, various statistics indicate a steady shift to client-server architectures in major OECD countries. In North America, the percentage of applications running on client-server systems is increasing rapidly (Figure 1.16). This trend is expected to continue, as almost half of the North American companies surveyed plan to spend "significantly" more on them in the next two years (Deloitte & Touche, 1996). In Europe, Germany is moving most rapidly towards client-server computing, followed by the United Kingdom, Italy, Benelux and France (EITO, 1996; IDC, 1995b). In Japan, among companies implementing "open systems", the percentage of those implementing client-server computing is also increasing (JIPDEC, 1996).

However, the level of LAN²⁰ implementation differs considerably across countries. Of the worldwide installed base of 4.8 million LAN servers in 1994, the United States accounted for 55 per cent, Western Europe 32 per cent, and the rest of the world 13 per cent (Figure 1.17). In 1994, 50 per cent of the LAN servers shipped worldwide went to the United States, 30 per cent to Western Europe, and 18 per cent to the

rest of the world (IDC, 1995a). Differences in LAN implementation can be explained by two factors: the rates of PC diffusion and connectivity. In terms of number of corporate PCs per 100 white-collar workers, leading countries such as Norway, Switzerland and the United States had more than 100, major Western European countries 60 to 80, and Japan only 24 (Figure 1.18). As for PCs connected to LANs, 64 per cent of corporate PCs are on a network in the United States but only 21 per cent in Japan (Dataquest in *Business Week*, 12 June 1995, p. 22).

The major recent development in networked computing is the growth of the Internet, which connects millions of host computers worldwide. As one of the vehicles for networked computing, the Internet is growing dramatically. The number of host computers connected to the Internet increased from 3.2 million in July 1994 to 6.6 million in July 1995 and to 12.9 million in July 1996 (Figure 1.19). Like LANs, the Internet is still most widely used in the United States, which accounted for 63.8 per cent of hosts as of July 1996 (Figure 1.20). American corporate domain hosts are increasing and constitute a quarter (3.3 million) of the total (Network Wizards, 1996). The Internet is becoming increasingly commercial, rather than academic, and the trend is primarily

◆ Figure 1.16. *Share of applications on client-server systems (North America)*

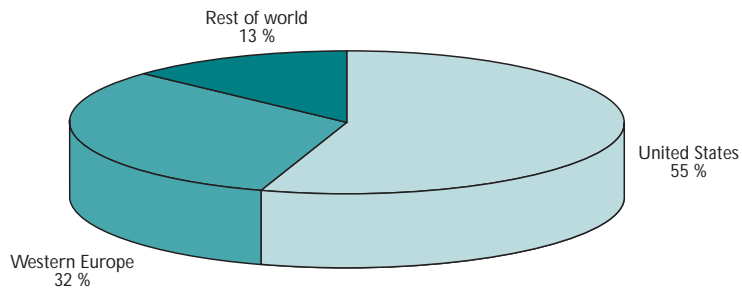


Source: Deloitte and Touche annual CIO surveys.

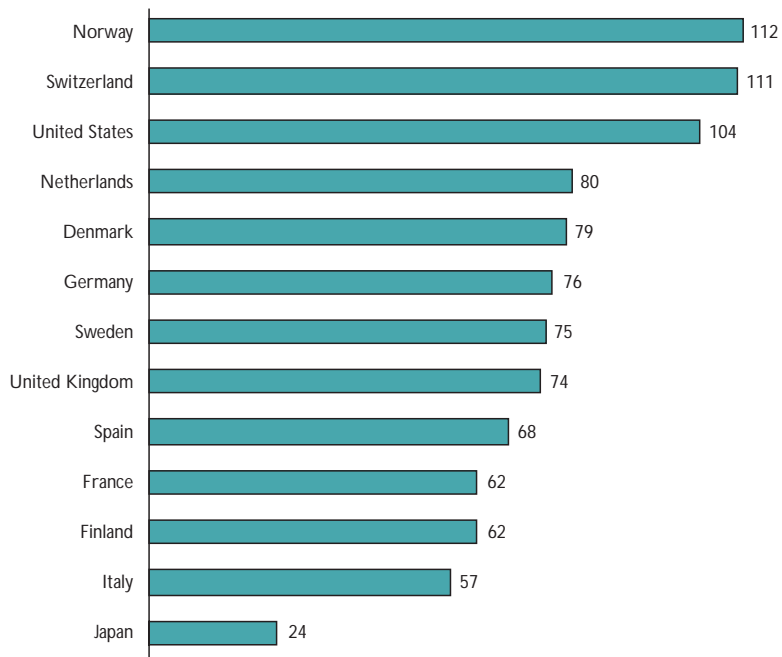
driven by US companies. At present, Internet traffic is estimated to flow mainly from servers to clients, with 80 per cent of the traffic flowing from server to client in mid-1995 and only 20 per cent the other way (Morgan Stanley, 1996). This would suggest that currently, much of the information obtained by Internet users comes from US corporations.

The Internet is being used by enterprises as a way to develop external communication channels, on the one hand, and internal corporate networks (intranets) on the other. Companies are exploiting the WWW to reach consumers for marketing, communications, and business transactions. In early 1996, about 35 000 US companies had a Web site, 8 000 of

◆ Figure 1.17. *Worldwide LAN server installed base, 1994*
Total = 4.8 million units

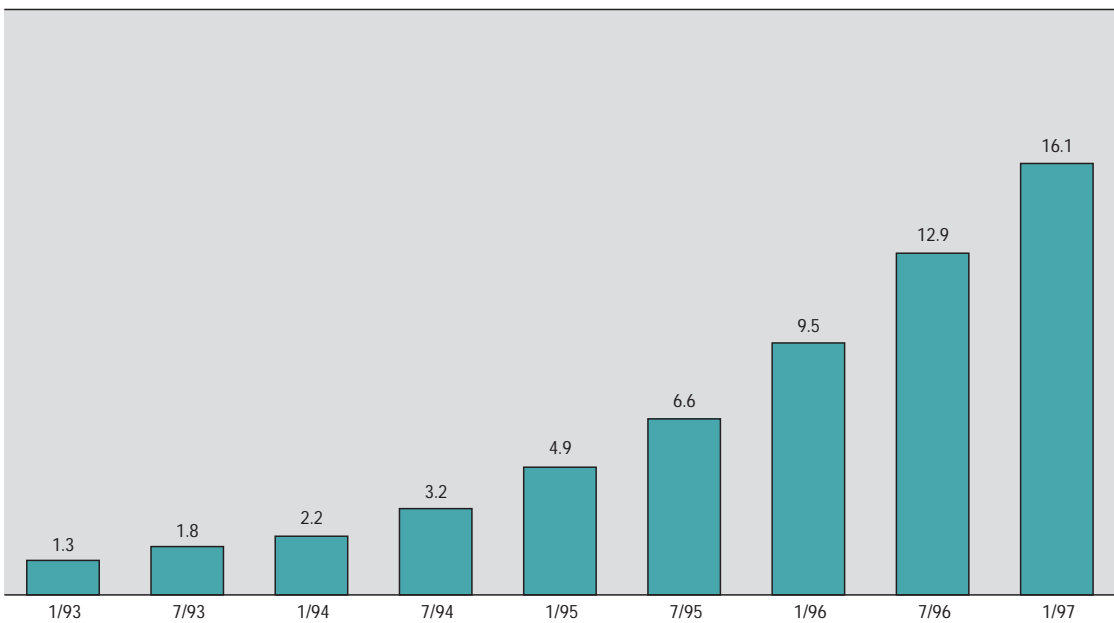


◆ Figure 1.18. *Number of PCs per 100 white-collar workers, 1994*



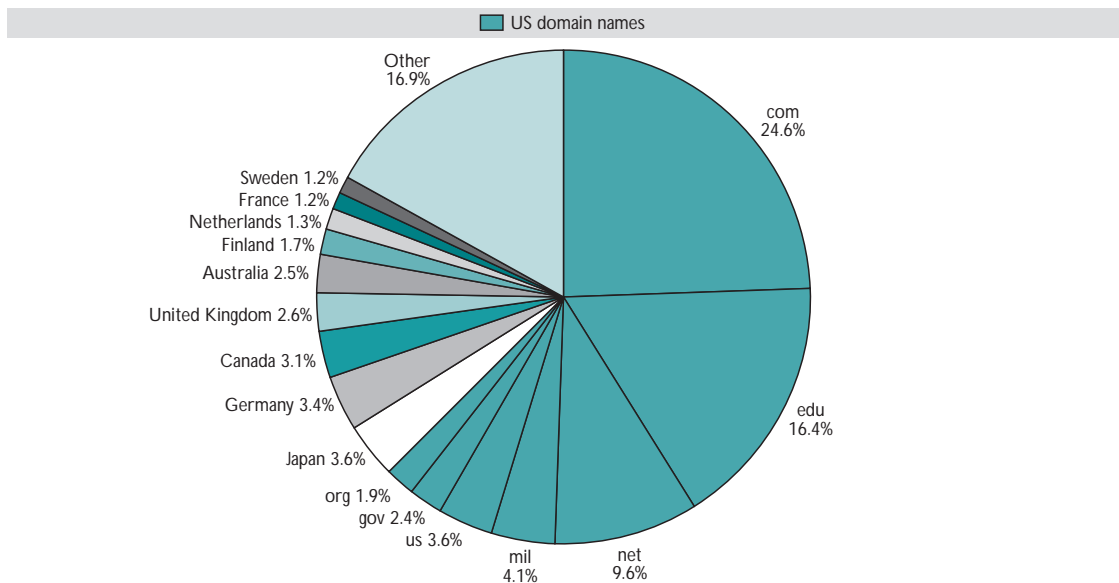
Source: IDC in EITO, 1996.

◆ Figure 1.19. *Number of Internet hosts worldwide*
Million units



Source: Network Wizards, 1997.

◆ Figure 1.20. **Internet hosts by domain name**
 Total = 16.1 million hosts (January 1997)



Source: Network Wizards (<http://www.nw.com>).

them were taking orders, and 5 000 were settling credit card payments; in contrast, only 299 Japanese companies were taking orders and 48 were settling credit card payments (Nomura Research Institute and Technology Management Associates, 1996).

At the same time, intranets are growing rapidly. Corporations commonly use these private networks that support TCP/IP and HTML²¹ to allow employees to browse through corporate information, such as schedules, company events, employee manuals, technical standards, etc. Roughly half of the servers on the WWW are said to be for intranets (*Wall Street Journal*, 7 November 1995). Intranets already represent a significant business opportunity for IT companies; Netscape, for example, sells 70 per cent of its software for intranets and 30 per cent for the Internet (Morgan Stanley, 1996). Intranets are likely to grow rapidly, at least in the United States. A survey shows that 22 per cent of the Fortune 1000 companies already use Web servers for internal applications and an additional 40 per cent are considering doing so (Forrester Research in *Datamation*, 15 May 1996, p. 60, <http://www.datamation.com>).

Networked computing requires the deployment of client and server computers. Billions of desktop

computers are already in place, and companies wishing to benefit from networked computing are beginning to invest in servers and various networking software. To cultivate and meet demand, IT companies are introducing innovative products and improving price performance at an unprecedented pace in order to take advantage of this rapidly evolving, non-commodity market.

Corporate server market

As the trend towards networked computing gains momentum, competition is intensifying among hardware and software companies in the server market. This section provides an overview of corporate servers (by platform and software) in terms of growth, major suppliers, and driving forces. Although Internet servers generally overlap with corporate servers, they are discussed separately in the section that follows, owing to their special characteristics.

Server platform

Servers are computers that provide services to client computers connected via a network. Servers are defined by the use to which they are put, not by

hardware features. Most commonly, they are dedicated machines that provide a range of services from basic file sharing, print sharing, and internal LAN communications to access to or provision of applications such as database, e-mail, fax, and workflow and sophisticated applications such as large databases and on-line transactions. For this reason, servers can be computers of almost any size and capability. This section classifies server platforms into three categories ranging from high- to low-end: enterprise servers, superservers and workstations, and PC LAN servers.

Enterprise servers are defined by Dataquest Inc. as systems more powerful than work-group servers but somewhat less powerful than mainframes, with most systems using multiprocessing to speed performance. In this high-end segment of the market, servers use proprietary microprocessor architectures and operating systems. In terms of server-host spending (including hardware and operating system software), all UNIX²² systems and the OS/400 represent more than half of the total and IBM's MVS²³ mainframes account for most of the rest (Gartner Group in EITO, 1996).

UNIX servers are gaining popularity, a trend that is expected to continue as corporate demand for packaged business applications continues to grow. Companies are shifting away from IBM's MVS mainframes to UNIX servers as they move from custom applications to packaged business applications (e.g. human resources, financial and manufacturing applications built on RDBMS products) in order to achieve cost reductions and gain further flexibility in networking and database management systems. In 1995, UNIX enterprise servers represented an US\$18 billion market worldwide. The major UNIX midrange server vendors were Hewlett-Packard, IBM, and Sun Microsystems; in 1995, their server revenues increased by 36, 12, and 22 per cent, respectively (*Datamation*, 15 June 1996). Server suppliers (including traditional low-to-midrange multi-user systems) are mainly US companies, along with a few Japanese and European ones (Table 1.10). While information on the growth in number of UNIX server shipped worldwide is not readily available, in Japan, for example, 74 800 UNIX servers were shipped in 1995, up by 51 per cent over the previous year (Gartner Group Japan in *Nikkei Sangyo Shimbun*, 25 April 1996, p. 9).

Superservers and workstations comprise the midrange segment of the server market. Superservers based on multiprocessors are growing rapidly owing to increasing demand for important server applications such as database, e-mail, fax, workflow, and

Table 1.10. **Top server suppliers worldwide**

Calendar year 1995 results; million US\$

Rank	Company	Country	Server revenue
1	IBM	United States	6 475
2	Hewlett-Packard	United States	3 650
3	AT&T	United States	3 529
4	Compaq Computer	United States	3 256
5	NEC	Japan	2 516
6	Tandem	United States	1 846
7	Toshiba	Japan	1 821
8	Digital Equipment	United States	1 689
9	Fujitsu	Japan	1 608
10	Siemens Nixdorf	Germany	1 226
11	Mitsubishi	Japan	871
12	Motorola	United States	773
13	Sun Microsystems	United States	650
14	Silicon Graphics	United States	610
15	Apple Computer	United States	569
16	Hitachi	Japan	486
17	Data General	United States	458
18	Groupe Bull	France	424
19	Wang Laboratories	United States	304
20	Olivetti	Italy	296
21	Stratus Computer	United States	276
22	Samsung	Rep. of Korea	161
23	Dell Computer	United States	159
24	Sequent	United States	157
25	Control Data	United States	155

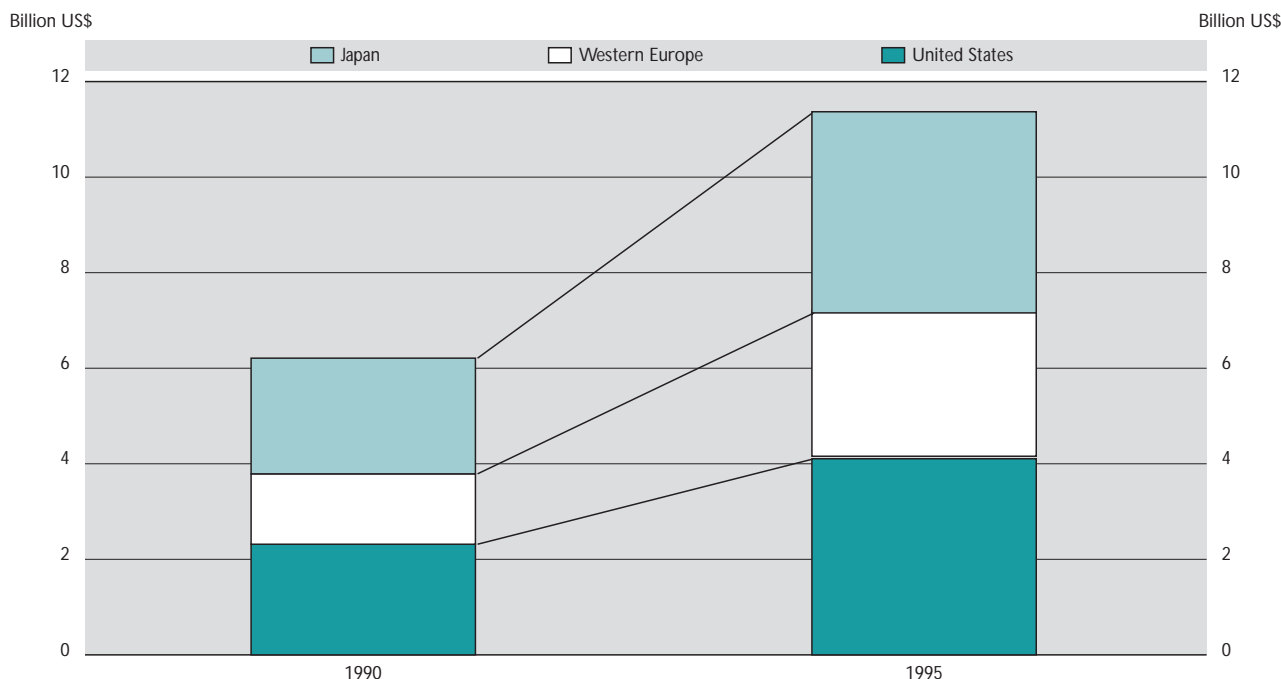
Note: Servers include traditional low-to-midrange multi-user systems.
Source: *Datamation*, 15 June 1996.

remote access, combined with the availability of multiprocessor technology in low-end machines. Shipments of superservers grew from 50 300 units in 1994 to 127 000 units in 1995, an increase of 152 per cent (IDC in *Computer World*, 18 March 1996, p.14, <http://www.computerworld.com>).

Workstations, microprocessor-based single-user systems with high performance relative to PCs (e.g. high graphical resolution, built-in LAN interface), are increasingly used as servers. Although it is not clear what portion of workstations are being used as servers, total units shipped have almost doubled in the last five years (Figure 1.21). Total workstations shipped stood at 779 385 units in 1994, in a market led by Sun Microsystems (36 per cent), followed by Hewlett-Packard (20 per cent), IBM (13 per cent), DEC (11 per cent), and Silicon Graphics (6 per cent) (*Datamation*, 1 June 1995, <http://www.datamation.com>).

Technological innovations in microprocessor chip technology have improved the performance of enterprise servers and superservers and driven demand. RISC (reduced instruction set computing) technology, which was introduced in the 1980s and surged in the early 1990s, simplifies architectures by

◆ Figure 1.21. *Workstation shipments for selected countries*



Source: IDC (1995b).

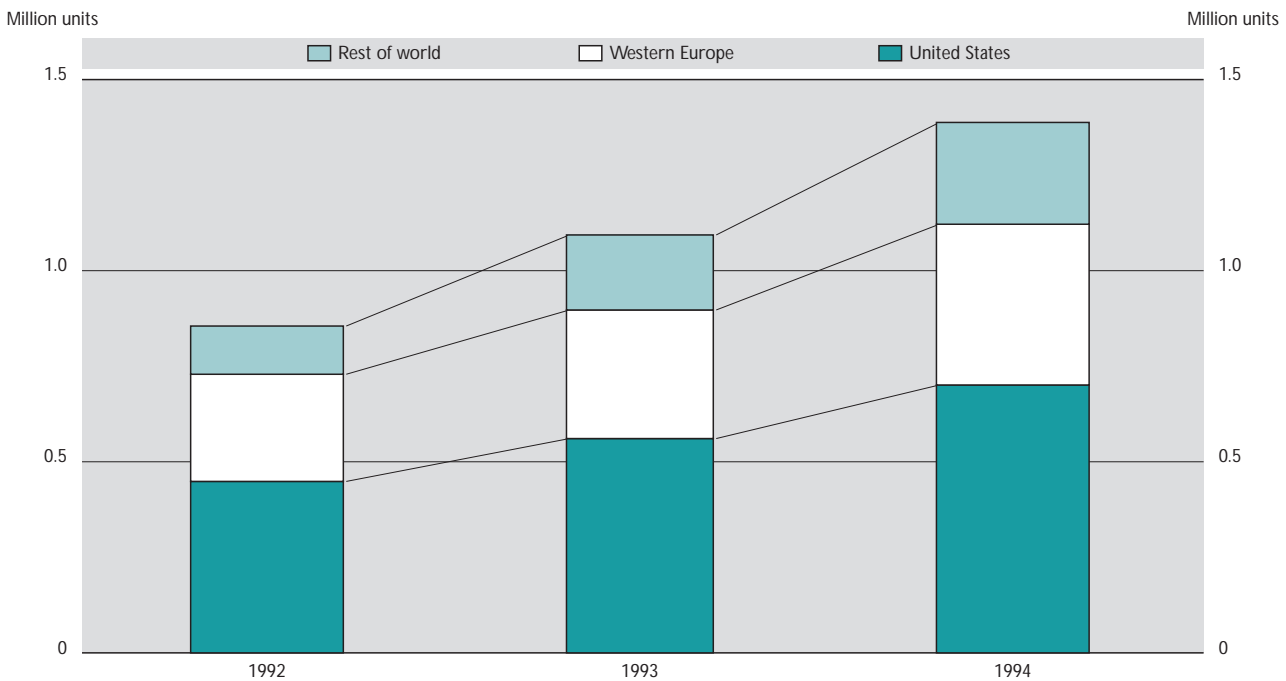
reducing the number of instructions and thereby improves performance. SMP (symmetric multiprocessing), a microprocessor architectural technology which supports multiple processors and thus boosts processing power, is another major innovation. By putting multiple RISC processors (from two to 36, with four to six as typical configurations) on SMP systems, manufacturers of RISC chips have succeeded in raising power. However, RISC SMPs are more expensive and therefore tend to be used for specialised applications.

In the low-end market segment, Intel is attempting to push its way into the server market with SMP systems based on Pentium Pro, the first CISC (complex instruction set computing) microprocessor with SMP functionality. A CISC SMP server with four processor models costs less than US\$15 000 or about half the price of a comparably configured RISC server (*Information Week*, 27 November 1995). While RISC-based servers currently dominate the server market, SMP servers using CISC chips represent significant competition. This is particularly true at the low end of the market, as users upgrading from PC LANs, who once turned automatically to RISC workstations, now have a viable alternative. If the CISC SMP system

gains popularity, it will bring inexpensive commodity standards to a market that is currently characterised by proprietary microprocessor architectures.

LAN servers (PCs and small-scale servers) provide various services to desktop computers on the network. Worldwide shipments of LAN servers are increasing as companies continue to invest in LANs for downsizing and LAN-based applications. In 1994, 1.4 million LAN servers were shipped worldwide, increasing the installed base, worldwide, by almost 30 per cent to 4.8 million units (Figure 1.22). The price-performance ratio of LAN servers is improving: the average configuration declined in price from US\$6 162 in 1992 to US\$5 886 in 1994, while average storage capacity quadrupled from 500 megabytes to 2 gigabytes (IDC, 1995a).

PCs accounted for more than 70 per cent of the total LAN server market. In 1994, PCs built and sold as servers accounted for 42 per cent of the worldwide LAN server market, and standard desk-top PCs running a network OS accounted for 33 per cent. Non-PC servers, such as workstations and minicomputers, accounted for the rest. The three major PC server vendors are Compaq (29 per cent of the market in 1994), IBM (18 per cent), and Hewlett-Packard (15 per

◆ Figure 1.22. *Worldwide LAN server shipments*

Source: IDC (1995a).

cent) (IDC, 1995a). PCs configured as servers are increasing and are likely to replace standard desktop PCs as users demand more integrated and tailored hardware (for storage and network controllers) and software (for configuration and management utilities).

Server operating systems²⁴

Until recently, most servers have been built using the manufacturer's microprocessor architecture and proprietary OS. As a result, UNIX OSs currently dominate for servers in the high-end market (e.g. HP-UX, IBM AIX, Sun Solaris) which are tied to the manufacturer's hardware. In turn, most machines that use UNIX have been servers. UNIX is likely to gain shares from mainframes, which will survive as specific database servers and/or large mission critical holding hosts. Although the extent to which UNIX will take share from mainframes is not clear, some analysts argue that the "year 2000 problem"²⁵ will accelerate this shift, as corporations may prefer migrating towards more flexible UNIX systems rather than modifying or rewriting current software that runs on mainframes.

With the proliferation of small-scale client-server systems in firms, UNIX is being challenged by Microsoft Windows NT at the low end of the server OS market. Windows NT (a 32-bit multi-task OS) has gained popularity since its introduction in 1993 for its multi-platform hardware support, the ability to act as applications server, and a common interface. NT servers are currently used primarily for low-end applications (e.g. file/print sharing, branch server) that typically support a small group of users for a relatively light workload. The low cost of NT server hardware based on Intel's Pentium platforms is responsible for NT's growing popularity in the low-end segment, where cost is often the determining factor for purchase. Computer vendors like Compaq, DEC, and HP have announced support for NT servers, and major software companies such as Computer Associates, Informix, Oracle, and Sybase are NT-enabling their major products.

Network operating systems (NOS), which are used to develop LANs, are dominated by Novell's Netware. In 1994, the NOS market grew 19 per cent in terms of licenses, but decreased in terms of sales value by 4 per cent to US\$2.3 billion because of strong pricing competition (IDC, 1995a). Also in 1994,

1 million PC LAN OS licenses, representing 19.5 million PC nodes, were shipped worldwide; 65 per cent were Novell Netware, followed by Microsoft Windows for Workgroups and Windows NT (9 per cent) and IBM OS/2 LAN Server (9 per cent). However, some industry analysts, including Gartner Group and IDC, predict that Windows NT will outrun Netware in terms of shipments to become the largest server OS by 2000 (*Nikkei Communications*, 18 September 1995, p. 61).

As PC LANs and e-mail systems continue to proliferate, the demand for groupware is increasing. Groupware is software that allows groups of users to receive and access messages, documents and files, typically within a department or firm and sometimes beyond the company. It is a catch-all term for products such as e-mail systems, directories, files, scheduling, and workflow. What distinguishes groupware from PC LAN file servers is that it features easier document management and graphical user interface (GUI).²⁶ Groupware also has other advantages over RDB (relational database) products for GUI, such as ease of customisation and control of access.

Sales of groupware packages of all kinds amounted to US\$2 billion in 1994. The leading groupware products include Lotus Notes, with 1.5 million users, followed by Novell's Groupwise and Microsoft's Exchange (*Business Week*, 26 June 1995, p. 54). While positioned as the leading product for extensive collaboration, including simultaneous update (database replication) and distribution of complex documents, Lotus Notes is increasingly challenged by Novell's Groupwise and Microsoft's Exchange as Novell makes its products more appealing to the large Netware base and Microsoft embeds Exchange into its OSs.

As companies base their internal networks on the Internet, some functions performed by groupware and Internet's World Wide Web (WWW) are beginning to overlap. Some analysts predict that, in response to the challenge from the Internet, groupware will become more open and compatible with Internet standards (making corporate directories compatible with international standards, developing tools to convert groupware databases into the Web format, etc.) (Forrester Research, Inc., 1996).

Internet server market

The Internet allows organisations and individuals to communicate with users who are estimated to number several tens of millions. There are many types of Internet applications (WWW, e-mail, and file trans-

fer protocol – FTP), which run on client-server architecture. Servers carrying these applications store information and send it, upon request, to client computers. Servers used for Internet applications have generally been highly configured and/or marketed as Internet servers.

Internet server platform and OS

Internet server sales increased by an estimated 30 to 35 per cent from 1994 to 1995 (Morgan Stanley, 1996). Sun Microsystems, the largest supplier of Internet servers, is estimated to have one-third of the Internet server base with its Netra Internet server line based on Sun's SPARC architecture with proprietary OS (Figure 1.23). Sun's Internet server revenue accounts for about 10 per cent of its total server revenue which grew by 22 per cent to US\$650 million in 1995 (*Datamation*, 15 June 1996, pp. 58-60). Sun faces competition from other server hardware vendors such as Digital, IBM, and Hewlett-Packard which are Web-enabling their product lines.

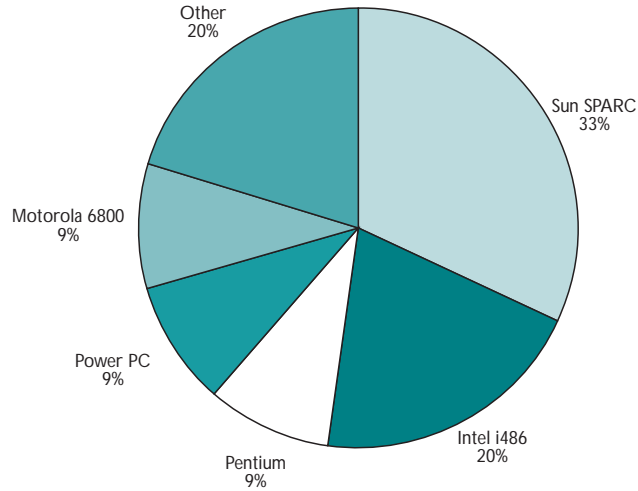
For Web servers, UNIX is the most popular OS with a 68 per cent market share owing to its traditional support for IP (Internet Protocol) and possibly to power requirements for Web servers. The leading UNIX OSs are Sun OS and Solaris, which together represent about half of the UNIX OS market, with Mac OS and Windows/NT constituting the rest (Figure 1.24). The Macintosh is preferred by many Web-site developers (probably because of its strong presence in the publishing and graphics markets) and is also popular as a Web server.

Despite UNIX's current domination, several significant trends are challenging Sun and other UNIX-based server vendors. IP is no longer confined to the UNIX world, as other computer OSs have been upgraded to include IP support (e.g. Windows NT), and many other networking OSs support many networking protocols (e.g. Novell's Netware). Although large servers are likely to be in demand to support electronic commerce and download applications as the Internet matures, the commodity technology based on Windows NT and Intel-based machines is posing a threat to UNIX-based servers by leveraging their advantages: Microsoft through its dominance of the desktop client computer environment, Intel through price performance.

Internet software

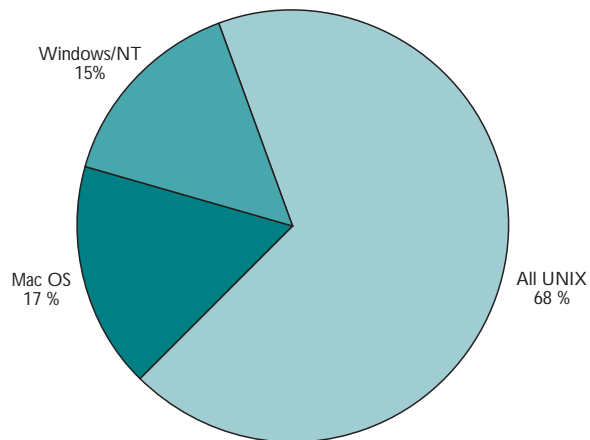
Sales of Internet software (including server software, browser software, Web-enabled database

◆ Figure 1.23. **Web servers by CPU**
January-March 1995



Source: Mirai.com survey in Morgan Stanley, 1996.

◆ Figure 1.24. **Web servers by OS**
January-March 1995



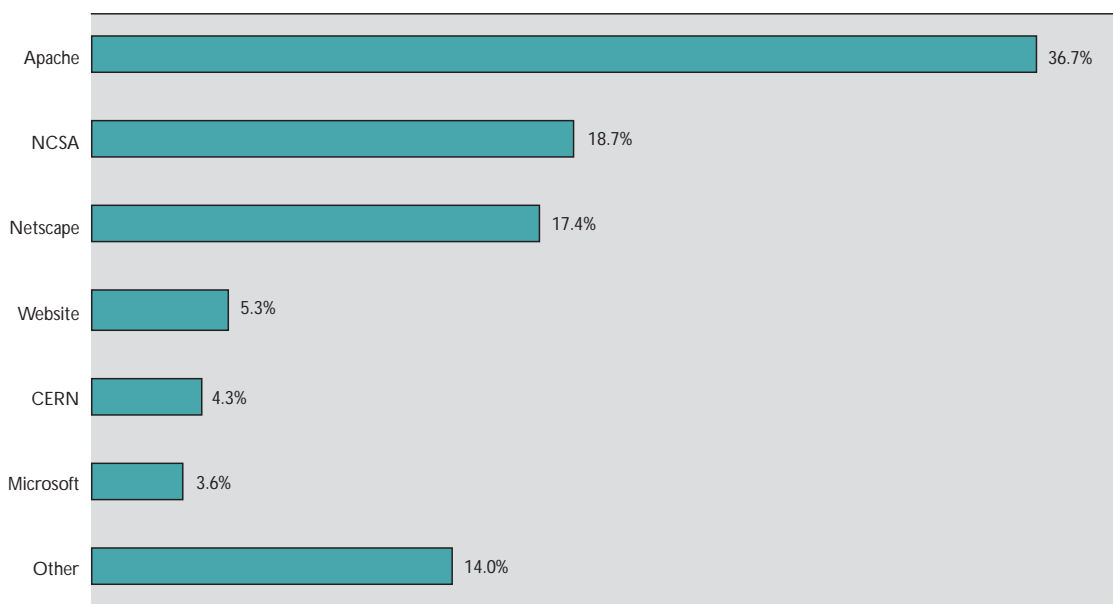
Source: Mirai.com survey in Morgan Stanley, 1996.

products, and development tools) are estimated at US\$900 million for 1995, and some analyst expect sales to grow to about US\$5.1 billion annually by the end of the decade (Morgan Stanley, 1996). Installed on machines that are permanently connected to the Internet, Internet server software enables servers to store and distribute data and information to client computers. It includes Web servers, FTP servers, gopher servers, etc., although most of the commercial server software applications are Web servers. Server software is likely to be the key building block for the Internet, as all other applications presumably must be compatible with server software.

The Web server software market has been dominated by free products such as Apache, NCSA and CERN on UNIX platforms; together, they have 60 per cent of the “.com” domain Web servers (Figure 1.25). Commercial products are rapidly gaining share; Netscape leads with 17 per cent market share and is followed by WebSite (O’Reilly & Associates), a 32-bit Web server, and Microsoft’s Internet Information Server based on Windows NT which runs on Intel-based machines.

Internet browser software, which runs on users’ machines and enables them to interact with host machines and other users, has been available without cost, thereby contributing greatly to the dramatic growth of the Internet. For commercial software companies, the browser software market alone has not yielded profits but has allowed them to establish a position as leaders in the Internet software market. By giving away its browser at an early stage, Netscape obtained a dominant position in the *browser* market and the largest share as a commercial software vendor in the *server* software market. Netscape’s sales, reported to be US\$80.6 million in 1995, are broken down as follows: 58 per cent browsers, 29 per cent servers, and 13 per cent services (Morgan Stanley, 1996). Microsoft is Netscape’s major competitor. Netscape provides a comprehensive set of browser and server software products for major computing platforms, including Windows, Macintosh, and UNIX, that are required by corporations with a heterogeneous computing environment. Microsoft’s strategy is to build Internet software into its expanding base of Windows 95 on the client side and NT on the server side.

◆ Figure 1.25. **Web server software market shares**
 Total = 171 738 “.com” servers (June 1996)



Source: Netcraft, 1996.

Box 1.1. Digital content – CD-ROMs

Today, thanks to the penetration of PCs, modems and CD-ROM drives into households, CD-ROMs (compact disk read-only memory) are the most established medium for publishing merged text, audio, graphics and video. Digital publishing is still in its infancy, and there is some question whether it will evolve or simply be an interim technology until on-line access becomes more widespread ("The Multimedia Wipeout", *The Economist*, 15 June 1996). Although the overall trend appears to be towards networked computing, constraints exist, such as congestion (see Part III) and the installed platform base. CD-ROMs offer an off-line means of delivering information.

Supported by strong growth in hardware, 1995 CD-ROM sales reached US\$1.8 billion in the United States (business software, 50 per cent; games, 12 per cent; home education software, 10 per cent; information, 10 per cent; other, 18 per cent) and US\$1.6 billion in Japan (games, 63 per cent; education, 21 per cent; reference materials, 9 per cent; adult, 7 per cent; "karaoke" and car navigation software excluded), an increase of 31 per cent and 65 per cent, respectively, from the previous year (Software Publishers Association, 1996; Multimedia Association of Japan, 1995). The French market was substantially smaller at US\$160 million (games, 40 per cent; education, 26 per cent; reference materials, 20 per cent; adult, 10 per cent; other, 4 per cent), but was growing at a rate of 70 per cent in terms of titles in 1994 (Documentation d'Analyses Financières SA, 1995). Sales volume is growing faster than turnover, an indication that the average price per unit is dropping. Of the estimated 15 000 CD-ROM titles available, only a handful have sold more than a million copies; most do not sell 100 000. The number of publishers is rising: of the approximately 2 000 US publishers in 1995, about 700 entered the market during the previous year. They include traditional publishers such as France's Hachette and Larousse and new entrants such as the United States' Microsoft.

In 1994, CD-ROMs accounted for no more than 1 per cent of publishing (newspaper, magazines, books, printing, CD-ROMs, on-line business and consumer information services), in the United States, Japan and France (Table 1.11); in the United States, on-line information services accounted for 8.4 per cent. Digital publications appear unlikely to replace paper-based publications, but in the case of encyclopaedias, for example, the CD-ROM version accounted for 60 per cent of total sales in 1994, growing from less than 100 000 copies in 1988 to more than 800 000, while sales of the paper version declined by almost half, from one million in 1988 (BAI and BCG, 1995). This is partly due to the fact that many CD encyclopaedias are now "bundled" with purchases of PCs. While reference volumes are particularly well suited to CD-ROMs, some are now venturing on-line as well, joining newspapers and magazines. For example, the *Encyclopaedia Britannica* is available on a subscription basis over the Internet. In addition to ensuring regular updates, the on-line version also supports hypertext links to other material on the Web, making it a reference tool to many Internet sites (Tapscott, 1996).

Table 1.11. Turnover in the publishing industry, 1994

	United States		Japan		France	
	US\$ bn	Per cent	US\$ bn	Per cent	US\$ bn	Per cent
Newspaper	43.7	24.7	23.6	16.6	5.2	21.0
Magazines	22.2	12.6	18.4	12.9	5.2	21.0
Books	23.4	13.3	10.3	7.3	4.3	17.3
Printing	71.0	40.2	87.0	61.2	8.6	34.7
CD-ROMs	1.4	0.8	1.0	0.7	0.2	0.8
On-line info. services	14.9	8.4	2.0	1.4	1.3	5.2
Total	176.6	100.0	142.3	100.0	24.8	100.0

Note: Newspaper sales for Japan and France include advertising revenues; French data are 1993 except for CD-ROMs and on-line services; French on-line services refer to Minitel services; Japan's CD-ROM sales excludes karaoke and car navigation software; US\$1 = ¥ 100 and FF 5.

Source: US: Software Publishers Association (<http://www.spa.org>), Christopher Burns; Japan: Dentsu Institute for Human Studies, Nikkei Newspaper, Multimedia Content Association of Japan (1995), MITI; France: Documentation d'Analyses Financières SA, France Telecom.

In summary, on the server side, many business applications, except those that are mission-critical, are migrating from mainframes to UNIX-based smaller and cheaper but nevertheless high-

performance enterprise servers, superservers, and workstations. Driving this trend is the improving cost performance of hardware based on microprocessor technology, the increasing added value of products,

and strong support from software companies to develop business applications for client-server systems. On the client side, desktop computers in the workplace are increasingly equipped with a network-capable OS, groupware, and/or Internet client software. The market is characterised by intense competition among software companies to achieve the largest installed base.

4. IT AND THE ECONOMY

Value added

Value added in ICT goods was US\$235 billion in the OECD area in 1993, a decrease of US\$2 billion from 1992. About one-fourth was performed in the office, computing and accounting equipment (OCA) sector. During the period 1990-93, value added in the information and communication technology (ICT) goods sectors increased at a significantly slower pace than total manufacturing, reversing the trend of the early 1980s (Figure 1.26). This downturn is mostly due to negative growth in Japan, the United Kingdom and Italy, and virtually zero growth in the United States, Germany and France. Increased competition, pressure

on prices, and a recent shift to standardisation were major factors contributing to this trend.

OCA value added in the OECD area increased at an average annual rate of 7.4 per cent between 1980 and 1993, as compared to 6.9 per cent for radio, TV and communication equipment (RTC) (Table 1.12). Value added in communication services as a share of GDP has remained fairly constant since the 1970s, with the United States displaying a consistently higher share than Europe (2.7 per cent of GDP in 1993 in the United States, versus 2.1 per cent in Europe). The share of ICT in manufacturing value added has remained stable in Europe since the 1980s (at around 6 per cent), although significant differences exist among countries: France, Germany, Sweden and the United Kingdom have maintained high shares (between 6 and 8 per cent), the Netherlands had the highest share in 1993 (around 10.6 per cent), and Finland has experienced the fastest growth (from less than 2 per cent in 1980, to over 6 per cent in 1993). The share has increased slightly in the United States (from around 4 per cent in the mid-1970s to over 7 per cent in 1993) and greatly in Japan (from 6 per cent to around 11 per cent in the same period) (Figure 1.27).

◆ Figure 1.26. *Average annual growth rate of value added (current prices) in ICT and total manufacturing in 17 OECD countries*

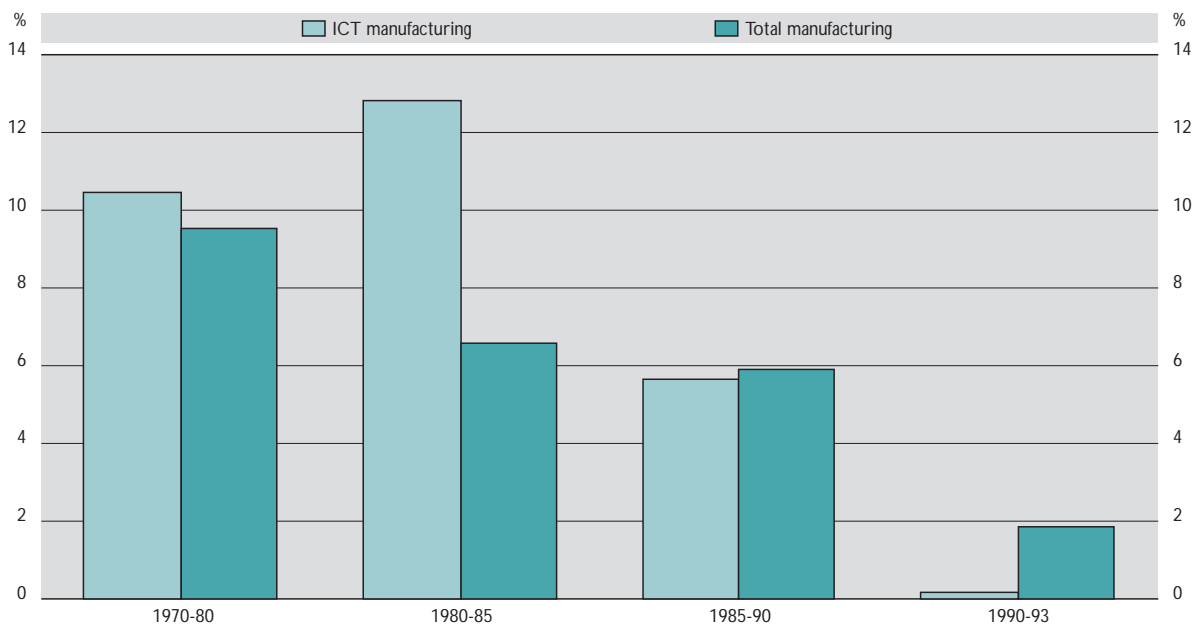


Table 1.12. Value added in selected ICT sectors, current prices

	Office and computing equipment			Radio, TV and communication equipment			Communication services			ICT goods as a percentage of manufacturing value added	
	Million PPPS		CAGR (%)	Million PPPS		CAGR (%)	Million PPPS		CAGR (%)	1980	1993
	1980	1993		1980	1993		1980	1993			
United States	10 057	22 879	6.5	27 207	58 376	6.0	69 000	170 800	7.2	6.3	7.3
Canada	318	682	6.0	1 246	3 429	8.1	5 145	11 570 ¹	7.6	3.5	4.8
Mexico	220	1 093	13.1	1 073	1 924	4.6	..	..		2.4	2.3
Japan	4 595	18 084	11.1	15 322	52 484	9.9	..	..		7.3	10.5
Australia	587	1 162	5.4	72	152	5.9	2 506	8 030	9.4	2.5	2.9
New Zealand	4	24	15.4	48	82	4.2	654	1 443 ²	8.2	1.1	1.1
Austria	..	..		302	805	7.8	1 416	3 655	7.6	..	..
Belgium	..	..		..	..		1 313	3 400	7.6	..	..
Denmark	38	116	9.0	183	443	7.0	534	1 676	9.2	2.9	3.4
Finland	47	195	11.6	126	768	14.9	696	1 713	7.2	1.8	6.0
France	1 974	4 325	6.2	4 837	10 052	5.8	9 505	24 304	7.5	5.6	6.7
Germany	2 969	5 286	4.5	10 437	24 548	6.8	13 434	30 839 ³	7.2	6.9	8.4
Italy	1 181	1 959	4.0	2 648	5 240	5.4	5 034	17 214	9.9	2.9	3.5
Netherlands	200	246	1.6	2 379	4 769	5.5	2 252	5 804	7.6	11.8	10.6
Norway	32	38	1.2	138	245	4.5	567	1 632 ¹	10.1	3.1	2.8
Portugal	24	10	-6.2	298	712	6.9	623	1 751 ²	10.9	2.7	2.7
Spain	126	252	5.5	1 556	2 188	2.7	..	..		2.3	2.4
Sweden	175	493	8.3	696	1 022	3.0	1 463	3 292	6.4	5.4	5.7
United Kingdom	1 365	3 536	7.6	5 005	8 324	4.0	9 275	23 355 ³	8.0	6.0	6.4
OECD-17	23 911	60 377	7.4	73 271	174 759	6.9	116 429 ⁴	285 084 ^{3, 4}	7.7	5.8	7.2

1. 1991.

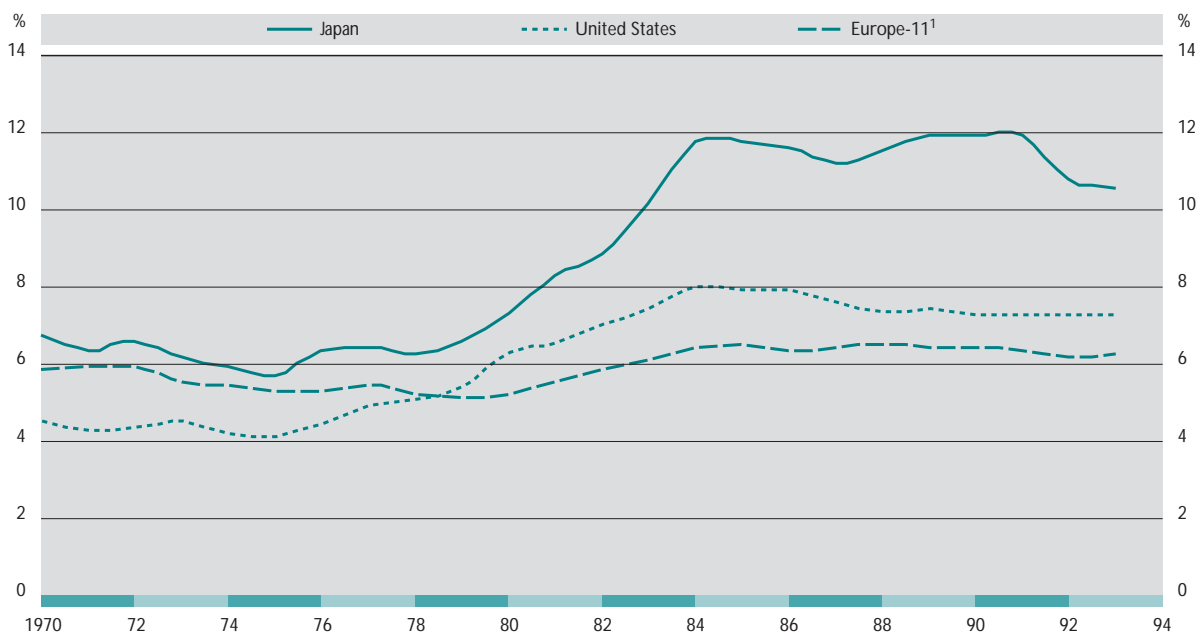
2. 1990.

3. 1992.

4. OECD-12 = United States, Australia, Austria, Belgium, Denmark, Finland, France, Germany, Italy, Netherlands, Sweden, United Kingdom.

Source: OECD, STAN database (DSTI), May 1996.

◆ Figure 1.27. *Share of ICT in manufacturing value added (current prices)*



1. Europe-11: Denmark, Finland, France, Germany, Italy, Netherlands, Norway, Portugal, Spain, Sweden, United Kingdom.
 Source: OECD, STAN database (DSTI), May 1996.

Employment

Total manufacturing employment in the OECD area declined from 72 million in 1978 to 66 million in the mid-1980s. After a slight increase in the late 1980s, the trend has been downwards, reaching 63 million in 1994. Only Japan significantly increased its share of total OECD manufacturing employment, from 18.9 per cent in 1980 to 23.7 per cent in 1993. The major share losses occurred in the EU-4 countries (France, Germany, Italy, the United Kingdom), whose share has declined from 37 per cent to 33 per cent over the same period. High-technology manufacturing employment increased significantly in the late 1970s and early 1980s, but has stabilised at around 12.5 million since the mid-1980s (Figure 1.28).

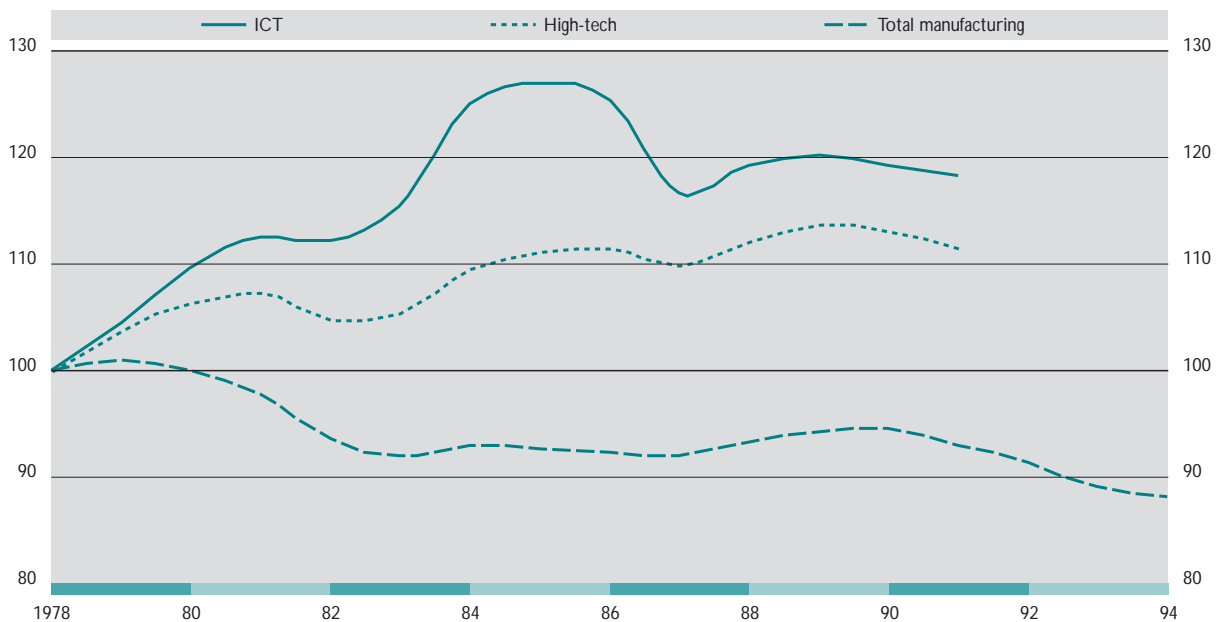
Total employment in the sectors producing ICT goods in the OECD area declined from 4.7 million in 1992 to around 4.5 million in 1993 (Table 1.13). Employment has declined consistently since the peak of 1985 at an average annual rate of 1.9 per cent. In the OECD area as a whole, employment in the OCA sector dropped to 913 000 in 1993, after a peak of 1.1 million in 1985, with the result that growth has been very slow since 1980 (at 0.6 per cent annually).

Employment in the RTC sector has been more dynamic, increasing from 3.4 million in 1978 to 4.1 million in 1985, then declining to 3.6 million in 1993. Recent job losses can be attributed in part to industry restructuring, as firms downsize and out-source certain non-core activities, as well as to changes in the regulatory environment.

The major regions show clear patterns with respect to employment in ICT manufacturing (Figure 1.29):

- North America witnessed large employment gains in the late 1970s, a sharp decline in the late 1980s, and a slower decline in the 1990s.
- Japan experienced strong employment growth in the early 1980s (9 per cent CAGR between 1978 and 1984), and overtook North America around 1987 as the region with highest employment in this sector. Since the early 1990s, there has been a slight decline due to the recession and increased outsourcing.
- Employment in the EU-4 declined regularly since the mid-1970s, stabilised at around 1.2 million, before dropping sharply in the

◆ Figure 1.28. *Employment trends in 14 OECD countries*
Index: 1978 = 100



Source: OECD, STAN database (DSTI), May 1996.

early 1990s (–4.3 per cent CAGR between 1990-93).

As a share of total manufacturing employment, employment in ICT manufacturing has remained stable in Europe (around 5 per cent), increased slightly in North America (from 6 per cent in 1970 to over 8 per cent in 1983-86, then down to under 7 per cent), and increased sharply in Japan during the early 1980s (from 7 to almost 12 per cent), followed by a gradual decline after 1991 (to around 11 per cent in 1993).

In most OECD countries, employment in communications services has remained stable since the 1980s. The relative size of this sector with respect to ICT manufacturing varies widely (90 per cent in the United States and the Netherlands, and six times as large in Norway in 1993). The overall trend has been towards an increase in relative size (except in Canada and the Nordic countries) (Table 1.13).

In the OECD area, average labour compensation in the OCA sector has been consistently higher than the manufacturing average. Differences between countries have been reduced, with labour compensation indices for most OECD countries steadily increasing and converging at around 1.6 times total manufacturing (from 1.3 times in the 1970s).

World production

World production of ICT goods surpassed US\$711 billion in 1994 (Figure 1.30 and Table 1.14). Annual growth slowed from 11.6 per cent between 1985-90, to 5.1 per cent between 1990-94. Although production still remains concentrated in the OECD area,²⁷ the OECD share has declined steadily, from over 90 per cent in 1985 to less than 80 per cent in 1994. Geographical shifts of production towards developing Asian countries have continued, with the share of worldwide ICT production in the DAEs rising from 6.3 per cent in 1985 to 17.7 per cent in 1994. Production in the DAEs has been growing very fast (21.8 per cent annually between 1985 and 1994 versus 6.9 per cent for the OECD-18).

The world's two largest producers, Japan and the United States, account for over 58 per cent of world production, with Japan's share steadily increasing to over 30 per cent in 1994, while the United States' production has been growing more slowly, so that its share of world production was 28.3 per cent in 1994, versus 44.6 per cent in 1985. Europe's production has declined in the early 1990s, with negative growth in all EU-4 countries. In 1994, both the Republic of

Table 1.13. **Employment in selected ICT sectors**

	Office and computing equipment			Radio, TV and communication equipment			Communication services			Percentage of ICT in total employment			
	Number employed		CAGR (%)	Number employed		CAGR (%)	Number employed		CAGR (%)	Goods		Services	
	1980	1993		1980	1993		1980	1993		1980	1993	1980	1993
United States	374 118	238 657	-3.4	1 256 060	1 077 310	-1.2	1 245 000	1 174 000	-0.5	1.7	1.1	1.3	1.0
Canada	13 541	11 614	-1.2	46 164	66 828	2.9	228 000	280 000	1.6	0.6	0.6	2.1	2.3
Mexico	5 649	7 054	1.7	67 058	56 273	-1.3	..	..	..	0.4	0.3	..	..
Japan	213 625	382 026	4.6	955 970	1 313 730	2.5	..	..	..	2.0	2.5	..	..
Australia	29 072	20 332	-2.7	2 519	2 226 ¹	-1.1	121 000	124 000	0.2	0.5	0.3 ¹	1.9	1.6
New Zealand	283	566	5.5	4 913	1 659	-8.0	..	..	..	0.4	0.2	..	..
Denmark	2 401	2 958	1.6	12 345	11 622	-0.5	46 320	41 915	-0.8	0.6	0.6	1.9	1.7
Finland	2 537	3 622	2.8	10 128	12 106	1.4	46 000	44 000	-0.3	0.6	0.8	2.0	2.3
France	49 208	56 244	1.0	223 843	175 139	-1.9	415 700	444 600	0.5	1.2	1.0	1.9	2.0
Germany	78 463	67 422	-1.2	444 935	419 758	-0.4	512 000	528 000 ³	0.3	1.9	1.7	1.9	1.8 ³
Italy	29 159	24 382	-1.4	101 138	61 102	-3.8	254 200	295 200	1.2	0.6	0.4	1.2	1.3
Netherlands	4 655	5 116	0.7	114 755	86 148	-2.2	76 074	83 000	0.7	2.4	1.7	1.5	1.6
Norway	1 735	3 198	4.8	10 355	5 459	-4.8	42 900	52 600	1.9	0.6	0.4	2.2	2.6
Portugal	584	496	-1.2	18 671	16 593	-0.9	42 000	43 700 ⁴	0.4	0.5	0.5	1.1	1.2 ⁴
Spain	4 516	4 809	0.5	52 791	38 798	-2.3	..	..	..	0.5	0.3	..	..
Sweden	8 733	11 174	1.9	40 137	30 967	-2.0	71 100	60 100	-1.3	1.2	1.0	1.7	1.5
United Kingdom	56 165	94 602	4.1	331 826	215 175	-3.3	..	..	..	1.5	1.2	..	..
OECD-17	845 373	913 940	0.6	3 691 088	3 588 668 ²	-0.2				1.4	1.3		

1. 1991.

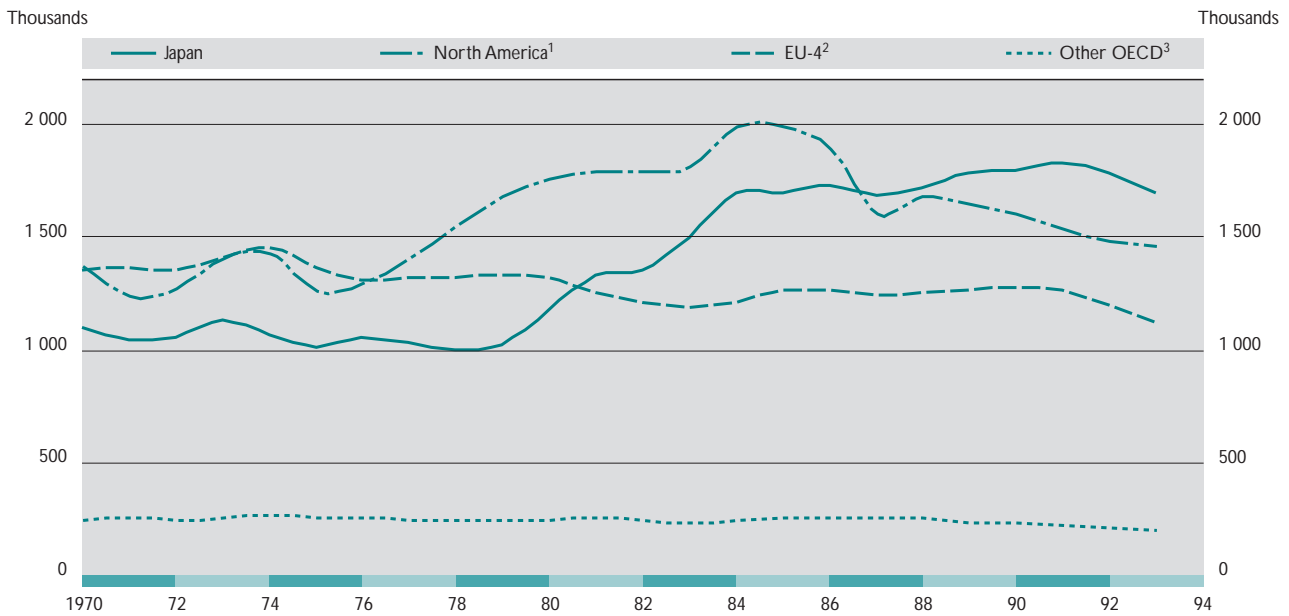
2. Includes 1991 data for Australia.

3. 1992.

4. 1990.

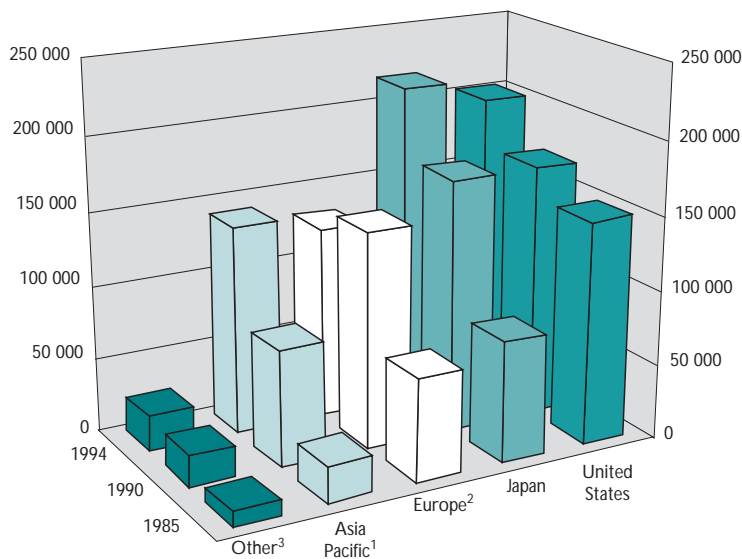
Source: OECD, STAN database (DSTI), May 1996.

◆ Figure 1.29. *Employment in ICT manufacturing*



- 1. North America: Canada, United States, Mexico.
 - 2. EU-4: France, Germany, Italy, United Kingdom.
 - 3. Other OECD: Australia, Denmark, Finland, Greece, Netherlands, New Zealand, Norway, Sweden.
- Source: OECD, STAN database (DSTI), May 1996.

◆ Figure 1.30. *World ICT production*
Million US\$



- 1. Asia Pacific: Australia, DAEs, India, Indonesia, Philippines.
 - 2. Europe does not include Greece, Iceland, Luxembourg, Portugal, Turkey.
 - 3. Other: Brazil, Canada, Israel, South Africa.
- Source: OECD Secretariat calculations, based on data from Elsevier Advanced Technology, *Yearbook of World Electronics Data*, various issues.

Table 1.14. **World production of ICT goods**

	1985		1990		1994		CAGR (%)		
	Million US\$	Share (%)	Million US\$	Share (%)	Million US\$	Share (%)	1985-90	1990-94	1985-94
United States	150 042	44.6	169 638	29.0	201 093	28.3	2.5	4.3	3.3
Canada	4 192	1.2	7 220	1.2	7 141	1.0	11.5	-0.3	6.1
Japan	81 509	24.2	169 855	29.1	216 350	30.4	15.8	6.2	11.5
Australia	944	0.3	2 493	0.4	2 799	0.4	21.4	2.9	12.8
Austria	957	0.3	3 173	0.5	3 299	0.5	27.1	1.0	14.7
Belgium	2 061	0.6	4 890	0.8	5 432	0.8	18.9	2.7	11.4
Denmark	608	0.2	1 247	0.2	1 273	0.2	15.4	0.5	8.6
Finland	793	0.2	2 330	0.4	2 905	0.4	24.1	5.7	15.5
France	13 761	4.1	26 750	4.6	21 942	3.1	14.2	-4.8	5.3
Germany	17 133	5.1	35 352	6.1	30 329	4.3	15.6	-3.8	6.6
Ireland	2 208	0.7	5 261	0.9	5 237	0.7	19.0	-0.1	10.1
Italy	7 660	2.3	18 573	3.2	14 753	2.1	19.4	-5.6	7.6
Netherlands	3 822	1.1	7 266	1.2	7 771	1.1	13.7	1.7	8.2
Norway	601	0.2	1 130	0.2	877	0.1	13.5	-6.1	4.3
Spain	2 183	0.6	7 171	1.2	5 016	0.7	26.9	-8.5	9.7
Sweden	2 958	0.9	5 263	0.9	4 138	0.6	12.2	-5.8	3.8
Switzerland	1 187	0.4	2 445	0.4	2 576	0.4	15.5	1.3	9.0
United Kingdom	14 049	4.2	24 274	4.2	23 912	3.4	11.6	-0.4	6.1
OECD-18	306 668	91.1	494 331	84.7	556 843	78.3	10.0	3.0	6.9
Chinese Taipei	5 745	1.7	14 208	2.4	22 800	3.2	19.9	12.6	16.6
Hong Kong	2 699	0.8	6 120	1.0	7 127	1.0	17.8	3.9	11.4
Malaysia	1 810	0.5	7 238	1.2	20 731	2.9	31.9	30.1	31.1
Rep. of Korea	6 191	1.8	22 311	3.8	35 010	4.9	29.2	11.9	21.2
Singapore	4 330	1.3	14 728	2.5	31 032	4.4	27.7	20.5	24.5
Thailand	583	0.2	3 882	0.7	9 368	1.3	46.1	24.6	36.1
DAEs	21 358	6.3	68 487	11.7	126 068	17.7	26.2	16.5	21.8
India	1 777	0.5	4 054	0.7	3 851	0.5	17.9	-1.3	9.0
Indonesia	527	0.2	1 085	0.2	3 595	0.5	15.5	34.9	23.8
Philippines	1 013	0.3	1 980	0.3	3 974	0.6	14.3	19.0	16.4
Asia (excl. Japan)	24 675	7.3	75 606	12.9	137 488	19.3	25.1	16.1	21.0
Brazil	4 140	1.2	11 057	1.9	12 656	1.8	21.7	3.4	13.2
Israel	769	0.2	1 730	0.3	3 144	0.4	17.6	16.1	16.9
South Africa	444	0.1	1 246	0.2	1 198	0.2	22.9	-1.0	11.7
Total	336 696	100.0	583 970	100.0	711 329	100.0	11.6	5.1	8.7

Source: OECD Secretariat calculations based on data from Elsevier Advanced Technology, *Yearbook of World Electronics Data*, various issues.

Korea and Singapore accounted for a larger share of world production than any European country.

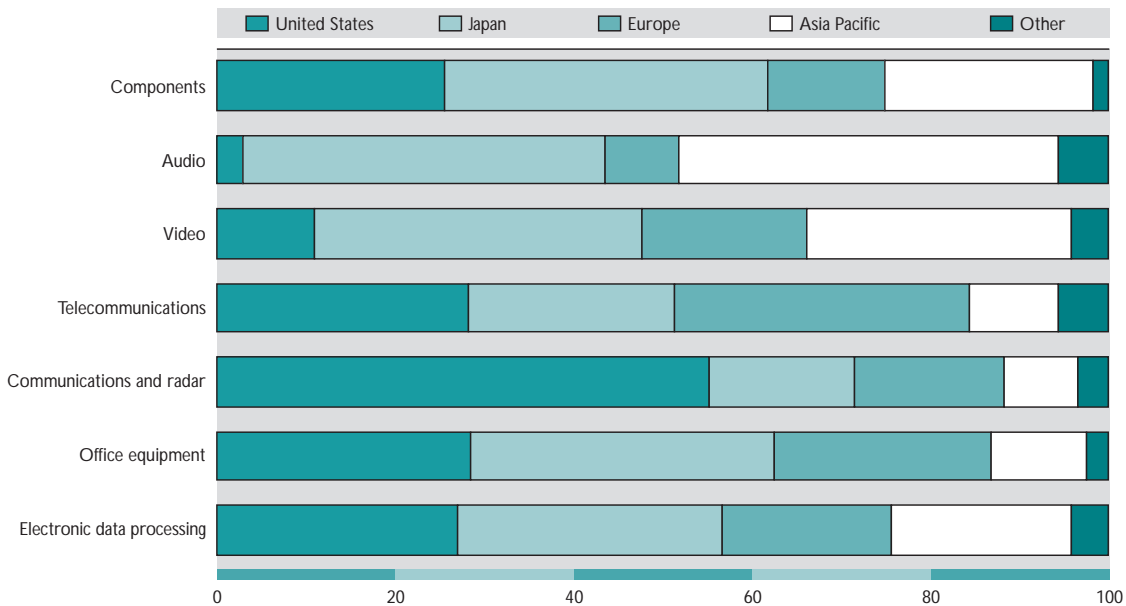
Within ICT production, there is a high degree of product specialisation by region, with the United States producing 55.1 per cent of the world's communication and radar equipment, Japan producing 36.1 per cent of the world's electronic components, Europe, 33 per cent of the world's telecommunication equipment, and the Asia-Pacific region, 42.6 per cent of the world's audio equipment (Figure 1.31).

In 1985-90, the fastest-growing product groups were electronic and data processing and office equip-

ment, but by the early 1990s, components had become the leading growth sector, not only in the United States and the Asia-Pacific region but also in Japan (Figure 1.32). Within this segment, the focus has been on the production of microprocessors and next-generation DRAMs.

During the latter period, Europe's decline in production is most marked in communication and radar equipment, as well as in electronic data processing machines, partly due to the overall economic recession, as well as considerable industry restructuring attributable to technological innovations, changing market patterns, and the continuing relocation of pro-

◆ Figure 1.31. *Breakdown of worldwide production of ICT by region, 1994*
Percentage



Source: OECD Secretariat calculations, based on data from Elsevier Advanced Technology, *Yearbook of World Electronic Data*, various issues.

duction facilities towards Pacific Rim countries owing to cost differentials (Genthon, 1995). Europe still maintains an advantage over Japan and the United States with regard to telecommunication equipment, including a positive trade balance and significant development of standards [Integrated Services Digital Network (ISDN), Global System for Mobile Communication (GSM), Digital European Cordless Telecommunications (DECT)].

The DAEs have strengthened their position as major producers of ICT goods. Some countries have significant shares of world production for particular goods: in 1994, Malaysia produced over 15 per cent of the world's audio equipment owing to a large influx of firms from Chinese Taipei and Hong Kong and to a deepening of the local electronics industry. Korean production accounted for over 10 per cent of the world's video equipment and over 8 per cent of world production of electronic components (Elsevier Advanced Technology, 1995).

In the last decade, ICT's share of manufacturing production has increased steadily in OECD countries (except Italy, the Netherlands, and Norway) (Table 1.15).

When the share of ICT in manufacturing production is plotted against its share in manufacturing employment in OECD countries, two clusters appear (high production/high employment and low production/low employment). In addition, there are two outliers: Japan, with very high shares of both production and employment, and the Netherlands, with a high share of production and an unusually high share of employment (Figure 1.33).

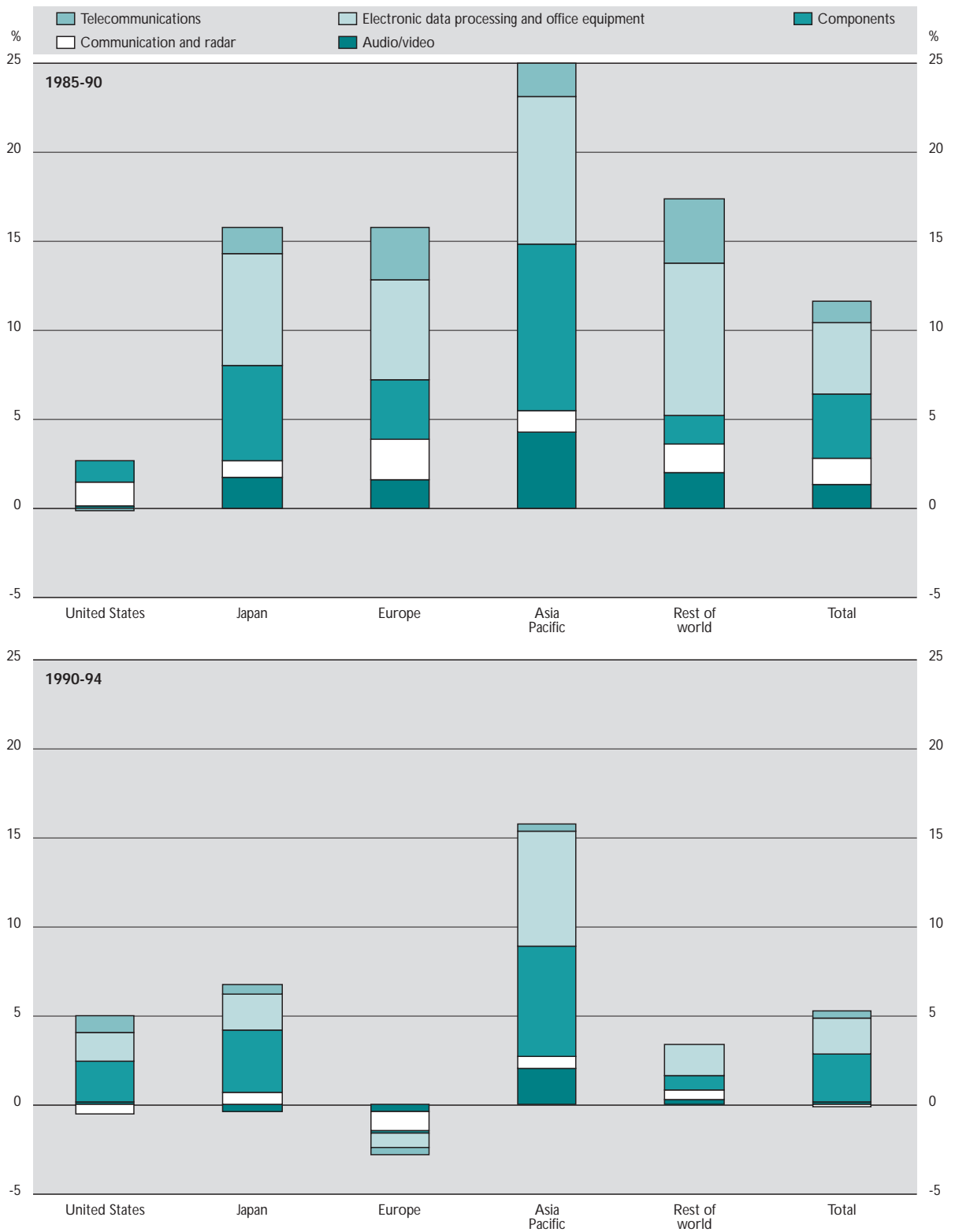
Trade in ICT

General trends in 1994

In 1994, total worldwide merchandise exports grew strongly, increasing 9.5 per cent in volume and 13 per cent in value terms, to more than US\$4 trillion. Exports of commercial services continued to grow strongly as well (8 per cent), but less so than merchandise trade, thereby reversing the pattern of the 1980s. Exports of commercial services now exceed in value exports of agricultural and mining products combined.

In 1994, world trade in office machines and telecommunication equipment (broadly defined to

◆ Figure 1.32. *Contribution by product to ICT goods production growth, 1985-94*



Source: OECD Secretariat calculations, based on Elsevier Advanced Technology, *Yearbook of World Electronics Data*, various issues.

Table 1.15. **Share of ICT in manufacturing production**

	Percentage		
	1985	1990	1994
United States	6.7	5.8	6.8
Canada	3.0	4.2	5.6
Mexico	1.5	1.8	1.8 ²
Japan	10.6	11.7	11.9
Australia	1.8	1.7	2.4
New Zealand	1.5	1.3	1.3 ²
Denmark	2.5	2.6	2.8
Finland	2.4	3.5	7.0
France	6.2	6.6	6.9
Germany	5.5	5.5	6.3
Italy	2.7	3.3	2.7
Netherlands	7.4	7.7	6.6 ²
Norway	2.8	2.4	2.1
Portugal	2.6	2.1	2.5 ²
Spain	2.2	2.4	3.7
Sweden	5.0	4.9	5.7
United Kingdom	6.1	6.6	7.5
G-7 countries	7.1	7.3	8.2
OECD-14 ¹	6.8	7.0	7.5 ²

1. Above countries excluding Mexico, New Zealand and Portugal.

2. 1993.

Source: OECD, STAN database (DSTI), September 1996.

include SITC Rev.3 groups 75, 76, 776) continued to grow at a strong pace (by 22 per cent from 1993 to over US\$469 billion). The leading exporters were Japan (20.1 per cent), the United States (16.8 per cent), Singapore (10 per cent), and the United Kingdom (5.9 per cent). The main importers were the United States (24.1 per cent), Germany (7.6 per cent), the United Kingdom (6.2 per cent), and Japan (4.8 per cent). The DAEs continued to expand their role and accounted for 20.9 per cent of world exports. Office machines and telecommunication equipment represented 11.5 per cent of world merchandise trade. The shares were particularly high for Asian exports (22 per cent) and North American imports (15.5 per cent). Figure 1.34, which shows regional trade flows in 1994, highlights four key findings:

- Europe is a net importer from both North America (US\$11.8 billion) and Asia (US\$33.9 billion);
- Asia is a net exporter to both North America (US\$53.9 billion) and Western Europe;
- the largest inter-industry flows are between Asia and North America, almost double those between Asia and Western Europe;
- there are very large intra-regional flows within Asia (US\$98.5 billion) and Western Europe (US\$85.3 billion).

ICT trade in OECD countries (through 1993)

Main trends

As of 1993, the US trade deficit was increasing steadily (US\$20.8 billion, of which US\$13.3 related to computing equipment) (Table 1.16), partly owing to the growing tendency of American firms to relocate to South-East Asia (particularly for parts and peripherals manufacturers), as well as to Europe. Japan maintained a strong trade surplus (US\$43.8 billion) but growth was slowing. Europe continued to experience a high deficit (US\$25.2 billion), except for communication equipment (a surplus of US\$3.2 billion).

The role of the new exporting countries (in particular the DAEs) continued to expand, with a strong trade surplus (US\$19.8 billion surplus with OECD countries) mostly in computer equipment. The strong growth of electronics industries in these countries is partly due to American and Japanese investments in the 1970s and 1980s. Intra-regional flows continue to be strong, with significant re-exports through Hong Kong and Singapore.

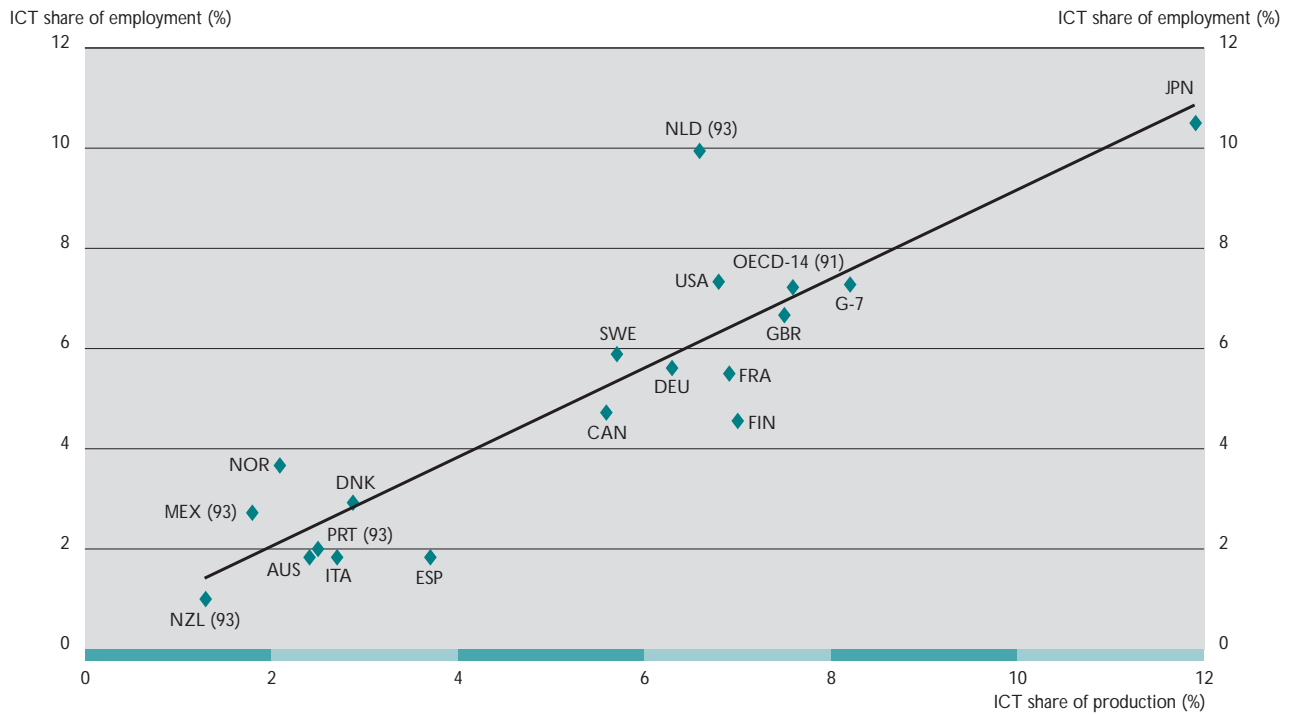
There has been little change in the destination of OECD exports of computer equipment, with over 86 per cent of exports remaining within the OECD area in 1993 (Table 1.17). Exports of electronic components have been increasingly directed towards the Asia-Pacific region, mainly at the expense of exports to Europe. With regard to OECD imports of computer equipment, Europe and the United States now account for less than 50 per cent of the total, while the share of the DAEs has increased from 18.5 in 1990 to 26.9 per cent in 1993. The same trend is observed in imports of electronic components, with the DAEs accounting in 1993 for a larger share (28.5 per cent) than either Europe, Japan, or North America.

Computing equipment

The DAEs increased their role as a significant source of OECD imports to account in 1993 for 37.1 per cent of OECD imports of storage equipment and 31.3 per cent of imports of peripheral equipment. Europe remained the primary source for CPUs (central processing units), accounting for 46.7 per cent of OECD imports.

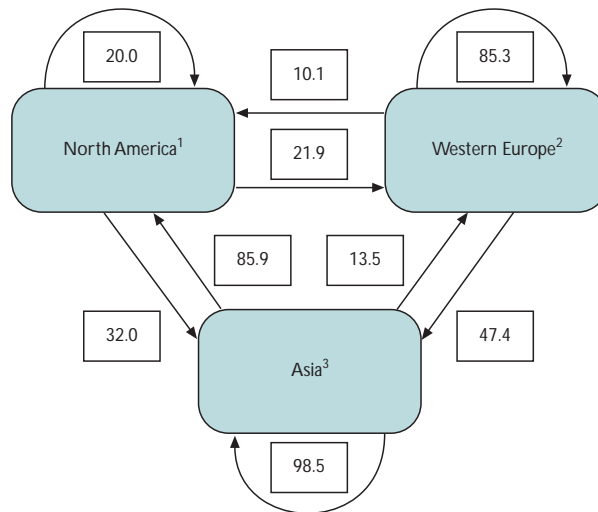
The index of export specialisation (or revealed comparative advantage) measures the share of a country's exports in a given industry in total manufacturing exports with respect to the OECD average for that industry. This index shows that the US specialisation in office and computing machinery has

◆ Figure 1.33. *ICT share in manufacturing, 1994*



Source: OECD, STAN (DSTI), September 1996.

◆ Figure 1.34. *Major regional flows in world exports of office machines and telecommunication equipment, 1994*
Billion US\$



1. North America: Canada, United States.
2. Western Europe: EU + EFTA.
3. Asia: Japan + DAEs.

Source: OECD Secretariat calculations from WTO (1995).

Table 1.16. **Computing equipment: leading OECD importing/exporting countries**

Billion US\$

	Exports			Imports	
	1990	1993		1990	1993
Japan	18.8	26.2	United States	23.4	38.7
United States	23.0	25.4	United Kingdom	12.3	14.8
United Kingdom	9.9	10.6	Germany	13.0	14.1
Germany	7.9	7.3	France	8.4	8.2
Netherlands	4.8	7.0	Netherlands	6.6	8.1
France	5.0	5.3	Japan	5.0	6.6
Ireland	4.5	5.0	Canada	4.5	6.1
Italy	3.9	4.0	Italy	4.8	4.7
Canada	2.1	2.7	Australia	2.4	2.7
Belgium/Luxembourg	1.1	1.1	Ireland	1.9	2.6
Total OECD	85.8	99.2	Total OECD	98.4	121.9

Source: OECD, NEXT database, July 1996.

decreased since the 1980s. That of the Netherlands, the United Kingdom, and particularly Japan has increased, while the relative specialisation of France, Germany and Italy has continued to decline. By 1993, the United States, Japan, and the United Kingdom had the highest indices for Member countries, at more than one and a half times the OECD average. The Netherlands was the only other Member country above the average.

The index of exposure to foreign competition (Figure 1.35), which takes into account both import penetration and export shares of production, reveals

that European firms continue to be highly exposed. This has been a recent development (since the mid-1980s) in the United States; Japan continues to be relatively less exposed to foreign competition.

Electronic components

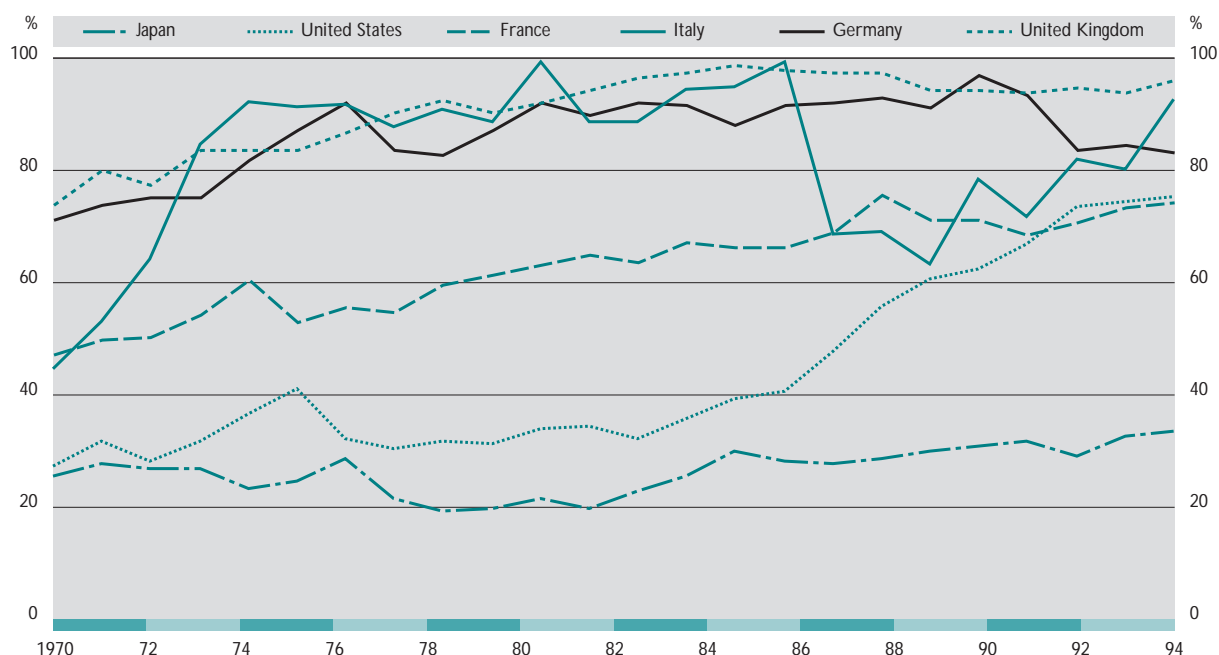
Trends have been similar for electronic components, with Japan increasing its share of OECD exports from 30 per cent in 1990 to 36.2 per cent in 1993 and the United States increasing its share of OECD imports from 33 per cent in 1990 to 37.3 in 1993 (Table 1.18).

Table 1.17. **Breakdown of OECD trade in computer equipment and components**

Percentage

	Computer equipment				Electronic components			
	Exports		Imports		Exports		Imports	
	1990	1993	1990	1993	1990	1993	1990	1993
OECD	87.8	86.5	79.1	69.3	59.3	50.2	68.0	60.5
North America	20.9	21.9	26.1	21.9	21.3	19.3	22.5	19.9
United States	16.8	17.5	23.8	19.7	15.3	15.7	17.5	16.6
Japan	4.2	4.2	17.1	18.3	2.8	2.4	16.4	17.9
Europe	60.7	58.6	35.7	28.9	34.8	28.2	29.1	22.6
Asia/Pacific	6.9	7.3	18.9	28.5	32.3	39.3	25.7	31.5
DAEs	6.0	6.5	18.5	26.9	29.3	35.9	23.6	28.5
Other	5.3	6.1	2.0	2.1	8.4	10.5	6.3	8.0
Total OECD Trade	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: OECD, NEXT database, July 1996.

◆ Figure 1.35. *Exposure to foreign competition: office and computing machinery*


Source: OECD, STAN database (DSTI), July 1996.

Communication equipment

Intra-OECD trade continued to represent the largest share of flows in 1993: 59 per cent of OECD exports and 70.6 per cent of imports. The DAEs are an important source of OECD imports, but their relative share decreased from 16.6 per cent in 1990 to 15.2 per cent in 1993. Europe remained an important destination of OECD exports, with a share of 37 per cent.

Exports of line equipment increased significantly (31.5 per cent of OECD exports in 1993) as did transmission equipment (29.9 per cent), mainly owing to investments in network development outside the OECD region.

In 1993, Japan remained the strongest exporter of communication equipment (24.6 per cent of OECD exports), particularly of receivers and terminals (over

Table 1.18. **Electronic components: leading OECD importing/exporting countries**

Billion US\$

	Exports			Imports	
	1990	1993		1990	1993
Japan	14.6	23.3	United States	15.7	22.9
United States	13.8	16.5	United Kingdom	4.6	6.1
United Kingdom	3.5	5.5	Germany	5.6	6.0
Germany	5.4	5.4	Japan	3.6	5.6
France	2.7	3.3	Canada	3.8	4.2
Netherlands	1.5	3.0	France	3.8	4.1
Italy	1.8	2.2	Italy	3.5	3.3
Canada	2.3	1.9	Netherlands	1.0	2.0
Austria	0.9	0.8	Ireland	0.7	1.2
Belgium/Luxembourg	0.4	0.5	Sweden	0.6	0.9
Total OECD	48.7	64.3	Total OECD	47.4	61.4

Source: OECD, NEXT database, July 1996.

Table 1.19. **Communication equipment: leading OECD importing/exporting countries**
Billion US\$

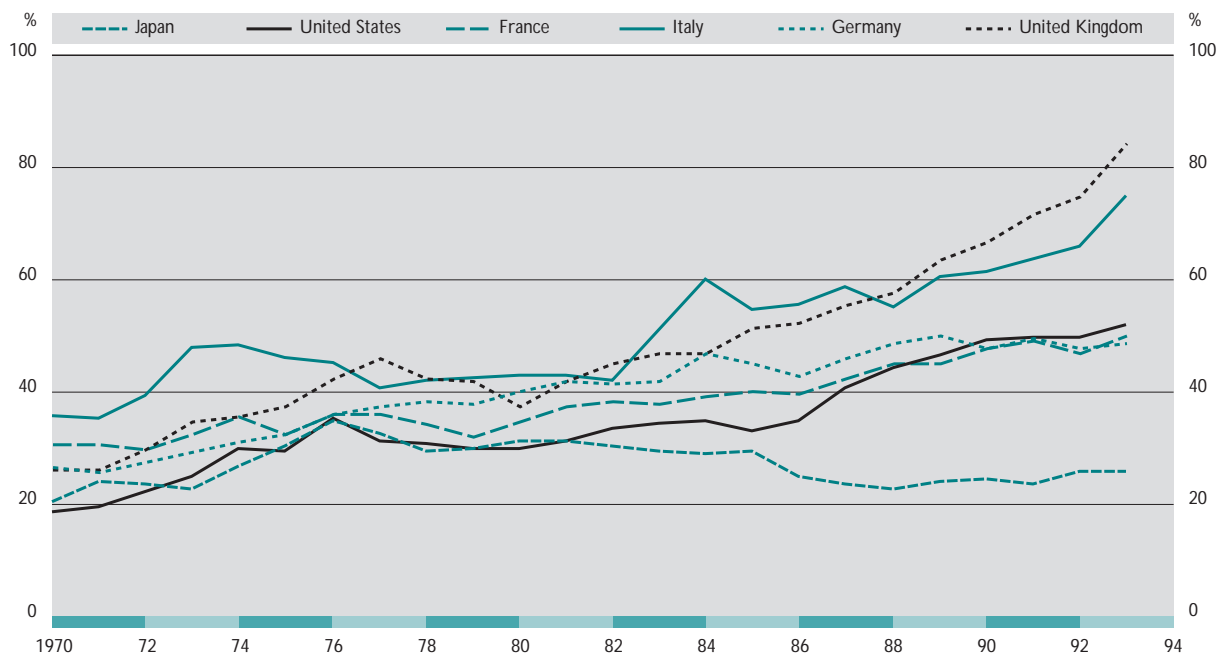
	Exports			Imports	
	1990	1993		1990	1993
Japan	5.6	7.6	United States	6.0	7.9
United States	4.1	6.8	Germany	1.2	2.6
Germany	2.2	3.6	United Kingdom	1.6	2.1
Sweden	1.8	2.2	Canada	0.8	1.3
France	1.4	1.9	Japan	0.8	1.1
United Kingdom	1.4	1.8	France	0.7	0.9
Canada	1.1	1.8	Italy	1.1	0.9
Finland	0.7	0.9	Netherlands	0.7	0.7
Italy	0.5	0.8	New Zealand	0.5	0.7
Belgium/Luxembourg	0.5	0.8	Sweden	0.5	0.6
Total OECD	21.5	31.0	Total OECD	17.6	22.6

Source: OECD, NEXT database, July 1996.

half of OECD exports for these products); nevertheless, US exports (particularly of transmission equipment) were growing faster (21.9 per cent of total). Germany remained a strong exporter of switching equipment (28.5 per cent of OECD exports). For line equipment, five OECD countries (Canada, Germany, Japan, Sweden, and the United States) each accounted for more than 10 per cent of OECD exports (Table 1.19).

For the major OECD exporting countries, the trend of the export specialisation index for the electronic equipment and components sector (which includes electronic components and communication equipment) is clear. Japan has maintained very high specialisation in this sector (more than twice the OECD average), the United States progressively increased its specialisation during the 1980s; the United Kingdom increased its specialisation over the

◆ Figure 1.36. *Exposure to foreign competition: electronic equipment and components*



Source: OECD, STAN database (DSTI), July 1996.

last decade, and the Netherlands progressively decreased its specialisation, from 150 per cent (of the OECD average) in 1970 to around 60 per cent in the late 1980s.

The index of exposure to foreign competition (Figure 1.36) reveals that only Japan enjoys a relatively unexposed market, while Italy and the United Kingdom continue to have increasingly exposed markets.

Trade in software

Although software still represents a relatively small share of trade compared to ICT goods, exports of software from the United States have grown strongly in the 1990s, averaging 23 per cent annual growth between 1990 and 1994 (Table 1.20). The G7 countries are still the leading markets for American exports (almost 58 per cent in 1994), but their relative

importance has been declining in favour of less developed regions such as South America, Africa and Eastern Europe.

Trends in ICT R&D

General R&D trends

In OECD countries, R&D spending has slowed since the mid-1980s. Sources of funding have shifted, with industry playing a greater role owing to budgetary constraints and cutbacks in defence-related R&D, although government still plays a significant role in some OECD countries (Canada, France, Italy). Firms have increasingly focused on experimental development (instead of basic research) owing to rising R&D costs, increasing risk, and shorter product cycles.

The multidisciplinary nature of new technologies and high costs/risks have encouraged partnerships and alliances (Hicks *et al.*, 1996). Recent trends in

Table 1.20. **Breakdown of United States exports of software products, 1990-94**

	Shares in percentage				
	1990	1991	1992	1993	1994
North America	34.2	32.2	30.0	29.2	30.7
Canada	33.0	30.6	28.1	26.9	27.3
Mexico	1.3	1.5	1.9	2.3	3.4
EU-4	26.2	24.6	26.2	24.8	22.0
France	4.6	4.5	4.3	3.8	3.7
Germany	8.3	8.7	10.4	10.3	8.4
Italy	2.7	1.8	1.9	1.5	1.7
United Kingdom	10.6	9.5	9.5	9.2	8.2
Asia	18.6	18.5	17.6	18.8	18.6
China	0.5	0.4	0.8	1.2	1.0
Chinese Taipei	1.5	1.4	2.0	2.1	1.6
Hong Kong	1.2	1.6	1.5	1.7	1.6
India	0.4	0.3	0.3	0.3	0.3
Indonesia	0.2	0.1	0.1	0.1	0.0
Japan	10.7	10.5	8.7	8.1	8.6
Rep. of Korea	1.9	2.0	1.9	2.6	2.8
Malaysia	0.2	0.3	0.3	0.4	0.4
Singapore	2.0	1.9	2.0	2.4	2.1
South America	1.1	2.2	2.4	3.6	4.3
Argentina	0.1	1.1	0.9	1.4	1.2
Brazil	0.7	0.7	1.2	1.8	2.6
Chile	0.2	0.3	0.4	0.4	0.3
Peru	0.0	0.0	0.0	0.1	0.1
Africa ¹	0.1	1.1	1.2	1.5	1.7
Eastern Europe ²	0.2	0.5	0.8	1.0	1.2
All other countries	19.6	21.0	21.8	21.1	21.6
Total, all countries (million US\$)	1 328.1	1 625.2	2 050.0	2 526.1	3 030.7

1. Africa includes Kenya, Nigeria and South Africa.

2. Eastern Europe includes Hungary, Poland and Russia.

Source: NSF (1996a), *Science & Engineering Indicators*.

R&D activities also include more interaction between producers, suppliers, universities and R&D organisations (often through ICT networks) (Howells, 1995), as well as a movement towards globalisation (international co-operation, trans-national joint research funding, strategic technology alliances).

According to data from the CATI (Cooperative Agreements and Technology Indicators) database developed at MERIT (Hagedoorn and Schakenraad, 1992), between 1990 and 1994, inter-regional strategic IT alliances (Europe-Japan, Europe-United States, and Japan-United States) increased from 86 to 105, while intra-regional ones increased from 136 to 172 (NSF, 1996). Other studies using a broader definition of both IT and technology alliances²⁸ estimate that the number of worldwide IT alliances increased from 2 721 to 4 358 during the same period (Vonortas and Safioleas, 1996).

R&D in the ICT goods-producing sectors

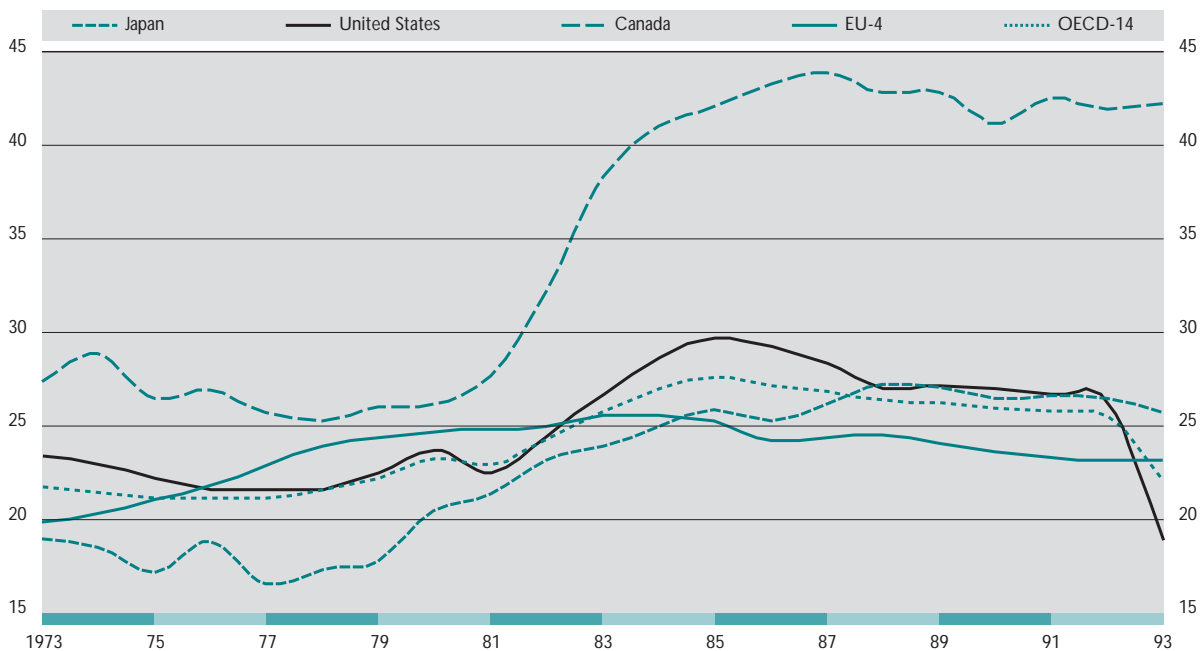
In a group of 14 OECD countries,²⁹ the ICT industries' share of manufacturing R&D (BERD) increased steadily until the mid-1980s, then declined gradually, except in Canada where ICT accounts for over 40 per

cent of manufacturing BERD (Figure 1.37). The United Kingdom saw strong growth to 1983, followed by a sharp drop (from over 35 per cent of manufacturing BERD in 1983 to less than 20 per cent ten years later), while France has had a consistently high share since 1974 (over 25 per cent). The United States suffered a sharp drop in 1993 (almost 10 percentage points), but it was mostly due to reclassification (see Box 1.2). Japan had lower shares than other OECD countries until the mid-1980s, but now has higher shares than both the United States and the larger European countries (around 25 per cent).

A geographical breakdown of BERD for OCA across the OECD area reveals that Japan's share of OCA BERD has increased (from 8 per cent in 1980 to 36 per cent in 1993). North America has seen a significant decline (from 74 per cent to 42 per cent) but still accounts for the largest share (Figure 1.38). For RTC, the geographical distribution has changed little, with Japan steadily increasing its share (up 10 percentage points between 1980 and 1993) (Figure 1.39).

R&D intensities (BERD/production) in OECD countries display mixed trends. In the OCA sector, there have been significant increases in the

◆ Figure 1.37. *Share of ICT in manufacturing BERD in selected OECD countries*



Source: OECD, STAN database (DSTI), July 1996.

Box 1.2. Firm reclassification in R&D surveys

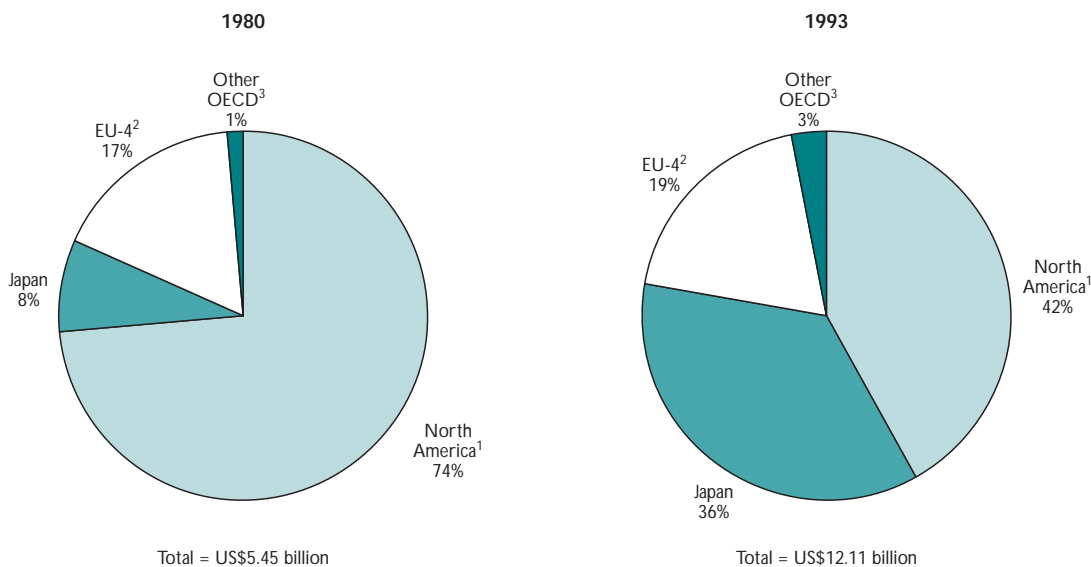
The reclassification of individual firms into different sectors can significantly alter total R&D expenditure figures for a given industry. Such reclassification can be due to changes in the primary activities of a company's establishments, as well as shifts in a firm's organisational structure (e.g. mergers and acquisitions, divestitures, etc.). In the United States, the reclassification of a single firm in 1992 resulted in a shift of more than US\$3 billion in R&D expenditure, or 2.5 per cent of US BERD for that year. In the 1993 US R&D survey, the change in activities of two large multi-unit companies resulted in a reclassification of activities from manufacturing to non-manufacturing, generating significant changes in R&D expenditure figures. It is estimated that in 1993 this amounted to over US\$5.5 billion being shifted to non-manufacturing R&D; this represented 6.4 per cent of total US BERD, and more than 30 per cent of OECD-14 BERD in the OCA sector.

Netherlands, Japan, Canada, and Spain but sharp declines in the United Kingdom, Denmark, and Finland (Figure 1.40). In the United States, the drop from 17.3 to 8.1 per cent between 1987 and 1993 was due to firm reclassification in R&D surveys, and it is estimated that the real R&D intensity of the sector remained at over 17 per cent. Overall, R&D intensities of countries are closer than they were in the 1980s (for a group of 12 countries, the variance decreased

by a factor of four between 1987 and 1993). In the RTC sector, intensities were higher overall in 1993 than in 1980 (except in the United Kingdom and the United States), although in most countries, R&D intensities have decreased since the late 1980s (Figure 1.41).

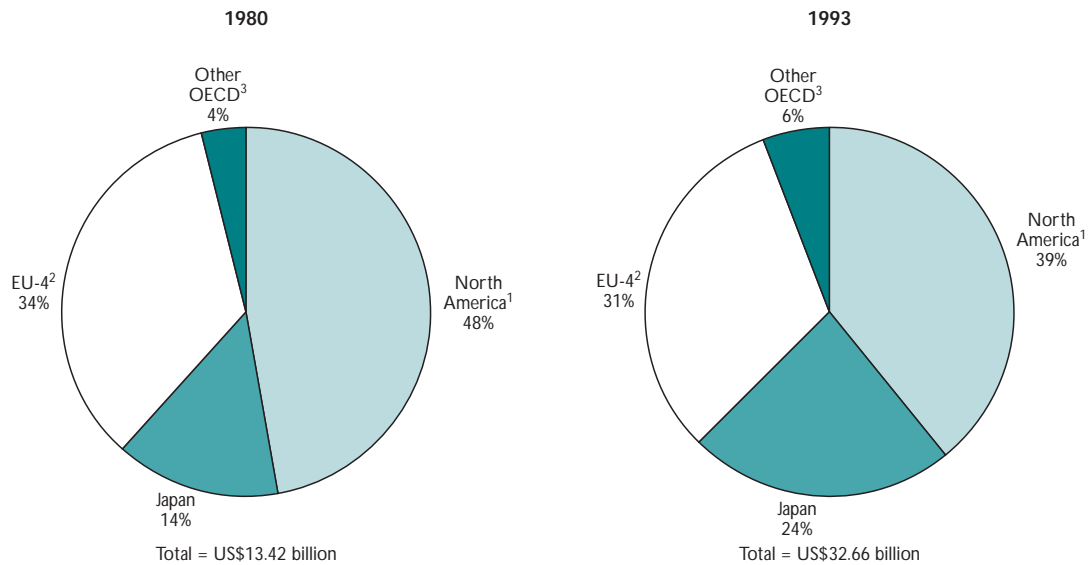
Preliminary data for the United States indicate that in 1994, almost one-fourth of all business R&D was performed by ICT industries (ITI, 1996).

◆ Figure 1.38. *Breakdown of OCA BERD within OECD*



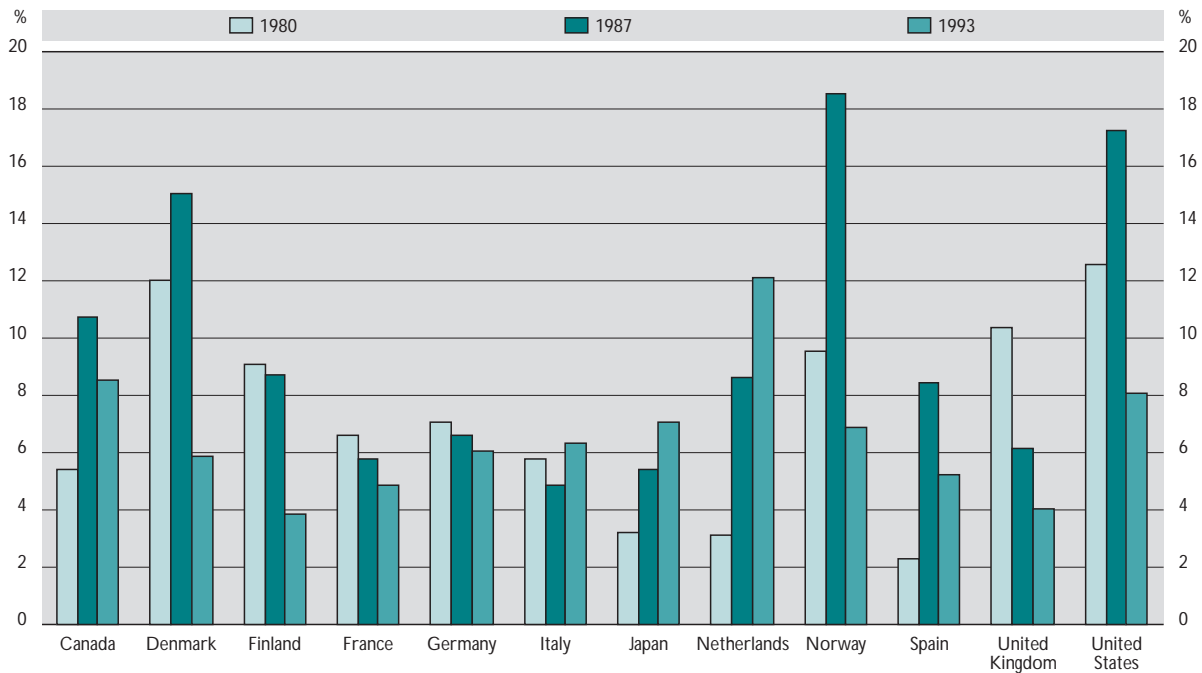
1. North America: Canada, United States.
 2. EU-4: France, Germany, Italy, United Kingdom.
 3. Other OECD: Australia, Denmark, Finland, Netherlands, Norway, Spain.
 Source: OECD, STAN database (DSTI), June 1996.

◆ Figure 1.39. *Breakdown of RTC BERD within OECD*



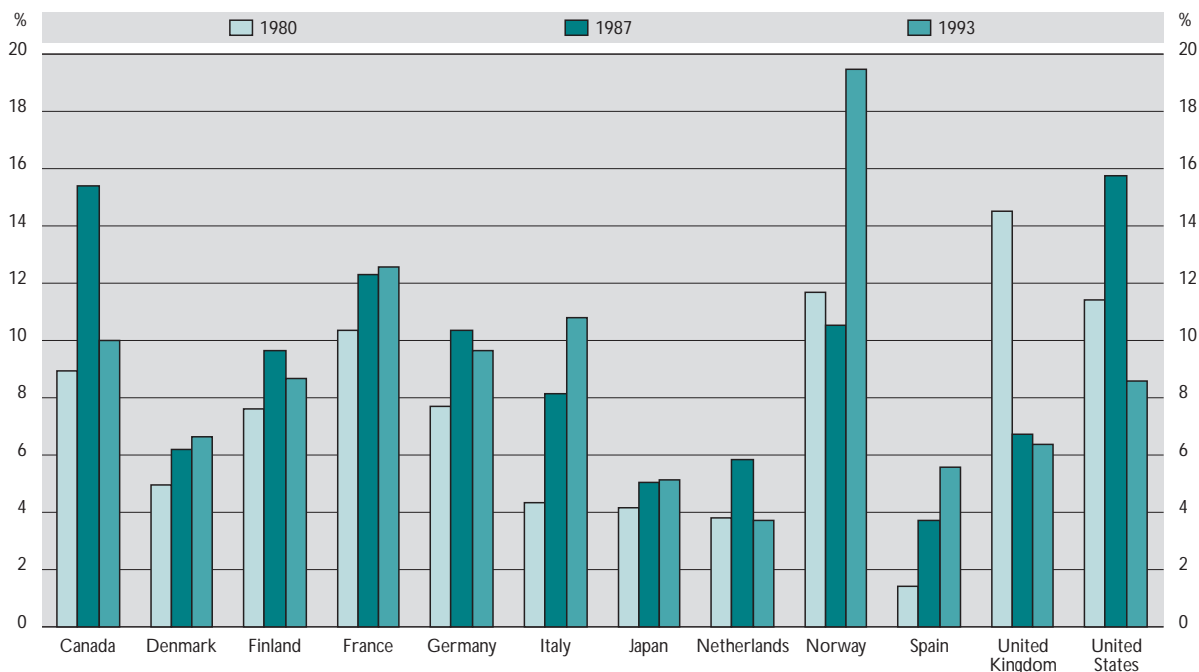
- 1. North America: Canada, United States.
 - 2. EU-4: France, Germany, Italy, United Kingdom.
 - 3. Other OECD: Australia, Denmark, Finland, Netherlands, Norway, Spain.
- Source: OECD, STAN database (DSTI), June 1996.

◆ Figure 1.40. *R&D intensities in the OCA sector*



Source: OECD, STAN database (DSTI), June 1996.

◆ Figure 1.41. *R&D intensities in the RTC sector*



Source: OECD, STAN database (DSTI), June 1996.

R&D in the services sector

There is widespread evidence that the share of services in business R&D is increasing. This probably has three main causes:

- *statistical*: reclassification of manufacturing firms into services (see Box 1.2), or different coverage of surveys;
- *organisational*: firms are increasingly outsourcing R&D activities to specialised firms, due to rising costs/risks;
- *technological*: services are in fact becoming more technology-intensive and more and more research is performed in new areas where IT and communications converge (e.g. multimedia).

Box 1.3. Software and R&D

Guidelines on the treatment of software were included in the *Frascati Manual* for the first time in the 1993 edition (OECD, 1994a). For a software development project to be classified as R&D, its completion must be dependent on the development of a scientific and/or technological advance, and the aim of the project must be resolution of a scientific and/or technological uncertainty on a systematic basis. Software-related activities of a routine nature are not considered to be R&D. The latter include work on system-specific or programme-specific advancements which were publicly available prior to the commencement of the work. Technical problems which have been overcome in previous projects on the same operating systems and computer architecture are likewise excluded, as are software-related activities such as supporting existing systems, converting and/or translating computer languages, adding user functionality to application programmes, debugging of systems, adaptation of existing software, and preparation of user documentation, which do not involve scientific and/or technological advances, are not classified as R&D collection. Likewise, market research is excluded.

R&D is thus only one of the stages in bringing a new software product to the market. Such innovation will also involve some of the routine activities listed above, plus the reproduction, distribution and all pre-launch marketing of the product.

Source: Young (1996).

Table 1.21. **Distribution of BERD across sectors in 1993**

	Percentage					Total
	Manufacturing		Services			
		Computer hardware		Computer services	Software consultancy	
Canada	62.3	5.3	30.6	4.9	..	100.0
Mexico	86.7	3.6	9.8	0.0	0.0	100.0
United States	73.6	4.1	26.1	8.5	..	100.0
Australia	55.7	0.9	31.7	7.3	6.9	100.0
New Zealand (1991)	58.8	..	35.2	..	..	100.0
Austria (1989)	94.1	..	4.0	..	..	100.0
Denmark	65.9	1.2	32.5	6.7	..	100.0
Finland (1994)	84.5	..	12.3	..	..	100.0
Greece	61.3	15.0	32.7	22.7	22.7	100.0
Iceland (1992)	66.9	..	17.3	..	..	100.0
Ireland	86.9	8.5	11.4	3.9	3.8	100.0
Italy	85.2	5.4	10.7	2.5	..	100.0
Netherlands	86.7	4.1	9.8	..	..	100.0
Norway	45.1	0.6	41.7	9.9	5.8	100.0
Portugal (1992)	76.9	..	21.2	..	..	100.0
Spain	76.9	2.6	15.9	3.1	2.6	100.0
Turkey	88.8	0.1	7.3	4.9	4.8	100.0
United Kingdom	77.6	4.5	18.2	5.3	..	100.0

Source: OECD, DIRDE database, January 1996, plus additional national sources.

IT-related R&D (see Box 1.3) has continued to grow, in terms of the share of ICT sectors in BERD and owing to a shift of product orientation (*i.e.* software R&D, including that performed by sectors other than computer services). Among countries that provide a separate accounting of R&D performed by services, it accounted for one-quarter or more than manufacturing R&D in half of these countries (Table 1.21). Within services R&D, ICT-related services such as computing services and software consultancy played an important role.

Although the data are not fully comparable at international level, the importance of R&D on software is clear from data provided by those countries that measure it. A survey conducted in Canada indicates that software accounted in 1993 for about 33 per cent of total R&D expenditures (24 per cent in manufacturing, 56 per cent in services). The 80 per cent R&D spending increase between 1988 and 1993 was mostly due to software R&D, particularly in SMEs. A special survey on R&D and software research conducted in the Netherlands estimates that in 1994, 41 per cent of all Dutch firms conducting R&D activities reported some type of software R&D, amounting to 23 per cent of their total R&D expenditures; however, the true figure is considered likely to be higher.

R&D surveys in Ireland point to increasing expenditures on software R&D, which accounted for 21 per cent of BERD in 1993, up from 7 per cent in 1988. This is largely due to large foreign-owned firms that conduct a growing share of their R&D activities through local affiliates. In Australia, the trend has been towards a decreasing share of software R&D (as a percentage of total BERD), which dropped from 26 per cent in 1990-91 to 20 per cent in 1994-95. A large share of total software R&D (22 per cent) is performed in small firms (less than 50 employees).

Table 1.22. **Software R&D and markets in selected countries, 1993**

	Million US\$		
	Software R&D expenditures	Packaged software market	Apparent in-house ratio (%)
Australia	440.0	1 044.1	29.6
Canada	1 618.5	2 054.3	44.1
Ireland	83.3	120.5	40.9
Netherlands ¹	695.3	1 814.3	27.7

1. 1994.

Source: OECD Secretariat calculations from DIRDE database, Australian Bureau of Statistics (1996a), Statistics Canada (1996a), Forfás (1995), Netherlands Central Bureau of Statistics (1996), and IDC (1995b) for packaged software markets.

Table 1.23. **Top 20 ICT firms by R&D expenditures**

Thousands of US\$ and percentage

Company name	Country	1995 R&D ('000 US\$)	R&D/Sales (%)
Siemens	Germany	2 075 292	8.2
Hitachi	Japan	1 945 633	6.5
AT&T	United States	1 518 235	4.7
Matsushita Electric Industrial	Japan	1 496 635	5.4
IBM	United States	1 383 072	4.7
Nippon Telegraph & Telephone	Japan	1 242 712	4.5
Toshiba	Japan	1 196 208	6.3
NEC	Japan	1 053 042	7.1
Sony	Japan	946 781	6.0
Ericsson	Sweden	929 982	15.3
Alcatel Alsthom	France	909 985	6.5
Motorola	United States	897 139	8.1
Mitsubishi Electric	Japan	655 828	5.1
Northern Telecom	Canada	644 780	14.8
Robert Bosch	Germany	643 358	6.5
Bell Canada	Canada	638 940	8.7
General Electric	United States	530 443	1.9
Canon	Japan	495 841	5.8
Intel	United States	453 673	9.6
Sharp	Japan	453 158	7.1

Source: DTI, UK R&D Scoreboard, 1996.

Table 1.24. **Top 20 ICT firms by R&D intensity (R&D/sales)**

Percentage

Company name	Country	1995 R&D intensity
Adobe Systems	United States	18.2
Cray Research	United States	18.2
Novell	United States	18.0
Advanced Micro Devices	United States	16.4
Lotus Development	United States	16.4
SAP	Germany	16.3
Ericsson	Sweden	15.3
Northern Telecom	Canada	14.8
Microsoft	United States	14.5
Analog Devices	United States	14.3
Tandem Computers	United States	14.2
DSC Communications	United States	13.4
National Semiconductor	United States	11.9
Silicon Graphics	United States	11.1
Storage Technology	United States	10.5
Teradyne	United States	10.4
Bay Networks	United States	10.4
Amdahl	United States	9.9
3Com	United States	9.8
Intel	United States	9.6

1. Among top 100 ICT companies based on R&D expenditure.

Source: DTI, UK R&D Scoreboard, 1996.

By comparing software R&D expenditures to sales of packaged software, countries for which data are available display high levels of what is apparently in-house software development (Table 1.22): close to 30 per cent in the Netherlands and Australia, over 40 per cent in Ireland and Canada (apparent in-house ratio = R&D software expenditures / total software expenditures, where total software expenditures = R&D software expenditures + packaged software market). These data suggest that total use of software by firms is much larger than what is indicated by market sales alone.

Firm data

While the firms that spend the most on R&D (Table 1.23) are geographically dispersed and vary widely in terms of R&D intensities (often due to their conglomerate nature), the ranking of firms by R&D intensity (Table 1.24) reveals the dominance of software firms and companies located in the United States.

NOTES

1. To facilitate comparison between Member and non-member countries, the current US\$ exchange rate has been used throughout.
2. In 1994, the total installed computing power of IBM mainframes rose by 40 per cent, and in 1995 its deliveries, expressed in computing power, rose by 60 per cent (*Le Monde Informatique*, 12 April 1996).
3. Several recent examples illustrate this trend. Pioneer Electronics was the first Japanese firm to take out a license for the Apple Mac OS operating system and market a Macintosh clone. Sony was also the first Japanese consumer-electronics firm to produce a PC and, for the first time, the product was launched in the United States before being put on the Japanese market. Finally, in late August 1996 Netscape, with the help of seven other major investors, set up a subsidiary to adapt a lighter version of its Internet browser software onto a number of chips for incorporation into equipment ranging from car dashboards to television sets.
4. Retailers are now free to set their own prices. Previously, the manufacturer set a recommended price and retailers then offered consumer discounts.
5. The 1996 edition of the *Informatization White Paper* by the Japan Information Processing Development Center (JIPDEC) refers to a sudden, unprecedented outbreak of "Windows 95 fever".
6. These data, compiled by the International Telecommunications Union from a variety of sources, should be taken more as an order of magnitude than as absolute figures; they cannot be compared with annual market data in units.
7. According to a JEIDA survey quoted in MITI, 1995a.
8. Microsoft, for example, spent over US\$200 million, or the equivalent of the annual market for packaged software in Hong Kong in 1995, on marketing for the launch of its Windows 95 software.
9. Examples include Thailand's "IT Year", Chinese Taipei's large-scale computerisation projects as part of the six-year Plan, Malaysia's "2020 Vision" campaign, the Philippines' "IT 2000" Plan, South Korea's programme to build an information highway between 1996 and 2010, telecommunications and information industries listed among the top ten priority industries in Chinese Taipei's Sixth National Development Plan, Singapore's "Manufacturing 2000", Malaysia's "Multimedia Super Corridor", launched in August 1996, and China's "Golden Projects".
10. The Science Park and Teletech Park in Singapore, the Hsinchu Industry and Science Park in Chinese Taipei, Technet and the Industrial Technology Centre in Hong Kong, Kuli High Tech Park in Malaysia, etc.
11. As an illustration of the growth potential of some markets that are still relatively small, *Computing Japan Magazine* (June, 1995) reports that Vietnam's installed PC base, estimated at 6 000 in 1992, had risen to 60 000 in 1994. This figure is roughly the number of PCs sold in one week in Japan.
12. See OECD, 1992a.
13. Dataquest, press release dated 24/04/96, and WSTS quoted in *Le Monde* of 21 May 1996.
14. In the first four months of 1996, the price of 4 megabyte DRAMs has been halved (*Electronique Internationale Hebdo*, 2 May 1996).
15. Dataquest estimates, quoted in Howell *et al.*, 1995.
16. EIAJ, in *Electronique Internationale Hebdo*, 25 January 1996.
17. The price of DRAMs on the international market in mid-May 1996 ranged from US\$16 to 18, compared with US\$46-52 only six months earlier, *Financial Times*, 28 May 1996, p. 25.
18. Several examples can be given of decisions announced around mid-1996 to scale down or cancel projects. Hyundai Electronics, the fifth largest DRAM manufacturer in the world, announced in late June 1996 that it planned to cut back DRAM production by 22 per cent from an estimated monthly output of 16 million bars. Rockwell International, the US manufacturer, announced in July 1996 that it had put off for at least a year starting production of wafers in the new plant it was then building at a cost of US\$1.2 billion, and that in the meantime it would buy its wafers from outside suppliers. Hitachi also announced in early July 1996, first, that it had postponed indefinitely the extension of its Takasaki plant, where monthly production was due to increase from one to three million components for an investment initially estimated at US\$189 million, and second, that the group had postponed until early 1997 the extension of its semiconductor plant in Germany.

19. The global network of networks that grew out of a research project funded by the Department of Defense (DARPA).
20. Local area network: a computer network limited to an immediate area, usually one building or one floor of a single building.
21. TCP/IP: transmission control protocol/Internet protocol is the communications protocol used on the Internet; HTML: hypertext mark-up language is a simple coding system used to format documents for viewing by World Wide Web (WWW) clients. The open nature of Internet technology is particularly attractive to corporate users who want to avoid investing in inflexible systems.
22. An operating system developed by AT&T that is widely used by universities. UNIX uses TCP/IP as its standard communications protocol.
23. Multiple virtual storage: an operating system for mainframes developed by IBM.
24. Operating system (OS): a computer-system-specific set of programmes that inter-operate with the computer system to control and process resources.
25. The "Year 2000 Problem" refers to legacy programmes that reference the year using only two digits and thus will function improperly as the year changes from 1999 to 2000.
26. Graphical user interface (GUI): an interface in which not only text but also graphics such as icons are used.
27. OECD share does not include Greece, Hungary, Iceland, Luxembourg, Mexico, New Zealand, Portugal, the Czech Republic, Turkey.
28. A broader definition of IT than MERIT/CATI is used in Vonortas and Safioleas (1996), comprising the computer, telecommunications, electronics, media, consumer electronics, finance/banking/insurance, office automation, and robotics/industrial automation sectors. In addition, "strategic alliances" includes alliances without specific technological content, such as marketing, distribution and advertisement activities.
29. OECD-14: Australia, Canada, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, Norway, Spain, Sweden, the United Kingdom, and the United States.

USE OF INFORMATION NETWORKS AND THEIR IMPACT ON ORGANISATIONAL STRUCTURES: FIRM-LEVEL EVIDENCE FROM JAPAN

1. INTRODUCTION

Although networking of computers is now rather routine, the impact on the firm remains poorly understood, largely owing to a lack of data on firms' use of IT in general and of networks in particular. Japan is an important exception, as the Ministry of International Trade and Industry (MITI) conducts a

survey of 23 000 Japanese manufacturing and distribution firms through its Basic Survey of Business Structure and Activities (BSBSA).¹ The survey includes a broad range of variables, such as basic financial indicators, employment characteristics, supplier relationships, and R&D expenditures, as well as use of information networks by type of application (see Box 2.1).

Box 2.1. Surveying network use in Japan

The Basic Survey of Business Structure and Activities (BSBSA) provides firm-level qualitative information on the use of information networks through three sets of questions.

The first set determines whether a firm has introduced intra-firm or inter-firm information networks or both.

The second set involves the types of information networks installed and their purpose, categorised on the following basis:

1. Ordering: use of networks to co-ordinate the purchase and delivery of products usually consisting of intermediary inputs or parts.
2. Production: networks are used to track the flow of production, optimise resources and identify problems.
3. Sales and inventory: tracking sales and inventory stocks by product category.
4. Distribution: intermediary and/or final product flow control, tracking by location and volume.
5. Technology: sharing technology information within and across different departments, or among related firms.
6. Accounting and finance: financial transaction co-ordination and analysis of internal accounting system.
7. Human resources: database system for personnel department.
8. Management planning: internal, cross-department project tracking and management planning system.
9. Marketing/customer information: information about customers and related marketing data.
10. Financial transactions: firm banking and other financial transactions.
11. Reservations and consumer information: on-line customer service, product information and product sales such as reservations.
12. General reference: retrieval system for general information such as phone numbers, employee bulletin boards, etc.
13. Other.

The third set identifies the ownership of information networks on the basis of seven groups: own firm or group, product suppliers, wholesalers, retailers, database providers, VAN (value added network) providers, and others.

2. NETWORK USE

Nearly two-thirds (64.6 per cent) of the firms surveyed had introduced an intra-firm information network (*i.e.* LAN) by 1991, and 43.8 per cent of the businesses surveyed had inter-firm networks. While the distribution of networks is relatively even across industries, the use of networks varies with firm size. Firms classified in the largest size class were nearly two to three times as likely to install an intra- or inter-firm network than those in the smallest size class. The differences based on the size of the firm are not surprising and are evident in other countries' surveys of advanced manufacturing technologies as well.² Three factors typically limit the diffusion of technology to small firms: the size of the initial capital investment, the need for in-house expertise, and the cost of adapting the technology to the firm's needs. Information networks are not an exception.

The importance of firm size in determining the adoption of networks persists regardless of the purpose of the network (Figure 2.1), although uses such as ordering, sales and inventory, and accounting tend to be cited by industries in all size classes, whereas uses for managing technology or for management

planning are more restricted. For example, large, high-technology industries, such as office equipment and computers, are much more likely to use networks for technology management (26.1 per cent) than traditional sectors comprised mainly of small firms, such as the food product industry (3.6 per cent).

The use of a network is related to an industry's position in the chain of production that stretches from the primary extraction of materials to the delivery of the product to the final consumer. Not surprisingly, upstream industries, such as primary metals, are not likely to need customer information, whereas downstream industries, such as retailers, need not concern themselves with production management. Inter-sectoral variations in the use of networks for production management, technology information management, and customer information management reveal that while IT networks are ubiquitous, their use is quite heterogeneous (Table 2.1).

For example, the use of networks for ordering and production purposes is high in the automobile and supply industry, owing to the close links that exist between assemblers and parts manufactures. The adoption of production control systems is high in

◆ Figure 2.1. *Effect of firm size on network use*

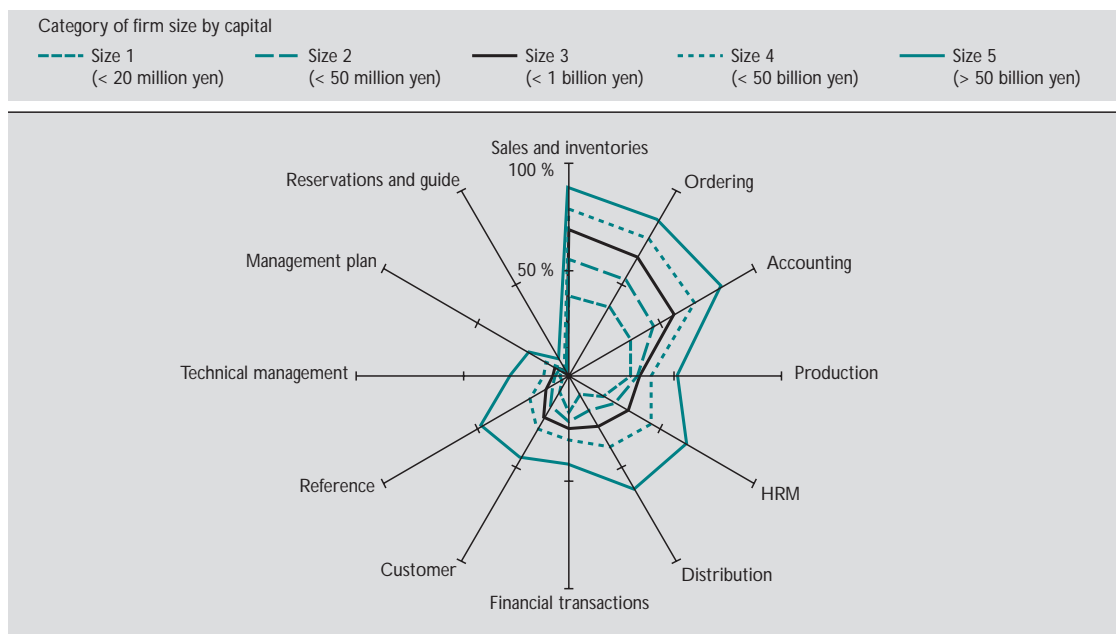


Table 2.1. **Distribution of network use by industry in Japan**

Percentage

	Sales and inventories	Ordering	Accounting	Production	Human resources	Distribution	Financial transactions	Customer	Reference	Technical management	Management planning	Reservation and guide
Food products	56.9	60.2	50.0	42.0	34.2	26.4	22.6	15.9	9.7	3.6	6.2	1.5
Textiles and apparel	55.4	50.0	45.5	45.9	27.6	26.0	19.5	8.3	6.1	5.6	7.2	0.9
Lumber, wood and paper	52.6	47.9	46.2	42.4	30.7	20.7	22.0	14.9	11.3	3.7	6.7	1.2
Chemicals excluding drugs	67.8	61.0	60.1	56.6	38.2	38.5	25.1	16.1	22.1	17.6	9.0	2.5
Drugs	71.8	59.7	59.7	58.8	42.6	45.8	33.8	26.4	38.4	15.7	12.5	1.9
Petroleum and coal product	67.2	59.0	59.0	62.3	41.0	44.3	27.9	16.4	37.7	27.9	6.6	4.9
Plastics and rubber	60.3	62.0	46.3	49.8	31.2	28.3	22.4	10.3	9.0	10.1	5.1	0.9
Stone, clay and glass	55.3	43.1	47.5	42.6	30.2	17.6	19.9	8.6	7.7	6.2	5.5	1.0
Primary metals	60.0	59.0	49.6	55.9	33.6	23.0	22.7	9.1	11.6	9.0	6.4	1.0
Metal products	52.7	49.9	47.5	50.0	31.7	18.0	20.3	8.2	7.1	7.8	4.8	0.6
General machinery	50.7	51.3	50.3	51.8	33.2	16.0	23.1	16.5	10.4	16.2	6.5	1.7
Office equip. and computer	57.1	60.8	53.7	62.1	36.1	27.4	28.7	16.1	17.6	26.1	9.5	5.3
Electrical machinery	48.8	59.9	49.5	57.4	34.2	18.6	21.8	10.4	11.9	15.1	4.5	1.5
Electronic supplies	63.2	65.6	55.3	68.4	41.1	29.3	24.6	9.6	14.0	21.6	8.1	2.1
Communication equipment	59.6	56.8	52.5	62.8	39.3	23.0	26.2	10.4	14.2	23.0	13.1	2.7
Electrical appliances	58.9	60.6	52.9	60.2	34.9	28.0	23.3	12.6	15.2	20.6	7.9	2.6
Automobiles and supplies	54.8	75.0	50.6	61.5	38.6	26.7	27.6	10.6	15.0	22.1	9.4	1.6
Other transport equip.	46.8	45.5	50.5	50.9	34.2	10.8	24.8	9.0	8.6	14.0	8.1	1.4
Optical precision machinery	54.1	55.4	51.0	56.7	34.4	20.4	26.8	8.9	13.4	17.2	2.5	0.6
Other precision machinery	61.0	61.5	52.0	56.5	35.0	20.5	24.0	16.5	13.0	17.0	7.0	1.5
Wholesale	72.8	67.0	58.3	16.2	28.8	33.3	27.4	27.6	16.4	5.1	9.1	2.0
Retail	73.8	65.7	62.1	8.7	36.9	27.3	26.4	47.4	21.1	5.8	12.1	7.6
Construction	36.6	33.2	47.2	31.5	27.2	8.5	22.6	17.4	12.8	13.2	8.9	1.7
Service	42.8	34.6	42.3	15.9	28.8	10.6	21.2	23.6	18.3	13.9	6.7	5.8
Average	63.1	60.3	53.9	35.1	32.6	26.9	24.8	21.7	14.5	9.1	8.3	2.5

Source: MITI (1994a), BSBSA.

the electronics supplies industry, probably because process control is a critical element in the fabrication of high-precision microelectronics parts such as semiconductors. The drug industry relies on networks for sales and inventory and customer information for managing highly diversified product lines and maintaining close contact with institutional customers such as hospitals.

Whether a network is used for internal purposes only or for external purposes as well is directly related to its purpose. Internal networks are more frequently used for managing production, keeping track of sales and inventory, accounting, human resource management, management planning, and marketing and customer information. Inter-firm networks are used for ordering, distribution, technology management, financial transactions, and reservations and customer information. Likewise, whether the network is owned by the firm or by a third party varies, depending on industry sector and network use. In manufacturing and distribution, for example, networks are usually managed by the firm itself, but when the network is used for financial transactions, reservation and consumer information, and general reference, third parties such as database providers often own the network.

Finally, networks generally have multiple applications in order to achieve synergism, as seen in the tendency for firms to develop complementary clusters of network use. The main clusters are: *business operations*, with strong links between ordering, production, and sales and inventory uses; *business support*, with complementary accounting and labour management uses; and *marketing*, involving customer and reservation and consumer information network applications. Technology management and management planning are network functions with links to each of these three groups and effectively act as hubs. Table 2.2 incorporates 12 network uses into the major groups, and indicates whether the function tends to be associated with internal or external networks.

3. THE IMPACT OF IT ON ORGANISATIONAL STRUCTURE

A growing body of research has identified the link between the adoption of information technologies and corresponding changes in the structure of organisations. These changes range from shifts in human capital requirements (Griliches, 1969; Berndt *et al.*, 1992) to changes in decisions about whether to “make” or “buy”, as information technology lowers the transaction costs of outsourcing what was previ-

ously produced internally (Brynjolfsson *et al.*, 1994). Some have even suggested that a complete re-engineering of the business process is required to fully take advantage of IT innovations (Hammer and Champy, 1993).

The BSBSA database on worker characteristics and supplier relationships can be used to explore the impact of information technology networks on organisational structure. Organisational changes associated with the adoption of information technology networks were identified in the following six categories:

- PLAN: changes in the percentage of persons engaged in business planning;
- R&D: changes in the percentage of persons engaged in research and development;
- IP: changes in the percentage of persons engaged in information processing;
- SALE: changes in the percentage of persons engaged in sales and distribution;
- BC: changes in the percentage of persons engaged in production (“blue-collar”);
- OUT: changes in the probability of increased outsourcing of total production.

Changes in these (dependent) variables were explained through a series of regression analyses that control for firm size and industry while allowing the various types of network use categorised in Table 2.2 to vary as dummy explanatory variables. (See Appendix for the description of coefficients, the magnitude of changes, and the statistical significance of these coefficients.) The major findings from this analysis are:

- In general, the use of information networks complements white-collar jobs and substitutes for blue-collar jobs. Although the data do not allow the identification of different skill levels, the coefficients for PLAN and R&D, which represent changes that increase the use of skilled occupations, are significant and positive, suggesting an upward skill bias. This is especially true for those firms that use networks for the management of technology, where the impact on R&D personnel is particularly large.
- Compared to other occupations in PLAN and R&D, the impact on information personnel (IP) is not as important, suggesting that the adoption of IT causes broad job reallocations,

Table 2.2. **Breakdown of uses of information networks**

	Intra-firm networks	Inter-firm networks
Business operations	<ul style="list-style-type: none"> - Production control - Sales and inventory control 	<ul style="list-style-type: none"> - Ordering system¹
Business support	<ul style="list-style-type: none"> - Accounting system - Human resource management 	
Marketing	<ul style="list-style-type: none"> - Customer information mgt.¹ 	<ul style="list-style-type: none"> - Reservation and guide system
Hub functions	<ul style="list-style-type: none"> - Management planning 	<ul style="list-style-type: none"> - Technology information mgt.
Other network uses		<ul style="list-style-type: none"> - Distribution management - Financial transaction¹ - General reference¹

1. Network uses likely to be owned by a third party.

Source: Adapted from Motohashi (1996).

rather than simply the creation of IT-related jobs.

- While the impact for white-collar workers is generally positive, the use of networks, regardless of purpose, has a negative impact on blue-collar jobs. Those firms that adopt a network for both business support functions (BS2: accounting system, labour management) and management planning had a significant reduction in their blue-collar work force.
- A number of network functions such as business operation (BO1,2), distribution (DIST) and technology management (TECH) are more likely to be related to outsourcing than to business support functions. When business operations are broken down into individual components, the ordering function is particularly important for outsourcing. This finding confirms the notion that IT networks have a positive impact on a firm's proclivity to outsource.

4. CONCLUSIONS

Firm-level data describing the use of computer networks by Japanese businesses both within and across firms show the distribution of computer networks and their effect on the organisational structure of firms. The data lead to the following conclusions:

- *The use of networks is relatively evenly distributed across industries.* Unlike other technologies, information technology is a "general-purpose technology" that can be used to manage operations of a manufacturing plant, provide logistics support for distribution sectors like retail trade, and track customer service for service sectors.

- *The probability of using a computer network is directly related to the size of the firm.* While the reason for this difference can not be determined from the data, other research suggests that the cost of acquiring and implementing the technology is an important factor (US Bureau of the Census, 1993a).
- *Different network uses are complementary.* Firms that use information networks for one function (e.g. production management) are likely to use other network functions (e.g. cost accounting) as well. This underscores the finding that the adoption of information technologies tends to have a pervasive effect and is rarely limited to a single application.
- The adoption of computer networks is associated with a shift in the occupational mix of the firm that favours white-collar jobs at the expense of blue-collar jobs. Rather than simply leading to a greater demand for information-processing jobs, IT networks tend to have a wider impact, positively affecting R&D personnel and managers while creating less demand for blue-collar production workers.
- *Firms' willingness to outsource some production activities increases with the adoption of computer networks.* The use of a network to streamline business operations is positively correlated with the probability of outsourcing. This might be explained by the fact that the use of information technology lowers transaction costs, thereby favouring "buying" to "making".

5. LIMITATIONS, UNANSWERED QUESTIONS AND FURTHER RESEARCH

Although the data give insight into the diffusion and use of computer networks in Japan, they have various limitations. A major limitation is the fact that the data reflect the situation as of 1991, prior to the rapid growth of the Internet, which has given small and medium-sized businesses a relatively inexpensive means of obtaining access to both intra- and inter-firm networks. This may change the size bias associated with the use of computer networks. MITI plans to release data from the second survey conducted in 1994 which should begin to shed light on this question.

Another issue is the difficulty of generalising these findings to countries other than Japan. A number of observers (Brynjolfsson, 1996) argue that a decentralised and flexible organisational structure is essential to reap the full benefits of computer networks in a firm, but Japanese firms are considered to be hierarchical and less flexible in hiring, firing, and reassigning work to accommodate a major reorganisation and to have relatively low computer (PC)

penetration rate (Negroponte, 1994; Vadon, 1996). For this reason, it could be argued that the organisational changes witnessed in Japan might offer a more conservative indication of what is happening in other countries. To evaluate this hypothesis, data from other countries and comparative analysis are needed.

This analysis also links the use of computer networks with a greater tendency to outsource production. It is likely that a significant portion of this outsourcing activity is going to foreign firms. As the Internet grows to form an international network of computers, this phenomenon will undoubtedly grow, further "informationalising" the globalisation process. Some Japanese firms already use the Internet to solicit bids from suppliers scattered throughout the world, and some German firms claim that they are losing lucrative market niches because the Internet makes it easier for customers to compare prices and find more competitive suppliers (Norman, 1996). From an international viewpoint, IT should increase competition and lead to an equalisation of wages across countries (Forge, 1995). Further work needs to be done in this respect.

Appendix

Regression results of labour demand equations by occupation and network use

	BO1	BO2	BS1	BS2	DIST	TECH	CUST
PLAN			+		+		
R&D		++			++	++	
IP	-				+	+	+
SALE	+	+		+		-	++
BC	-			-	-		

Note: Symbols represent the magnitude of changes for each coefficient: > -0.1 per cent (—); -0.1 to 0 per cent (-); 0 to 0.1 per cent (+); > 0.1 per cent (++) . Only those coefficients of statistical significance at the 5 per cent level are provided.

Source: Motohashi, 1996.

A number of network use variables are dummy variables where:

- BO1 is 1 when a firm adopts one or two out of the three business operation group networks.
- BO2 is 1 if a firm adopts all three business operation group networks.
- BS1 is 1 if a firm adopts one or two out of the two business support group networks and uses the network for management planning.
- BS2 is 1 if a firm adopts both of the business support group networks and management planning use.
- DIST is 1 if a firm uses the network for distribution purposes.
- TECH is 1 if a firm makes use of the network for management of technology.
- CUST is 1 if a firm uses the network for customer information management.

NOTES

1. This census survey was carried out for all firms, except those with fewer than 50 employees or less than ¥ 30 million in capital, whose main business is in manufacturing or distribution. ("distribution" refers to wholesalers and retailers.) The BSBSA also covers firms in the "other service" industry, but the survey particular to this group is not a census, contrary to a complete enumeration (with cut-off points) for manufacturing and distribution. In addition, the sample size of the "other service" industry is too small to permit a 3-digit level of industry classification. Aggregate results and a 1991 questionnaire for the survey are published in MITI (1994a). The detailed results on information network use are provided in Motohashi (1996).
2. Surveys on the adoption of advanced manufacturing technology, including information technology applications, show a strong correlation between technology adoption and firm size (see Dunne, 1994; and Baldwin *et al.*, 1995).

ACCOUNTING FOR IT QUALITY CHANGES AND THEIR IMPACT ON THE MEASUREMENT OF PRODUCTIVITY GROWTH

1. INTRODUCTION

This section of the *IT Outlook* examines the efforts that have been made to improve the accuracy of statistical measures of information technologies in the United States. To date, they concern three broad areas: accounting for quality changes in output, accounting for quality changes in inputs, and reducing the bias associated with using a fixed reference point for comparisons of price changes.

2. ACCOUNTING FOR QUALITY CHANGES IN OUTPUT

In order to analyse productivity, or simply calculate growth rates for that matter, it is important to obtain from each sector a measure of output, such as gross output (production) or value added, that is comparable over time. Such measures must not only adjust for relative changes in prices over time, but also for changes in product *quality*. Otherwise, changes in productivity might simply be due to changes in product attributes rather than to productivity gains or losses. However, accounting fully for quality changes is a complex process, and it is even more difficult when changes are large and rapid, as they have been in information technology sectors such as the computer industry. For example, although their price is roughly the same, the standard desk-top personal computer of 1996 differs significantly from that of 1981. Therein lies the weakness of the conventional “matched-model” technique, which attempts to calculate price changes by comparing identical models over time and which implicitly assumes that new models have characteristics similar to those of the old ones.

The hedonic function is an alternative statistical technique that does incorporate changes in product characteristics into the price index. It does so by looking at the “relation between prices of varieties or models of heterogeneous goods – or services – and the quantities or characteristics contained in them”

(Triplett, 1989). For computers, it typically relates movements in a product’s price to product characteristics such as millions of instructions per second (MIPS), memory or disk capacity, and processor speed (Cartwright, 1986). The hedonic technique allows for comparing a wide variety of models on the basis of a defined set of characteristics. While it is not always the best method for measuring price changes, it is recognised as more appropriate for products or industries that are experiencing large changes in quality (Eurostat *et al.*, 1995).

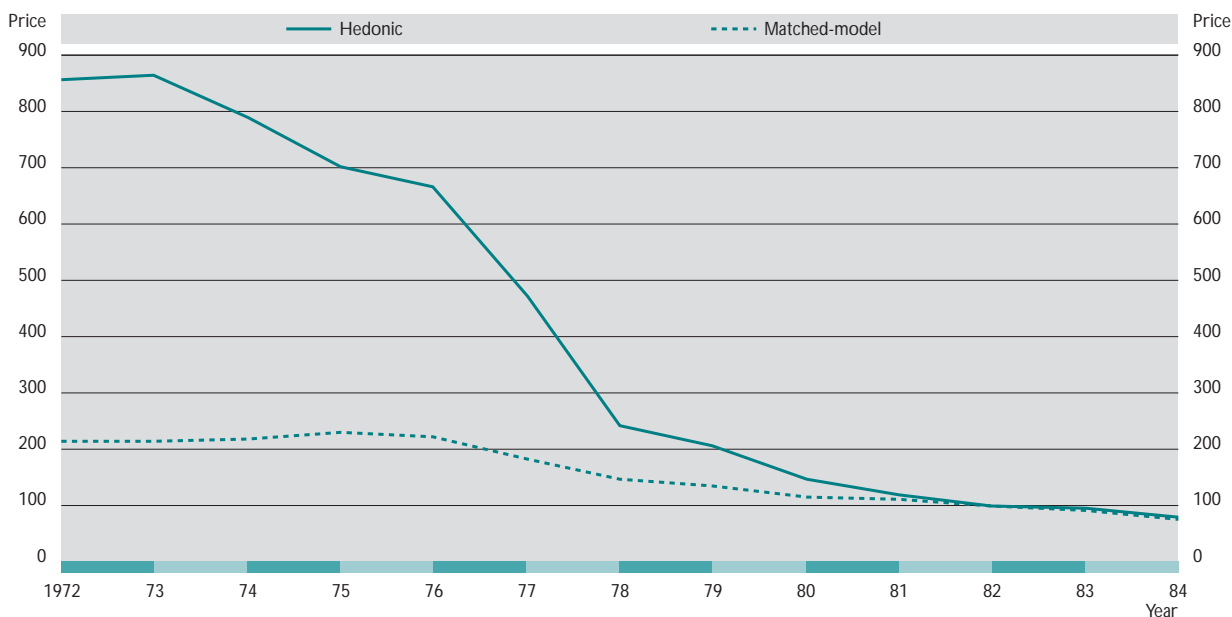
In 1985, the US Bureau of Economic Analysis (BEA) introduced a hedonic price index for computer processors (main frames) and selected peripheral equipment into its national accounts. The hedonic technique replaced the matched-model technique and used work done by IBM (Cole *et al.*, 1986) to cover the period 1969-84 (Cartwright, 1986). This new index differed dramatically from the old matched-model technique (Figure 3.1), and with its introduction, the 1985 share of office and computing machinery, measured in constant 1982 dollars, shot up from less than 18 per cent of all purchases of durable equipment to more than 21 per cent (Bureau of Economic Analysis, 1986 and 1987).

The introduction of the new index drew a good deal of public attention and a number of criticisms (Mishel, 1988; Denison, 1989; Young, 1989a). One important criticism concerned the omission of the quality improvements in inputs used by the computer industry (e.g. semiconductors), so that the productivity gains in these inputs were erroneously attributed to the computer sector; another was the distortion caused by BEA’s use of a fixed base year as a reference point for price changes.

3. ACCOUNTING FOR QUALITY CHANGES IN INPUTS¹

In 1996, BEA dealt with the first criticism by publishing new prices indexes for memory chips and microprocessors as part of a larger revision of the US

◆ Figure 3.1. *Comparison of matched-model and hedonic price indexes for US computer processors: 1972-84*
1982 = 100



Source: Cole et al. (1986).

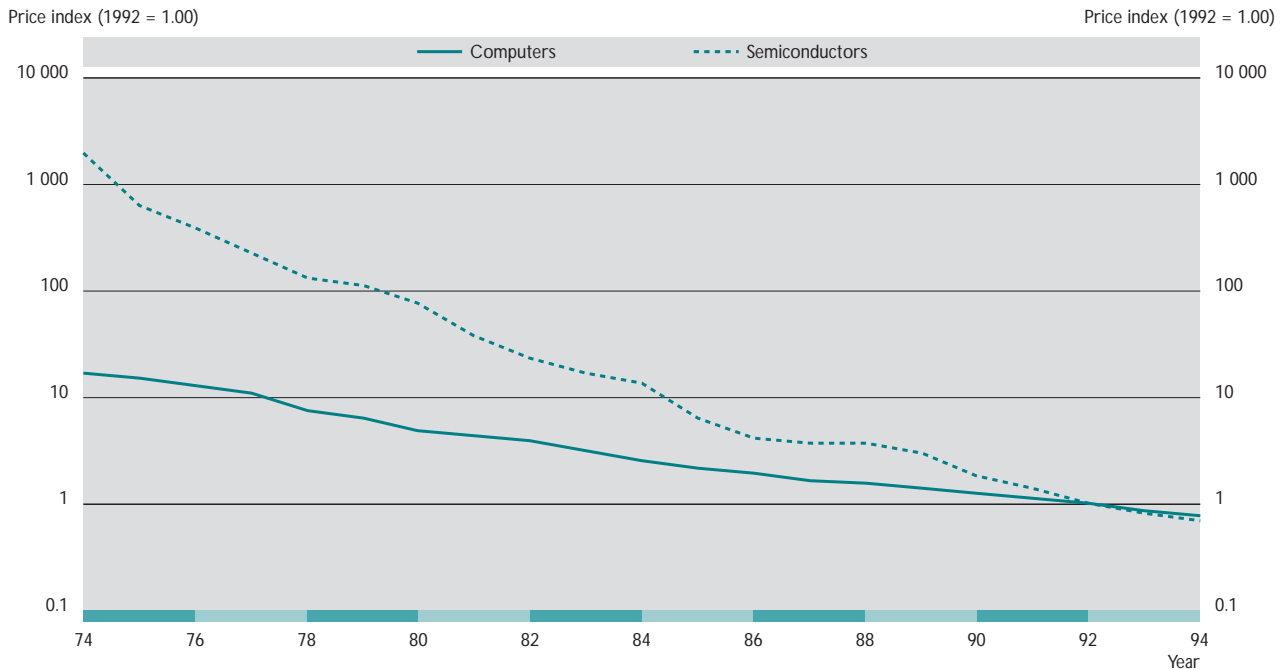
national accounts (Bureau of Economic Analysis, 1996). Unlike the hedonic price index for computers, which was based on a basket of product characteristics, these new price indexes were calculated using a single characteristic (a one-variable hedonic function): the price per kilobyte of memory on the chip. The weighted average of different types of semiconductors (e.g. DRAM, microprocessors) produces a price index that is falling at nearly three times the annual average rate of the hedonic index for computers (Figure 3.2). Depending on the share of inputs to the manufacture of computers represented by semiconductors (estimates are difficult owing to the fact that many semiconductors are purchased already installed on boards, where they are no longer classified as semiconductors), semiconductors account for anywhere from 2 to 15 per cent of the price decline in computers. The introduction of a hedonic index for semiconductors thus reduces the relative productivity of computers² from about 14 per cent a year (from 1974 to 1994) to somewhere between 4 and 11 per cent a year, depending on the share of inputs attributed to semiconductors. This adjustment for quality changes in semiconductors leads to three conclusions. First, previous estimates of productivity

increases in the computer industry were overstated. Second, productivity in the semiconductor industry has significantly outpaced that in the computer industry. Third, even after adjusting for quality improvements in semiconductors, the computer industry has still registered impressive productivity gains.

4. REFERENCE POINTS IN TIME³

A more fundamental problem concerns the choice of reference point to use as a basis of comparison and how to sum different industries to form an aggregate. In the past, a fixed set of prices from a particular base year were used as weights. They constitute a “snapshot” of the relationship between products, or the industries that produce them, at a given time; when related to changes in quantities in subsequent years, they yield a constant-price time series. Thus, GDP is the result of adding up s tonnes of steel at price s_p , the number of autos, a , at price a_p , the number of computers, c , at price c_p , and so on. Changes in the production mix that can be expected to occur as relative prices change is not allowed (e.g. substituting aluminium for steel as the price of

◆ Figure 3.2. *US semiconductor and computer price indexes*
Log scale



Source: Triplett (1996).

aluminium falls relative to that of steel). In the United States, this snapshot was updated every five years and then applied to the whole time series, which frequently covered many decades. This is not very problematic if relative prices and the output mix are stable over the period. However, if a good's price is falling, its importance is overstated until the snapshot is taken again. This happened for computers. For example, a PC with a 286 microprocessor (e.g. an IBM-AT) cost about \$2 000 in 1987 but could easily have been purchased for half that price at 1992 prices, leading to the disappearance of computers in 1987 using 1992 prices; conversely, a PC with a 486 microprocessor cost about \$2 000 in 1992, but the cost in 1987 prices would have been more than twice that, causing an explosion in computers in 1992 using 1987 prices. The use of fixed weights explains to a large degree the importance of the computer sector in US investment, output growth, and productivity.

The introduction of hedonic price indexes for computers in 1985 was the key factor behind a subsequent US government decision to switch its method of calculating growth in GDP and industrial output from fixed weights tied to a particular base year to a "chain-weighted" index, which allows weights to

change over time (Young, 1989b). As expected, the new weighting scheme lowered the growth rates for GDP after 1987 (the old base used for fixed weights) and increased it for the period prior to 1987. More than half of the overestimate for the period after 1987 could be attributed to the computer sector (Landefeld and Parker, 1995).

This change in technique had a dramatic effect on business-sector productivity growth rates, with a change of between 15 and almost 60 per cent in longer-term productivity trends and an elimination of the productivity recovery of the early 1990s (Table 3.1). The impact on single years was even larger: the productivity gain from 1992 to 1993 was essentially abolished, and, on a quarterly basis, the adoption of chain weighting caused the signs of productivity growth to flip in some quarters.

5. CONCLUSION

Statistical measures that attempt to capture the economic impact of information technologies are in a period of transition, and improvements in one dimension force corresponding changes in others. In the United States, early improvements designed to mea-

Table 3.1. **A comparison of US labour productivity¹ growth rates: fixed vs. chained weights**

Annual average growth rates			
Trends	a Fixed	b Chained	b-a Difference
1 960-73	2.6	3.0	0.4
1973-79	0.7	1.1	0.4
1979-90	0.8	1.0	0.2
1990-94	1.6	1.1	-0.5
1960-94	1.5	1.8	0.3
Single years			
1990-91	1.3	0.7	-0.6
1991-92	2.8	3.2	0.4
1992-93	1.2	0.2	-1.0
1993-94	1.3	0.5	-0.8
Recent quarters			
94:1	0.2	-2.5	-2.7
94:2	-0.5	1.9	2.4
94:3	3.0	2.6	-0.4
94:4	2.7	0.9	-1.8
95:1	1.3	-1.1	-2.4
95:2	4.3	3.0	-1.3
95:3	2.0	1.4	-0.6

1. Non-farm business-sector compound average annual rates of change.
Source: Dean (1996), Table 9.

sure better the technological advances occurring in the computer industry spawned changes in how other sectors are measured and in the technique used to aggregate sectoral changes into an economy-wide picture. While they are only a start, these improvements further refine our understanding of the economic impact of information technologies. Oliner and Sichel (1994), for example, show the importance of computer software and computer services in accounting for US productivity growth.

The uneven rate of statistical advances in this area in OECD Member countries further limits international comparisons. Only a few countries use hedonic price indexes to calculate constant-price output or productivity for the computer sector, so that international comparisons at this level of detail are impossible. The combined use of hedonics and chained-weighted estimates of GDP growth or business-sector productivity by the United States makes international comparisons with countries that use fixed-weight indexes⁴ less comparable at a more aggregate level as well (Dean, 1996).

NOTES

1. This section is based on Triplett (1996a).
2. Roughly the price decline of computers minus the price decline of semiconductors weighted by their share in all inputs to computers.
3. This section is based on Dean (1996).
4. Currently, only four OECD Member countries – France, the Netherlands, Norway and the United States – calculate changes in GDP using chained weights.

THE GLOBALISATION OF INFORMATION TECHNOLOGY INDUSTRIES: FOREIGN DIRECT INVESTMENT DATA FROM THE UNITED STATES

Information technologies (IT) are among the most international and globalised industries (OECD, 1996a). Their international nature is evident in the trade data which show that, in most large countries, the share of IT production that is exported is two to three times the average of exports from other industries. It climbed to 40 per cent in France in 1991, to 88 per cent in the United Kingdom in 1992, and to 45 per cent in the United States, 52 per cent in Germany, and 27 per cent in Japan in 1993.

Globalisation is best quantified by analysing inward and outward foreign direct investment (FDI) in the IT industry. In 1993, the output of computer equipment manufacturers produced by foreign affiliates of US firms was 40 per cent greater than total domestic production in the United States. Because the comprehensiveness of the data varies considerably across countries, this analysis only covers the United States.

1. OUTWARD FOREIGN DIRECT INVESTMENT

The US data on the IT industry can be broken down into four segments on the basis of the 1987 US Standard Industrial Classification:

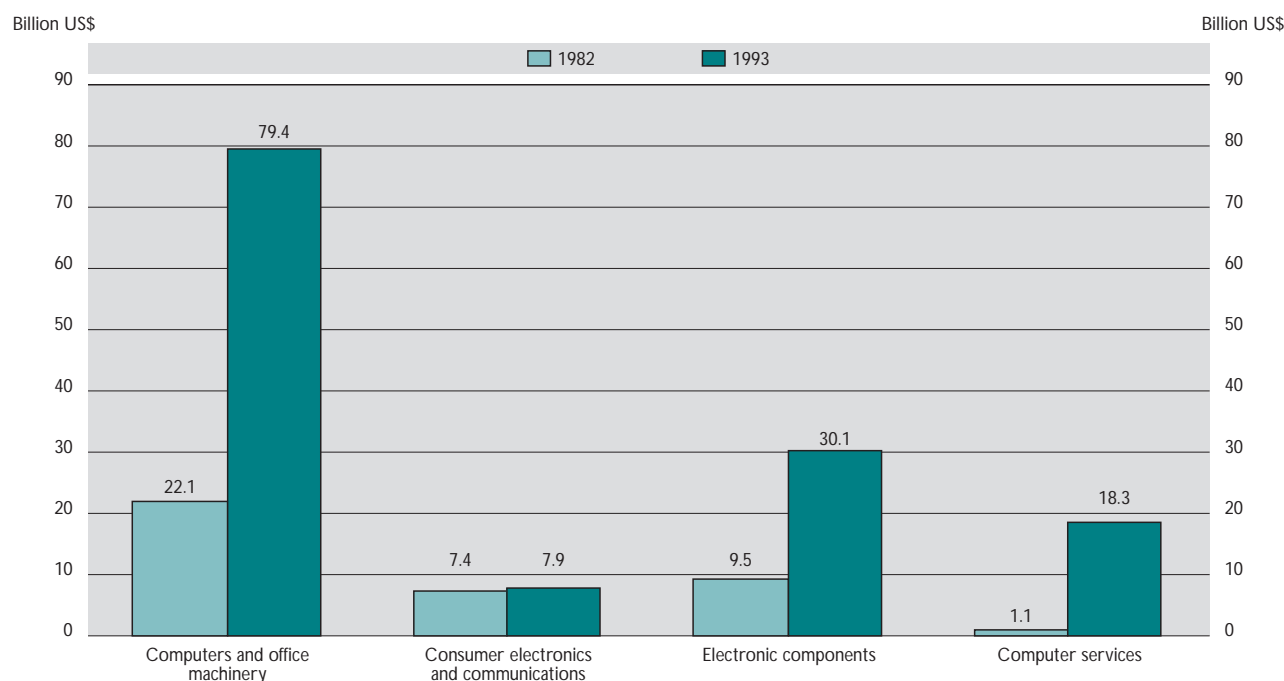
- computers and office machinery: mainframe, mini and personal computers, computer storage devices, computer terminals and peripheral equipment;
- consumer electronics and communications: telephone and telegraph apparatus, radio and television broadcasting and communications equipment;
- electronic components: printed circuit boards, semiconductors;
- computer services: computer processing and services, data preparation, information retrieval, facilities management.¹

Between 1982 and 1993, total IT industry sales by US affiliates operating abroad grew twice as fast as the average for US affiliates in all industries combined and at three times the rate for manufacturing affiliates. Computer services sales rose most sharply (at an annual rate of 29 per cent), followed by computers and electronic components (12.3 and 11 per cent, respectively) (Figure 4.1). In contrast, sales in consumer electronics and communications were sluggish and probably declined in volume. Some hardware manufacturers began to obtain over 50 per cent of sales from software and consulting, a reflection of an overall industry trend (see Part I). Nevertheless, at year-end 1993, turnover in computer services was still less than a quarter that of computers and office machinery, whose sales exceeded those of the other three sectors combined.

Computers and office machinery

Between 1982 and 1993, the number of US affiliates abroad in the computer and office machinery industry rose from 90 to 151; 90 per cent were majority-owned.² Over the same period, sales per affiliate doubled, while average size shrank from 2 000 to about 1 500 employees.

A comparison of total assets of US foreign affiliates (outward FDI) with assets of foreign-owned affiliates in the United States (inward FDI) shows that for the period 1985-93, outward FDI assets were generally well over ten times inward FDI assets. The situation is somewhat better for Asian computer firms than for European ones, but in 1993 US FDI in Asia was still more than eight times inward Asian FDI. Total outward FDI assets were US\$52 billion in 1985 and US\$121 billion in 1993, while total inward FDI assets were US\$2.8 billion and US\$8 billion, respectively (OECD, 1996a).

◆ Figure 4.1. *Sales of US IT affiliates¹ abroad*

1. Majority- or minority-owned firms, except for consumer electronics and communications (majority-owned only).
Source: OECD, Database on the Activities of Foreign Affiliates (DSTI).

In 1993, total assets of US foreign affiliates were distributed as follows: Europe, US\$75 billion; Asia-Pacific, US\$33 billion (and increasing steadily); and rest of the world, US\$13 billion. In the same year, total assets of foreign companies' affiliates in the United States amounted to US\$4.3 billion from Europe and US\$3.8 billion from Asia. Inward FDI assets from the rest of the world were negligible.

In 1982, over 73 per cent of the sales of US affiliates were to Europe, but by the end of 1993, they had dropped to 58 per cent, half of which to the United Kingdom and Germany. This shift corresponds to a restructuring of activity, with virtually all new affiliates being established in the Asia-Pacific area. The latter's share of aggregate sales of computers and business machinery, which amounted to less than 2 per cent in 1988, climbed to over 31 per cent of world sales of US affiliates in 1993.

The strategy of US multinationals in this sector, as in others, appears to have been to give priority to meeting local demand in their affiliates' home-country markets (45 per cent of total sales). Nevertheless, the proportion of sales to the US market rose from 8 per cent in 1982 to 21 per cent in 1993. More-

over, a significant share (over 34 per cent) was destined for markets outside the host countries, with an overwhelming majority of the exports being routed through US affiliates based in those markets.

Over the same years, sales outpaced *employment* in US foreign affiliates by almost three to one. The only significant net job creation occurred in the Asia-Pacific area. While affiliates operating in most other parts of the world cut staff (Table 4.1), those located in Asia created some 74 000 new jobs, to account for 38 per cent of all employees of US affiliates in this sector (Figure 4.2).

The shift of US affiliates to Asia may have been prompted by labour cost differentials. In Asia, average employee compensation in 1993 (wages and salaries plus employer-paid contributions) was only half that in Europe, and only a third or a fourth that of Europe in certain countries. Labour productivity in Asia was 73 per cent that in Europe, but the average annual growth rate was almost three times as high (14 per cent in Asia versus 5 per cent in Europe). Moreover, in the early 1990s, profit ratios in Europe turned negative, and this may have given US investors another reason to look to Asia.

Table 4.1. **Employment in majority-owned US affiliates abroad**

Thousands

	Computers		Consumer elec.		Elec. components		Comp. services	
	1982	1993	1982	1993	1982	1993	1982	1993
Total	160.2	219.6	160.8	40.5	208.1	285.0	10.0	77.6
Canada	14.6	12.2	4.2	3.9	7.6	6.0	0.5	4.6
Japan	13.9	⁴	0	0	5.5	14.8	0	5.0
Europe	112.8	115.1	110.5 ³	16.1	43.8	75.4	7.0	54.2
Latin America	10.4	8.2	17.8	9.0	32.4	71.5	1.2	3.7
Africa	0	0.1	⁴	0	0.1	0	-	-
Midde East	0	0.2	⁴	2.4	0.5	2.3	0.2	1.1
Asia-Pacific	8.3	82.8 ¹	22.5	8.1	117.4	114.3	0.3	5.5
Australia	-	1.0	3.5 ²	0.9 ²	0.8	0.7	0.7 ²	3.2 ²

1. Excludes Australia.

2. Includes New Zealand and South Africa.

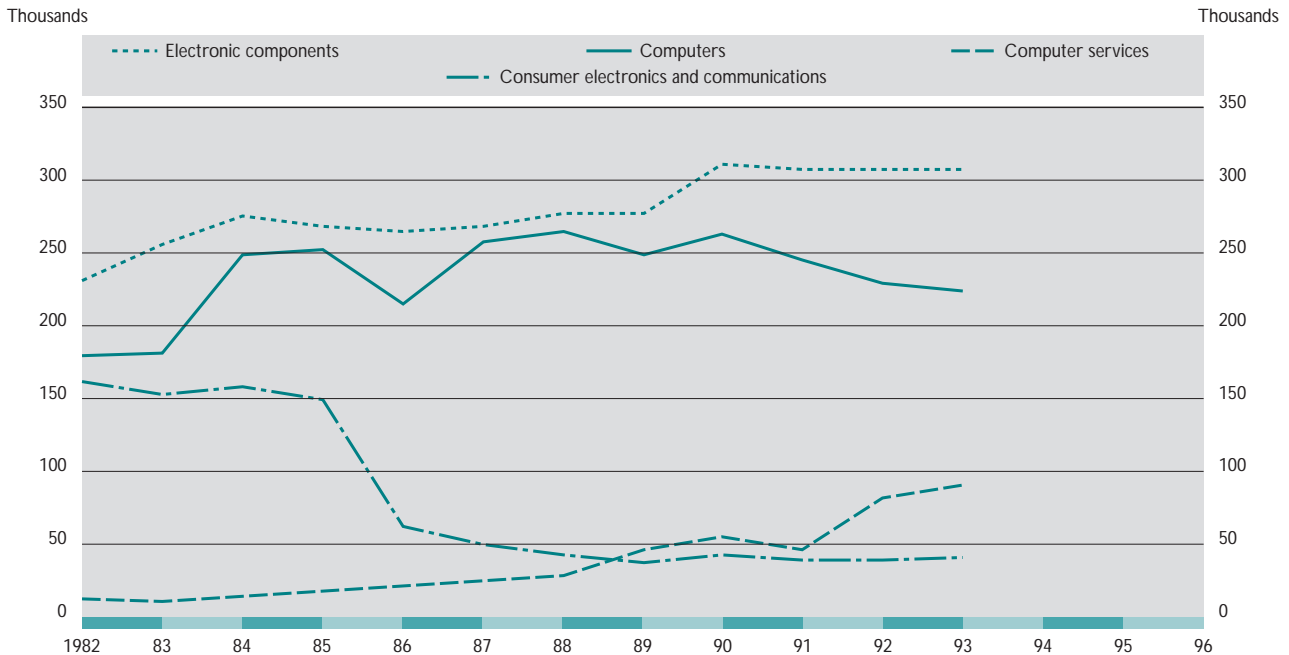
3. EU only.

4. Suppressed to avoid disclosure of individual company data.

Source: OECD, Database on the Activities of Foreign Affiliates (DSTI/EAS)

In 1989, the share of R&D expenditure that US affiliates performed in Europe was roughly the same as that of sales, at around 60 per cent, down from 1982, owing mainly to a shift of R&D expenditures to Japan and the Asia-Pacific area. Computer affiliates spent five times as much on R&D as component affi-

ates and seven times as much as affiliates in computer services. Moreover, computer makers were the only IT affiliates to finance their own research, but they also performed twice as much R&D for their parent companies or other affiliates in the same group as they did on their own behalf. This suggests

◆ Figure 4.2. **Employees of US IT affiliates¹ abroad**

1. Majority- or minority-owned firms, except for consumer electronics and communications (majority-owned only).

Source: OECD, Database on the Activities of Foreign Affiliates (DSTI).

that research performed by affiliates was intended more for international than for local consumption. In addition, the R&D intensity (R&D outlays as a percentage of sales) of US affiliates in the computer industry was considerably below the OECD average, suggesting that most R&D was carried out by parent companies in the United States.

Between 1982 and 1986, the US computer and office machinery *trade balance* surplus fell steadily, and in 1987 it turned negative. By 1993, the trade deficit stood at US\$16.8 billion. It was attributable to trade with the Asia-Pacific area (US\$26 billion overall in 1993, with deficits of US\$132 billion with Japan, US\$6 billion with Singapore, US\$5 billion with Chinese Taipei and US\$1.7 billion with the Republic of Korea), whereas the trade balance showed a solid surplus with the European Union over the entire period.

Three-quarters of the US deficit was with unaffiliated companies, with affiliates, the deficit stemmed exclusively from trade with partners in Asia. *Intra-firm trade* (i.e. the share of trade between affiliates and parent companies in a sector's total trade) was up sharply between 1982 and 1993, climbing from 23 to 35 per cent for exports and from 28 to 32 per cent for imports.

Consumer electronics and communications

Consumer electronics and communications is the only one of the four IT industries from which US firms began to withdraw extensively from affiliates in the latter half of the 1980s. The withdrawal was marked by an initial phase of substantial divestment of majority-owned affiliates, followed by a second phase of massive retreat from minority holdings.

Dollar sales of US (majority- and minority-owned) affiliates lost momentum in the period 1982-85, but regained ground in 1986. Between 1987 and 1989, sales trends levelled off for both categories of affiliates, culminating in 1990 with a withdrawal from minority-owned units. One consequence of the restructuring was a reduction in payrolls around the world, especially in Europe (Figure 4.2). *Employment* in European affiliates fell from 103 200 in 1985 to 14 000 in 1986 and remained at approximately that level until 1993. The countries hardest hit were Belgium, Germany, Italy, and Spain. Elsewhere, workforce reductions were more modest, dropping from 22 500 to 8 100 in the Asia-Pacific area and from 17 800 to 9 000 in Latin America.

Exceptionally high *productivity gains* were obtained essentially by cutting staff. Even so, it was not in Europe, where job losses were most severe, that the gains were greatest, but in the Asia-Pacific area. This was due to Europe's decline in nominal sales, which in 1993 were below their 1982 level, whereas sales in Asia rose by a factor of 2.7 over the same period. For majority-owned Asian affiliates as a group, productivity rose at three times the rate of wages and salaries. Profit ratios for Asian affiliates of US firms, between 1988 and 1993 in particular, were among the highest of the four sectors examined, at approximately 9 per cent.

The US *trade balance* deficit in the consumer electronics and communications sector was fairly large, at between US\$12 and 16 billion for the years reviewed. Over half of the trade deficit was with Japan, the rest with China, Chinese Taipei, Mexico, the Republic of Korea, and Singapore. More than 94 per cent of the overall deficit of the consumer electronics sector stemmed from trade with unaffiliated firms.

The direct consequence of these trends was a sharp decline in *intra-firm trade* in consumer electronics. For exports, it dropped from 56 per cent of all trade in 1982 to 9.5 per cent in 1993, and for imports, from 23 to 5.3 per cent. In addition, the proportion of consumer electronics products in parent company imports from affiliates dropped significantly (from 93 to 71 per cent) because of the faster growth in imports from unaffiliated suppliers.

Electronic components

Between 1982 and 1993, US firms created about 150 new affiliates worldwide in the electronic components industry. Most of the sales and employment of US foreign affiliates were outside the OECD area. Europe's share of sales remained fairly stable at between 34 and 36 per cent of the total, half of which in the United Kingdom and Germany. The largest share of sales was in the Asia-Pacific area, which in 1993 accounted for over 56 per cent of the total.

Majority-owned US affiliates hired an additional 77 000 employees over the period, generating 31 600 jobs in Europe and 39 100 in Latin America. The importance of Latin America, rather than the Asia-Pacific area, as a source of half of all the new jobs is rather surprising, since in 1993 labour productivity in the Asia-Pacific areas was seven times that in Latin America, where wage and salary costs were 60 per cent higher. Moreover, profit ratios of Asian affiliates were well above the overall average through-

out the period, while those in Latin America were very low (and even negative in 1988). The decision to locate in Latin America was probably influenced by other factors, such as stricter local-content regulations, tax incentives or other advantages.

Research and development was aimed more at local than at international needs. In contrast to the situation in computers and office machinery, 83 per cent of the R&D performed by electronic components affiliates was for their own needs. About half of US affiliates' R&D expenditure was in Europe, 10 per cent in Canada, and 27 per cent in Japan.

In the early 1980s, the largest portion of affiliates' sales (39 per cent) went to the US market, 32 per cent to local markets, and the rest to other countries. In 1993, this trend was reversed, in favour of local markets; the United States still accounted for a relatively large proportion of sales (29 per cent), but one that was down significantly.

The US *trade balance* in components ran a constant deficit, essentially with two countries – Japan (80 per cent of the deficit) and South Korea (20 per cent) – but the volume of the deficit was only one-third and one-half that recorded for consumer electronics and for computers and office machinery, respectively. It was split almost equally between affiliated and unaffiliated firms.

In components, the United States seemed to want to lessen its dependence on foreign suppliers, including its own affiliates abroad. Meanwhile, the share of imports by US parent companies of components from affiliates abroad (as a share of their total imports) rose to 95 per cent in 1993, owing to a slowdown in imports from unaffiliated suppliers. In addition, *intra-firm trade* increased appreciably; in the case of imports, it rose from 22.5 per cent in 1982 to 34.6 per cent in 1993, whereas the figures for exports, although higher, showed little change (from 42.3 per cent in 1982 to 45.1 per cent in 1993).

Computer services

Over the past 15 years, US affiliates in computer services experienced extremely rapid growth, in terms of both sales and number of employees. The number of affiliates climbed from 97 in 1982 to 398 in 1993, and computer services were the only one of the four sectors analysed in which the average size of a unit increased, from 125 to 213 employees. The vast majority of computer services affiliates were located within the OECD area (which accounted for over 85 per cent of sales, with 70 per cent in Europe).

Over those twelve years, *employment* in computer services affiliates expanded by around 68 000 jobs – almost as many as in electronic components affiliates and more than in computers and office machinery affiliates. In 1993, a third of the employees in Europe were in the United Kingdom, another third was split between France, Germany and the Netherlands, and the remaining third in other (mainly EU) countries. In Japan, US affiliates only began to be established in 1987-88.

R&D expenditure by computer services affiliates was relatively modest in comparison with outlays by the computer and office machinery and the electronic components sectors. About 40 per cent of R&D was carried out by parent companies on their affiliates' behalf. In Europe, most R&D was performed by and for affiliates in the United Kingdom and the Netherlands.

Over 80 per cent of sales were to host-country markets; barely 2 per cent went to the US market.

2. INWARD FOREIGN DIRECT INVESTMENT³

Foreign investment in US electronics industries was dominated by multinationals from Europe, Canada and Japan. Whereas Japanese investors tended to favour small new US electronics enterprises, European investors generally acquired much larger firms.⁴ In 1994, in the *computer and office machinery* sector, European affiliates accounted for 49 per cent of all foreign affiliate sales and 41 per cent of employment, whereas Japanese affiliates generated 31 per cent of sales and 47 per cent of employment. Among Europeans, French companies made the largest investments: Groupe Bull's take-over of Honeywell's computer division and of Zenith Data Systems. French affiliates provided about 27 per cent of the jobs among the sector's foreign affiliates. Other European countries had more modest shares, led by Germany (10 per cent) and Switzerland (2 per cent). Certain Japanese firms (Toshiba and NEC) acquired US computer makers and employed more people than all of the European companies combined. Since the early 1990s, certain Asian firms – particularly from Chinese Taipei, Hong Kong, the Republic of Korea, and Singapore – made small acquisitions, which represented 1.5 per cent of sales and 6 per cent of employees.

In 1994, in the *consumer electronics and communications* sector, European firms accounted for 42 per cent of sales and 46 per cent of employment of all foreign affiliates combined. Once again, French

affiliates dominated sales and employment (with shares of 30 per cent and 28 per cent, respectively): Thomson acquired the TV manufacturer RCA/GE and Alcatel invested in manufacturers of telephone equipment. Next came the United Kingdom, which specialised in telephone equipment (Plessey), while Germany (Siemens and BASF), the Netherlands (Philips) and Sweden (Ericsson) accounted for less than 2 per cent of telephone equipment sales and employment. Japanese companies, which accounted for 26 per cent of sales and employed 16 per cent of the workforce, specialised in the production of records, video cassettes and CDs through affiliates of Sony and TDK. In addition, Japan's NEC and Fujitsu set up affiliates to make telephone switching equipment. In that area, Canada's Northern Telecom held a strong position, with US market shares just below those of the United States' AT&T. Investment by other Asian firms, including Samsung (Republic of Korea) and Tatung (Chinese Taipei) in television manufacturing, was modest, at less than 2 per cent of aggregate sales by foreign affiliates.

In *electronic components*, European affiliates generated 57 per cent of the sales of foreign affiliates and some 51 per cent of their employment. The

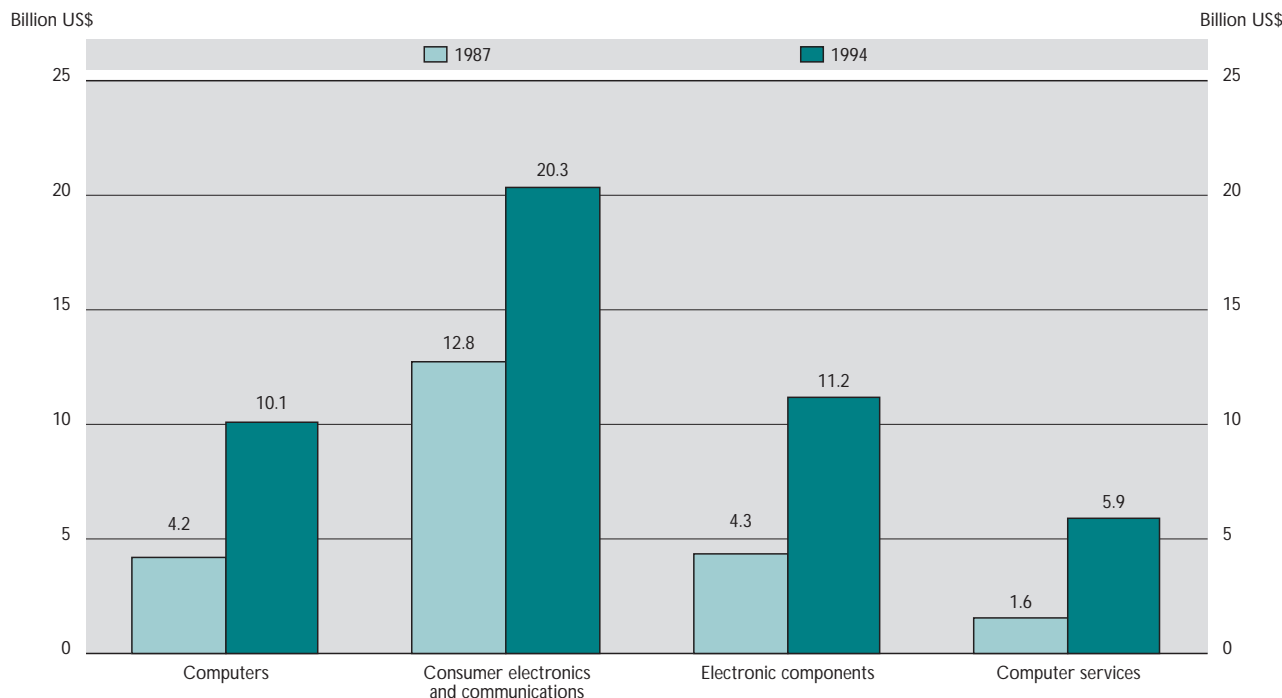
shares of Japanese affiliates in sales and employment were 37 and 41 per cent, respectively. Two European countries, Germany (Siemens) and the Netherlands (Philips), accounted for over 40 per cent of sales and some 23 per cent of the workforce. The chief Japanese multinationals producing electronic components in the United States were Toshiba, NEC, Fujitsu, Hitachi, Matsushita and Sony. Affiliates of firms from Canada (Northern Telecom) and certain Asian countries, particularly the Republic of Korea (Samsung) and Chinese Taipei (Hualong and Tatung), had only very modest shares of sales (between 2 and 4 per cent).

Computer services were dominated by European affiliates, which generated 75 per cent of the sales of foreign affiliates and employed 68 per cent of the workforce. Japanese affiliates had only a relatively modest share, with 5 per cent of sales and employment.

Sales and employment

Between 1987 and 1993, sales of foreign IT affiliates in the United States more than doubled, from US\$23 to US\$47 billion (Figure 4.3). This was twice the growth rate of sales of US affiliates abroad in the

◆ Figure 4.3. Sales of foreign IT affiliates in the United States



same industries, although US sales abroad exceeded foreign sales in the United States by three to one.

Sales of computer services rose most sharply (at an annual rate of 22 per cent), followed by electronic components (14.5 per cent), computers (12.9 per cent), and consumer electronics and communications (10.5 per cent).

The relative withdrawal of US firms from consumer electronics, which also affected US investment abroad, was followed by a substantial influx of foreign affiliates to the United States. Without their presence, the US trade deficit in the sector would probably have been far wider.

Employment rose far less sharply than sales, at least until 1993, with 2.3 per cent annual growth vs. 12.0 per cent for sales. During the 1990s recession, foreign affiliates, which had created 66 400 jobs between 1987 and 1990, trimmed their workforce (cutting 21 100 jobs in 1991, 4 100 in 1992 and 14 700 in 1993). These losses were mainly in computers and office machinery (down 25 200) and components (down 14 600); consumer electronics and computer services maintained their employment levels.

Estimates for 1994, however, show an overall year-on-year loss of 34 900 jobs, concentrated in consumer electronics and communications (down by 24 500) and, to a much lesser extent, the computer industry (down 6 500).

The role of foreign investment in the US economy

Foreign affiliates played an expanding role in US economic activity. Between 1987 and 1993, their share of total employment rose from 10 to over 15 per cent in computers and office machinery and from 11 to 13 per cent in consumer electronics and electronic components. While the overall US computer sector lost 86 000 jobs over this period, foreign affiliates created about 900. Similarly, in the IT industry as a whole, foreign affiliates created 6 000 additional jobs while aggregate employment dropped by 70 000. These jobs paid above-average wages for the sectors involved, and for manufacturing in general.

Returns on foreign investment were very heavily influenced by cyclical trends in each sector. Profit ratios were extremely disappointing in the computer industry throughout the period under review, and were relatively mediocre in electronic components, at least until the end of the recession. They were, however, far more satisfactory in computer services and consumer electronics and communications, which suffered less from the recession.

Research and development

Aggregate R&D outlays of foreign affiliates in the United States in the four sectors rose from \$1.3 billion in 1987 to \$2.7 billion in 1994. Computer services, with 37 per cent annual growth, saw the sharpest increase in R&D expenditure, followed by consumer electronics and communications (14 per cent) and computers and office machinery (7 per cent). In contrast, R&D outlays in electronic components declined by an annual average of 3.7 per cent. In consumer electronics and computer services, the bulk of R&D was performed by European and Canadian affiliates; in the computer sector, by Japanese affiliates; and in electronic components, by European and Japanese affiliates.

In 1994, Japanese affiliates performed 75 per cent of the R&D of foreign affiliates in the computer and office machinery sector and 42 per cent of the R&D in the electronic components industry. European-owned firms accounted for 32 per cent of the R&D of foreign affiliates in electronic components and 76 per cent in computer services, a sector where the presence of Japanese affiliates was modest.

In the four sectors, over 98 per cent of R&D funding was provided by the affiliates themselves, and the work was performed on their own behalf. The electronic components industry carried out some 10 per cent of its research for other customers. Contracts from the federal government represented only a small fraction (less than 0.2 per cent) of the R&D outlays of foreign affiliates.

Trade

Between 1987 and 1993, exports and imports of foreign affiliates grew much more rapidly than trade by all domestic and foreign electronics firms: while aggregate trade almost doubled, exports and imports of foreign affiliates more than tripled. Exports and imports of consumer electronics and communications affiliates grew most sharply, at nearly twice the sector's overall pace. Electronic components and computer equipment affiliates followed.

The aggregate trade balance of the foreign affiliates in the four sectors of the IT industry showed a deficit over the period 1987-94, but the gap began to widen in 1990 and affected all sectors except computer services, where trade was extremely slight. The export/import ratio worsened in the computer sector (from 0.66 to 0.46), changed little in consumer electronics (from 0.33 to 0.36), and bounced back in electronic components (from 0.45 to 0.75). Nevertheless,

in 1993 over 75 per cent of the trade deficit of foreign affiliates was attributable to consumer electronics, 20 per cent to computers and office machinery, and less than 5 per cent to electronic components.

In terms of trade, foreign affiliates in all sectors (and especially consumer electronics and communications) generated deficits, except for computer services, which recorded a slight surplus. Only a small portion of computer services was exported (barely 5 per cent of turnover); the other sectors' export ratios varied between 11 and 16 per cent, *i.e.* well below those of domestic firms. A substantial portion of foreign affiliates' trade, particularly imports, was

conducted with parent companies (between 45 and 70 per cent, depending on the sector).

In the computer and office machinery sector, over 85 per cent of the trade deficit from foreign affiliates came from Japanese firms; European affiliates generated surpluses (US\$140 million). The deficits in consumer electronics and electronic components were more evenly divided between affiliates of Japanese and European corporations. The surpluses in computer services were largely attributable to European firms and, to a lesser extent, Japanese and Latin American companies.

NOTES

1. These categories are based on 1987 US Standard Industrial Classification codes 357, 366, 367 and 741, 742 and 743.
2. Majority-owned foreign affiliates are those in which the combined direct and indirect ownership interests of all US reporters for the affiliate exceed 50 per cent.
3. The data used in this section are only available from 1987. They encompass all foreign affiliates in the United States, whether foreign ownership involved a majority or a minority interest. In this, the figures differ from most statistics on US affiliates abroad, which cover only majority-owned units.
4. Donald H. Dalton, "Foreign Direct Investment in the US Electronics Industry", in *Foreign Direct Investment in the United States: Review and Analysis of Current Developments*, Economics and Statistics, US Department of Commerce, August 1991.

ACCESS TO AND USE OF INFORMATION TECHNOLOGIES AT HOME

1. INTRODUCTION

Since the launching of information infrastructure initiatives in the early 1990s, policy makers intent on ensuring accessibility to the information highway, and to the services it will provide to all, have found it important to assess the availability and use of computers and modems, which, together with communications networks, constitute the major components of these infrastructures. "Universal access at a reasonable cost" is an objective of many countries' action plans for the information infrastructure/information society. As a first step to analysing this issue, several OECD countries undertook surveys of computer use during the 1980s.

The availability and use of information technologies within and by governments and for education and training are covered in Part II. This section focuses on the availability and use of IT in households.

2. HOUSEHOLD ACCESS

IT penetration rates in households reflect how much access household members have to information technology goods and services.¹ They show that the share of households equipped with computers and related goods grew significantly between the early and mid-1990s (Table 5.1). Supported by substantial price reductions and greater numbers of applications, computer penetration reached a quarter or more of households in Australia, Canada, Denmark, Germany, the Netherlands, Sweden, and the United States by the mid-1990s. The share of households equipped with a PC and a modem, *i.e.* households with access to on-line services and the Internet, is much lower.

While not all households necessarily wish to purchase a computer, *income* is clearly the most important differentiating factor with respect to household penetration rates. Given the strong relationship between income and other socio-economic variables

(employment status, occupation, educational level of householder), this variable explains most of the variation in household penetration rates (the correlation coefficient, or R^2 , is 0.77) (Figure 5.1). For every \$10 000 increase in income, the likelihood of a household owning a computer increases by 7 percentage points.

In Canada in 1995, household penetration rates varied from 12.3 per cent for the lowest quartile (income under US\$17 256) to 50.2 per cent for the highest (income above US\$50 834), compared to an overall average of 28.8 per cent. Recent data from Australia (February 1996) also indicate wide variability: from 9.5 per cent (income below US\$9 630), to 52 per cent (income above US\$42 222), with an average for all households of 29.5 per cent. In Japan in 1993, household penetration rates ranged from 3 per cent for those with income under US\$16 277, to 20.7 per cent for those with income over US\$40 693 (the average being 11.9 per cent). In the United States, where more disaggregated data are available, the 1993 figures range from 5.8 per cent (income under US\$10 000), to 60.3 per cent (income over US\$75 000), with an average rate of 22.9 per cent.

Other demographic characteristics provide additional evidence of widespread disparities among households:

- Access to computers varies greatly with *age* and *family type*. Households where the head of household is between 35-44 and 45-54 years of age have the highest penetration rates (Figure 5.2). This is partly due to the presence of children and teenagers, the most avid computer users, in these households (Figure 5.3). It is also linked to higher overall income levels, particularly of those in the 45-54 age bracket.
- Differences in levels of education are also significant explanatory variables. In Sweden in 1995, persons aged 16 to 64 who had completed two or more years of university studies

Table 5.1. ICT equipment diffusion in selected OECD countries, 1990 and 1995¹

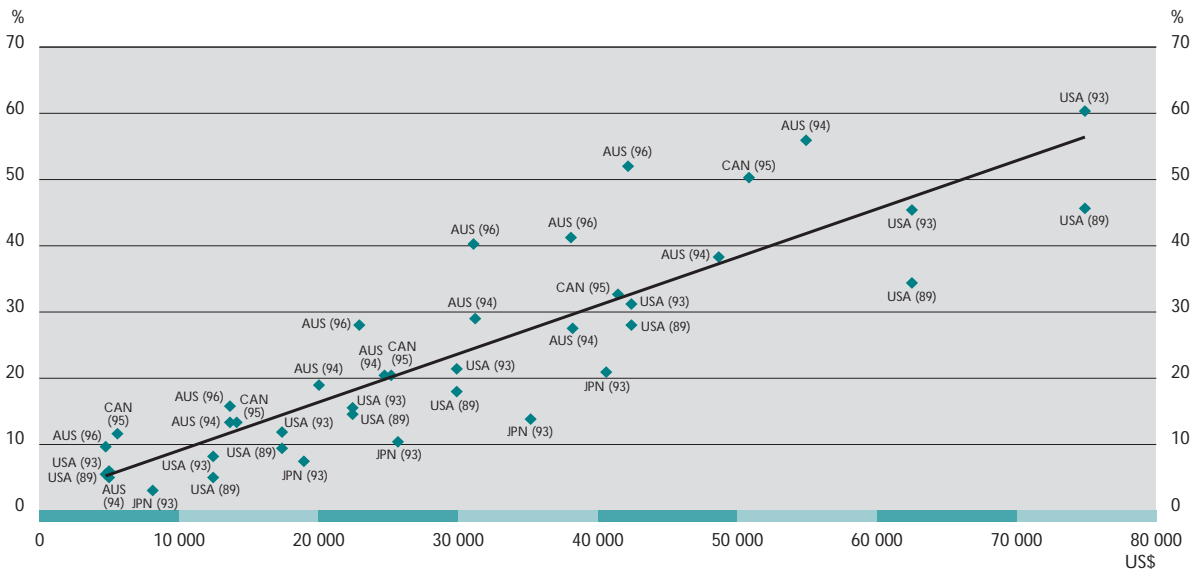
	United States		Canada		Japan		United Kingdom		Ireland		Spain	
	1990	1995	1990	1995	1991	1995	1990	1995	1990	1995	1990	1995
Population (millions)	249.9	263.1	27.8	29.6	123.9	125.2	57.4	58.5	3.5	3.6	39.0	39.2
Households (millions)	93.3	98.5	9.6	11.0	41.0	43.1	21.9	23.4	1.0	1.1	11.3	12.2 ⁵
Installed base of:												
Personal computers (millions)	54.2	86.3	2.7	5.1 ⁵	8.6	19.1	4.7	10.9	0.4	0.5 ⁵	1.1	3.2
Fax machines (thousands)	5 084	14 052 ⁵	300	525 ⁴	5 000	6 000 ⁹	750	1 800	53	80 ⁴	144	215 ⁴
Videotext terminals (thousands) ¹⁰				105 ⁴		128 ⁴		104 ⁴				480 ⁴
Number of mainlines/ 100 inhabitants	54.6	62.7	55.0	59.0 ⁵	45.4	48.7	44.2	50.2	28.1	36.5	32.3	38.5
Percentage of households equipped with:												
Videotext												
Fax machines		6 ^{5, 7}			5.5 ²	10 ⁹						
Personal computers	15	25.5 ³	16.2 ⁷	28.8 ⁷	11.5 ⁹	15.6 ⁹		20 ⁸		18		12 ⁸
Modem-equipped PCs		15 ⁴		9.8 ⁷				4 ⁴				
CD-ROM players	3.1 ^{2, 11}	14 ^{5, 11}						7 ¹⁷				7 ¹⁷
Cable TV		51 ¹⁴	71.4 ⁷	73.4 ⁷		19 ¹⁴		4 ¹⁴		40 ^{5, 13}		6.6 ^{5, 13}
Satellite TV (direct)								12.4 ^{4, 13}		3.3 ^{4, 13}		7.2 ^{4, 13}
	Netherlands		France		Germany		Italy		Belgium		Denmark	
	1990	1995	1990	1995	1990	1995	1990	1995	1990	1995	1990	1995
Population (millions)	15.0	15.5	56.7	58.1	79.4	81.9	57.6	57.0	10.0	10.1	5.1	5.2
Households (millions)	6.0	6.5 ⁵	21.9	22.5 ⁴	34.0	36.9	20.0	21.1 ⁵	3.9	4.0 ⁴	2.2	2.4
Installed base of:												
Personal computers (millions)	1.4	3.1	4.0	7.8	6.6	13.5	2.1	4.8	0.9	1.4	0.6	1.4
Fax machines (thousands)	180	500	580	1 200 ⁵	696	1 447 ⁵	170	202 ⁴	67	165 ⁴	100	185 ⁴
Videotext terminals (thousands) ¹⁰				6 540 ⁴		378 ⁴		200 ⁴				
Number of mainlines/ 100 inhabitants	46.4	52.5	49.5	55.8	40.2	49.3	38.8	43.6	39.3	45.7	56.6	61.3
Percentage of households equipped with:												
Videotext			16.9 ¹²	20 ^{4, 12}								
Fax machines				2 ⁸								
Personal computers		27 ⁸	11 ^{2, 12}	14.3 ¹²		25 ⁸		14 ¹⁹		21 ⁸		32 ^{6, 16}
Modem-equipped PCs				1 ⁸		3 ⁴						12 ^{6, 16}
CD-ROM players		10 ¹⁷		4.5 ⁸		11 ¹⁷		6 ¹⁷		7 ¹⁷		19 ^{6, 15}
Cable TV		92 ^{5, 13}		7 ¹⁴		42 ¹⁴		0.01 ^{5, 13}		90 ¹⁴		
Satellite TV (direct)		3.1 ^{4, 13}				17.5 ^{4, 13}		0.2 ^{4, 13}		0.4 ^{4, 13}		

1. Or closest year. When possible, official sources have been used.
2. 1992.
3. November 1994.
4. 1993.
5. 1994.
6. March 1996.

- Source: OECD Secretariat, based on data compiled from ITU and:
7. Statistics Canada.
 8. GFK Estimates.
 9. Japanese Economic Planning Agency.
 10. OMSYC.
 11. IDATE.
 12. INSEE.

13. Cable & Satellite Europe, January 1994. Quoted in "Les chiffres clés de la télévision et du cinéma", Paris 1995.
14. Ovum, quoted in *Les Echos* of June 12 1996.
15. Gallup Institute, for the newspaper *Berlingske Tidende*, quoted in "IT in Figures 1996", Ministry of Research and Information Technology, Denmark.
16. IDC.
17. Inteco.

◆ Figure 5.1. **Computer penetration rates, by household income¹ in Australia, Canada, Japan and the United States**



1. Household incomes were converted to US\$ using PPPs. Income values were obtained by taking the midpoint of each income bracket, except for the upper open-ended ranges where the lower bounds were used.

Source: Australia: Australian Bureau of Statistics (1994, 1996b), *Household Use of Information Technology*.
 Canada: Statistics Canada (1996b), *Access to the Information Highway: Canadian Households*.
 Japan: Economic Planning Agency in JEIDA (1995), *PC White Paper*.
 United States: US Bureau of the Census (1993b), *Computer Use in the US*.

were almost twice as likely to have access to a computer at home than those who had only completed upper secondary school (Figure 5.4). In Canada and the United States, there is strong evidence that the householder's educational level has a significant impact on computer availability at home (Figure 5.5). Completion of high school by the householder increases penetration rates by a factor of 1.7 in Canada (1995) and 2.1 in the United States (1993). In Canada, if the householder had completed a university degree, family members were more than twice as likely to have access to a PC than if he or she had only completed high school; in the United States, they were almost three times as likely.

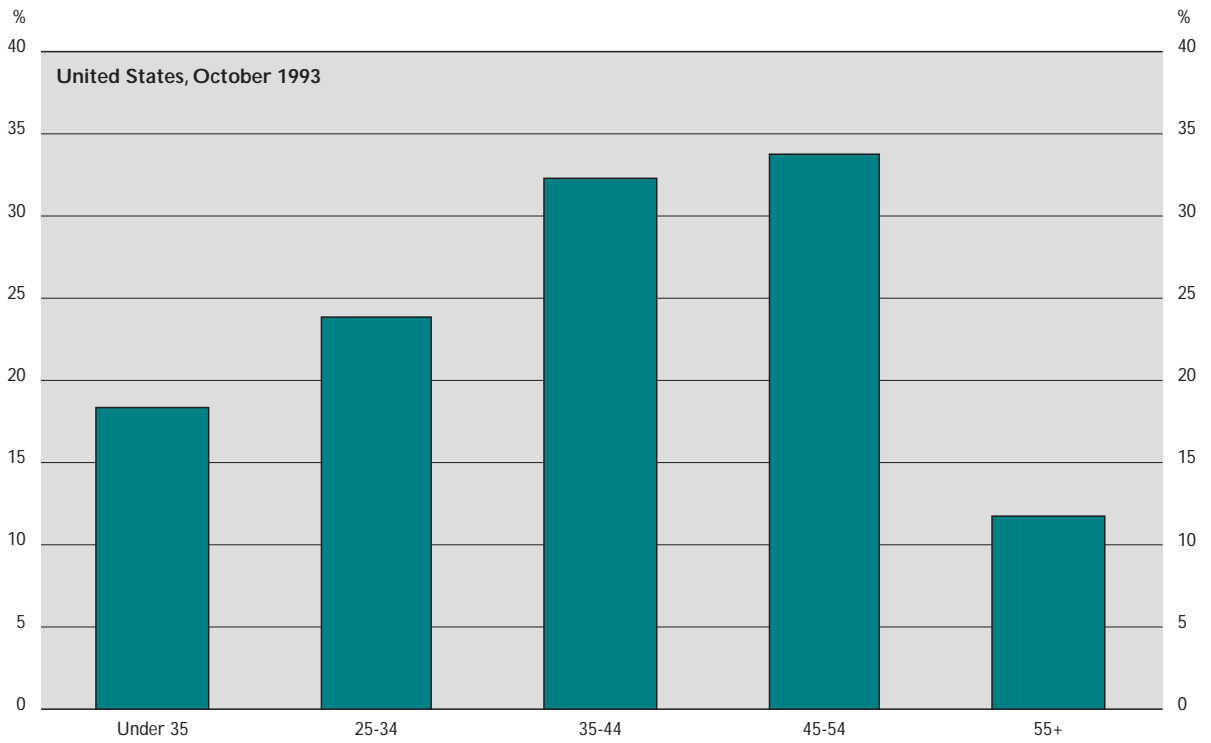
Labour force characteristics such as *employment status* and *occupation* of householders, through their impact on income, strongly influence the presence of information and communication technologies (ICTs) in households. In Canada and Japan, households where the householder is self-employed have the highest penetration rates, partly owing to work at home (Figure 5.6), while those where the householder

(or user) is unemployed are, as expected, below average (Figures 5.6 and 5.7). Data for the United States, France and Sweden also indicate that workers in white-collar occupations (whether highly skilled, such as managerial and professional, or less skilled, such as technical, sales and administrative) are much more likely to have access to computers at home than those employed in blue-collar jobs.

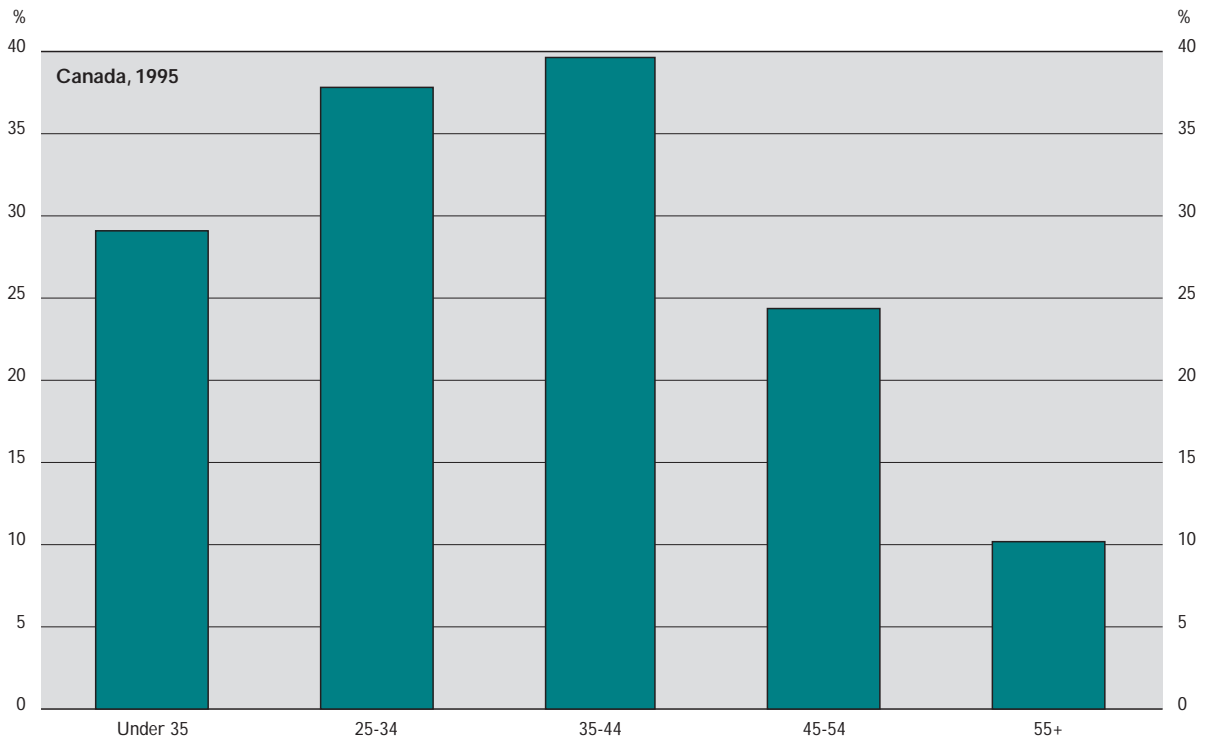
The *location* of households, both residential and regional, is also an important determinant of ICT penetration in households.

- Urban households typically have higher computer penetration rates than rural ones in all income brackets. Penetration rates in urban areas vary between 33 per cent and 17 per cent of households/individuals, in contrast to rural areas where the range is between 24 and 11 per cent on average (Figure 5.8). In every state of Australia, for example, computers had penetrated a far greater proportion of households in capital cities than in rural areas. City households accounted for 72 per cent of all home computers in 1994.
- The difference by residential location is even more pronounced for households that also

◆ Figure 5.2. *Percentage of households using a computer, by age of householder*

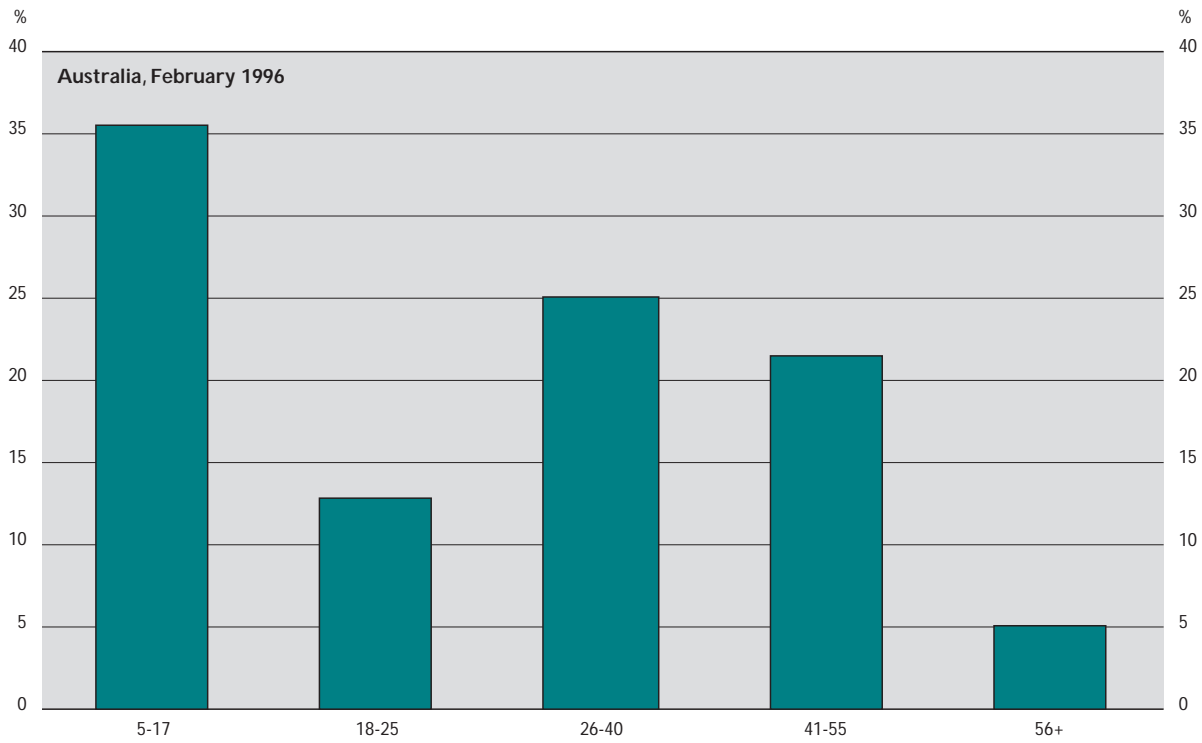


Source: US Bureau of the Census (1993b), *Computer Use in the US*.

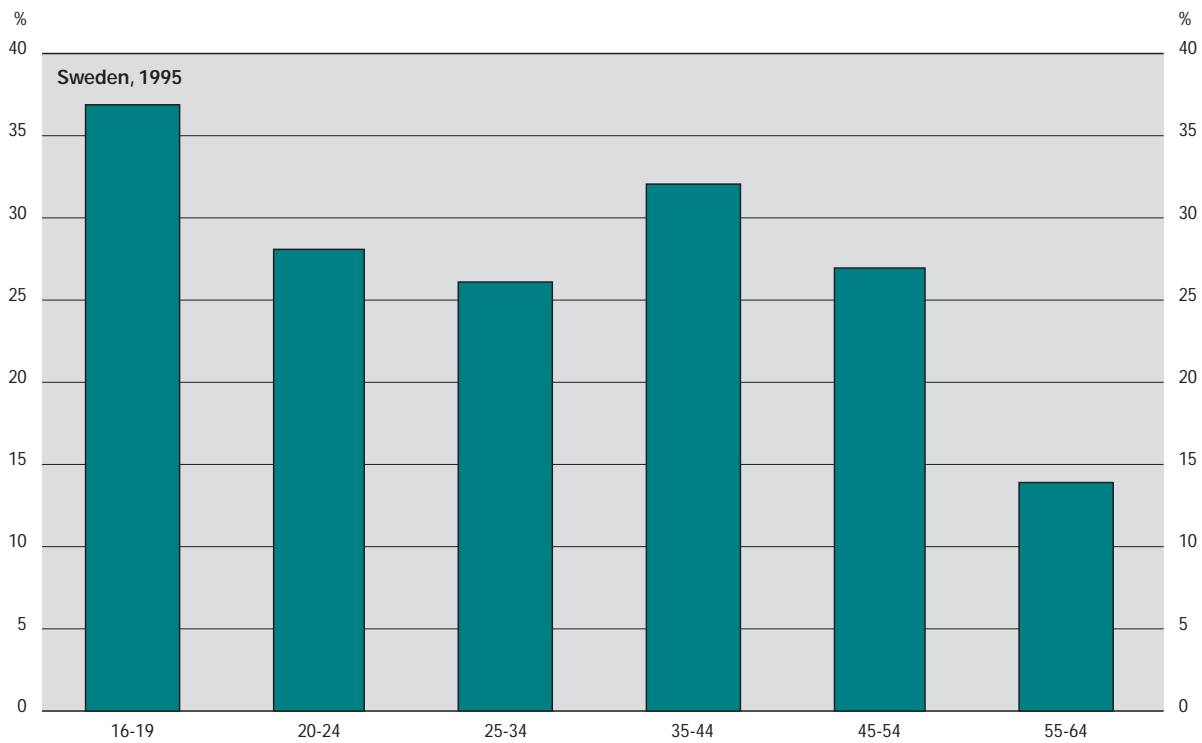


Source: Statistics Canada (1996b), *Access to the Information Highway: Canadian Households*.

◆ Figure 5.3. *Percentage of persons using a computer at home, by age*

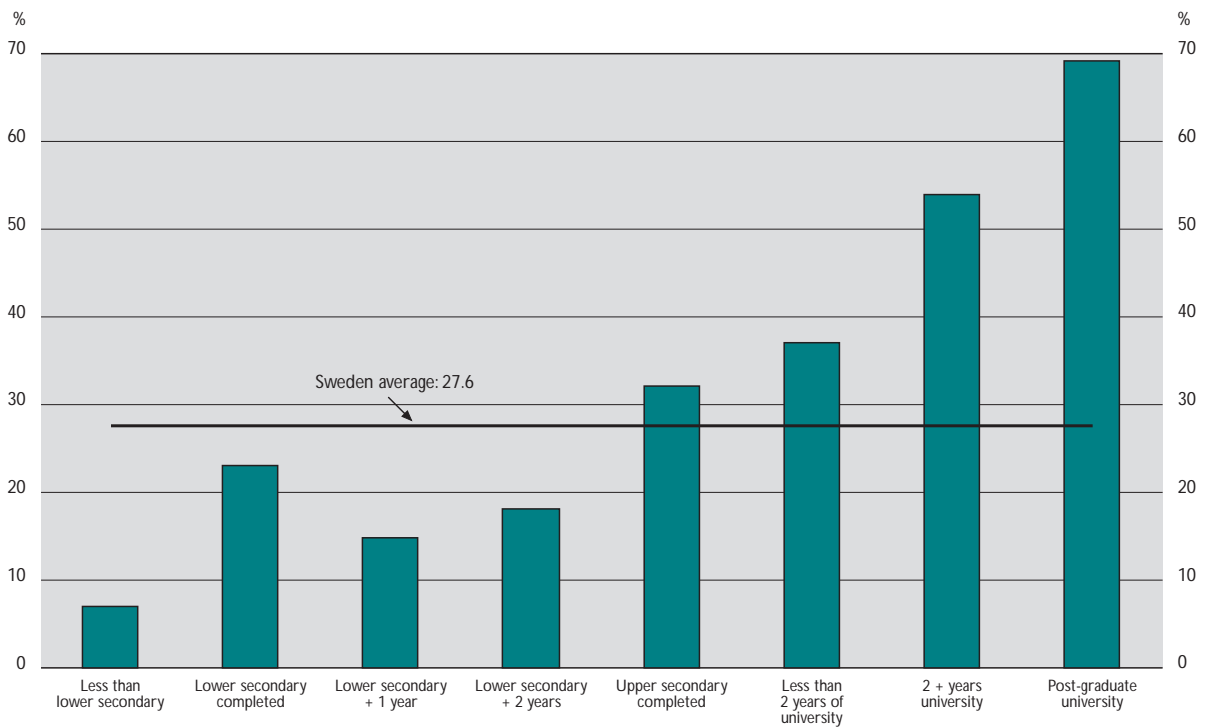


Source: Australian Bureau of Statistics (1996b), *Household Use of IT*.



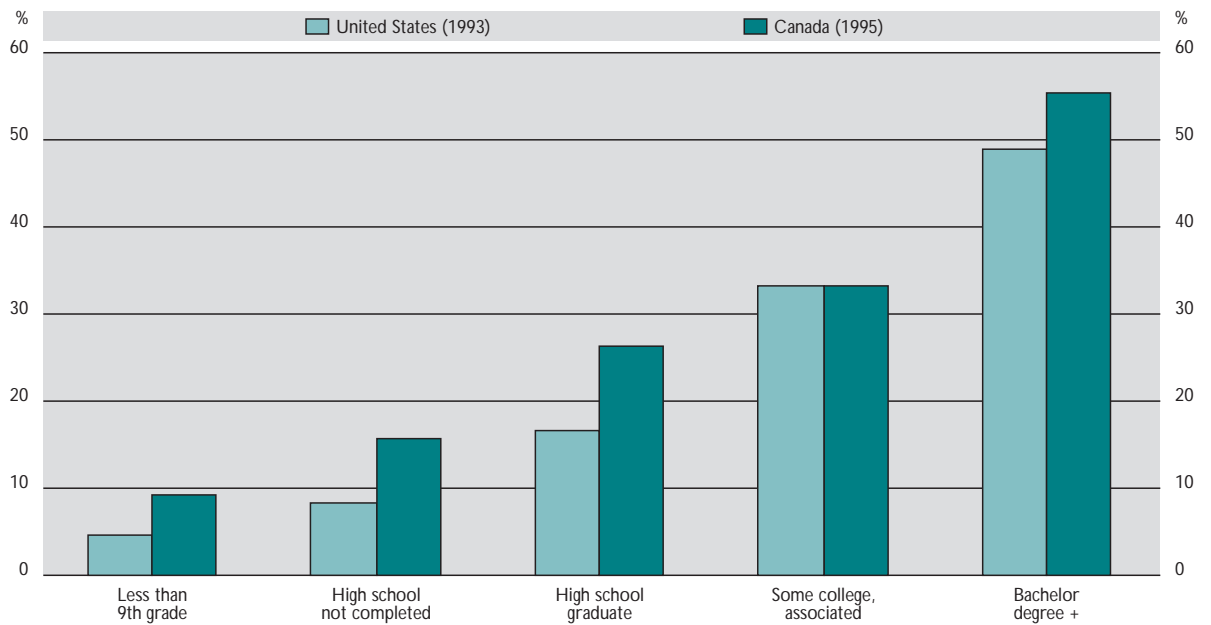
Source: Statistics Sweden (1995), *Computer Habits Survey*.

◆ Figure 5.4. *Use of PCs at home, by education level of user (age 16-64), Sweden 1995*



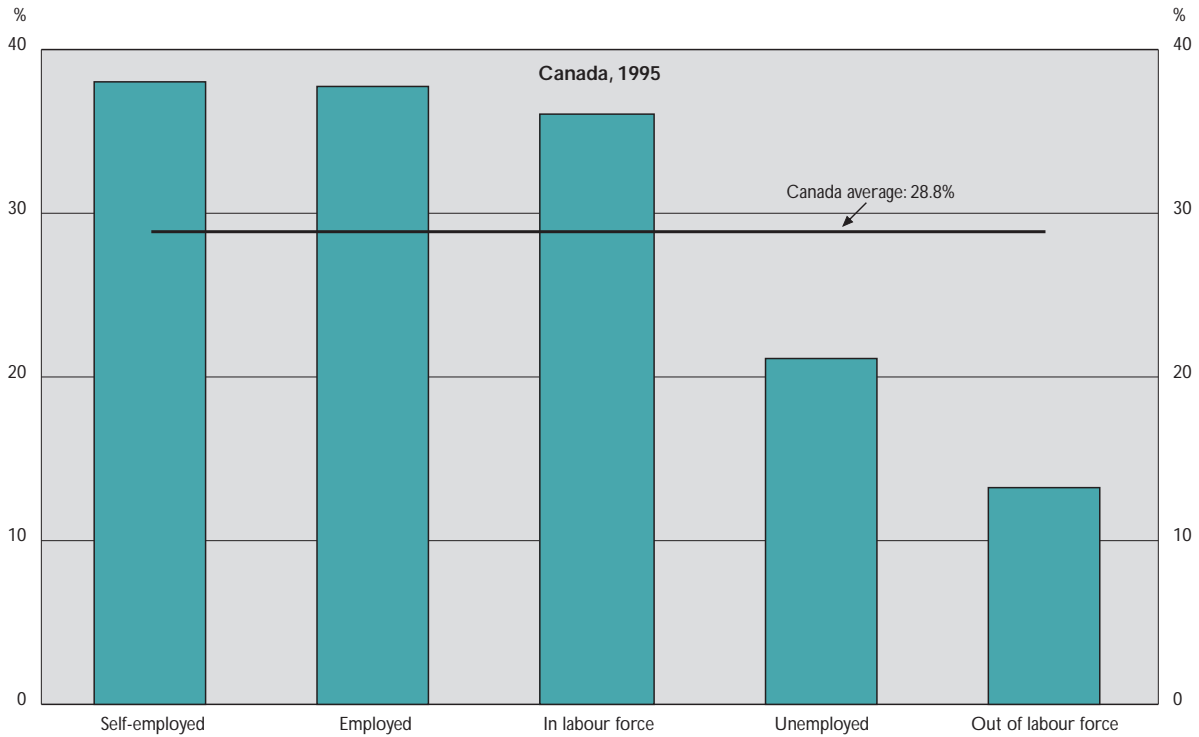
Source: Statistics Sweden (1995), *Computer Habits Survey*.

◆ Figure 5.5. *Household penetration rates, by educational level of householder, United States (1993) and Canada (1995)*

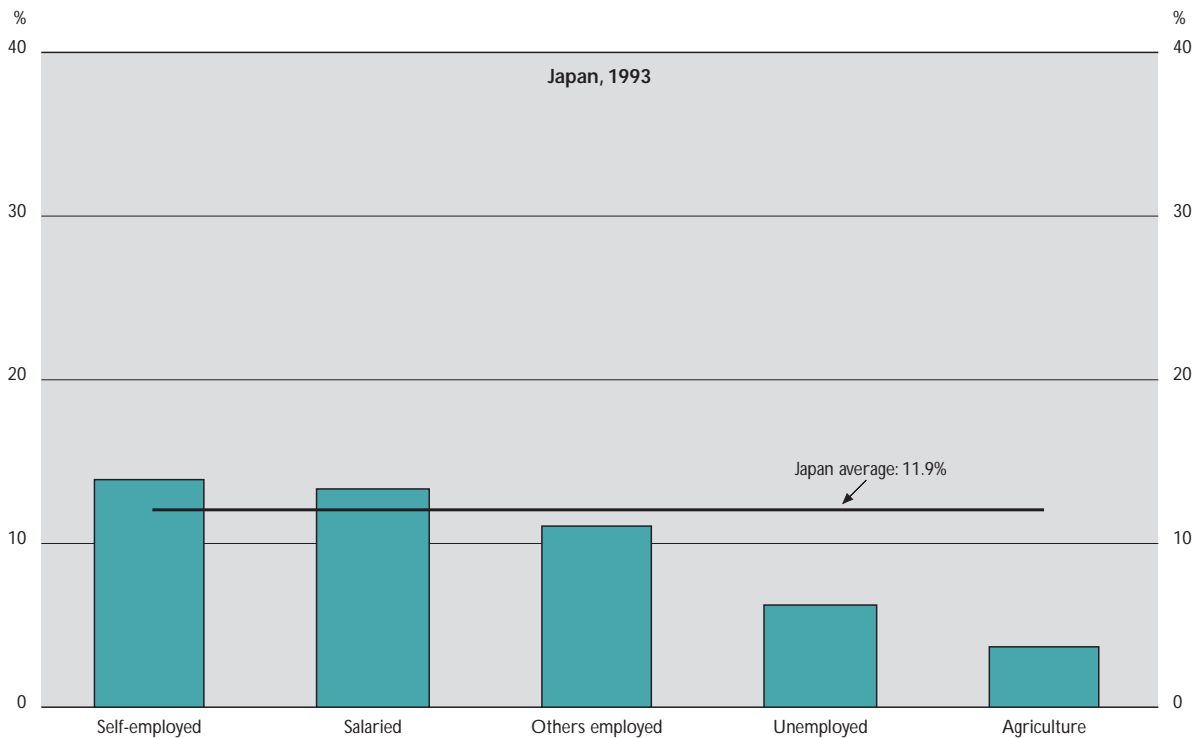


Source: Canada: Statistics Canada (1996b), *Access to the Information Highway: Canadian Households*.
 United States: US Bureau of the Census (1993b), *Computer Use in the US*.

◆ Figure 5.6. *Computer penetration rates in households, by employment status of householder*

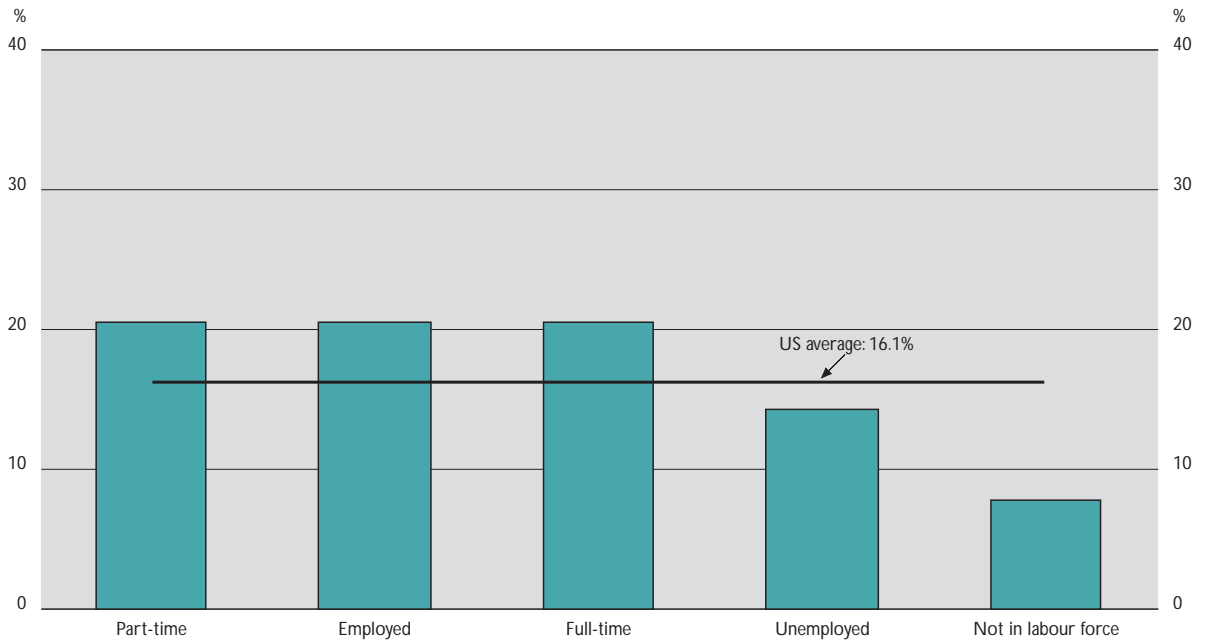


Source: Statistics Canada (1996b), *Access to the Information Highway: Canadian Households*.



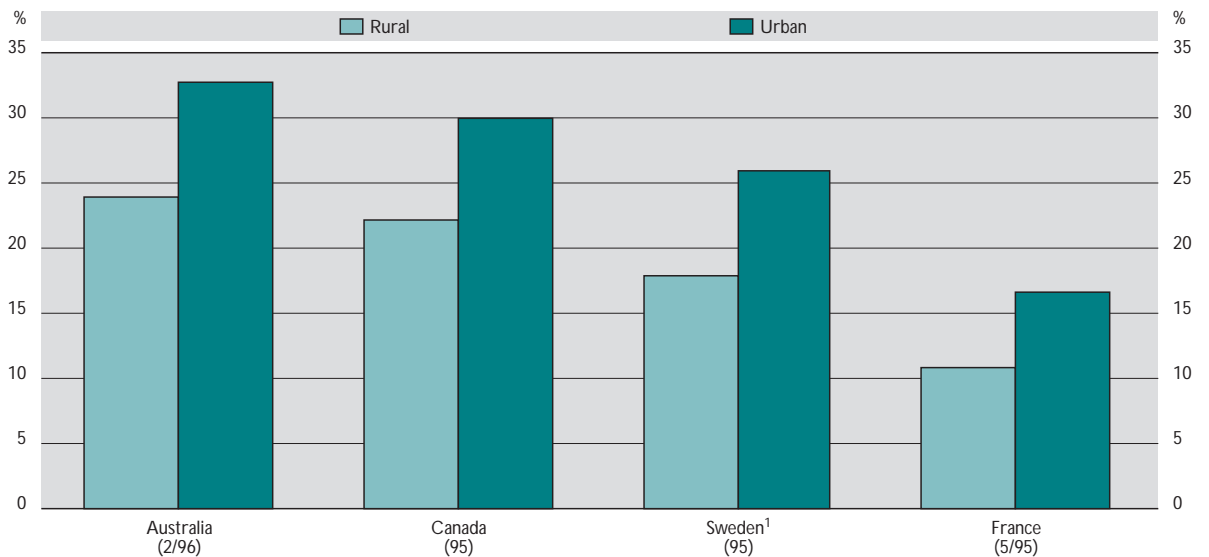
Source: Economic Planning Agency in JEIDA (1995), *PC White Paper*.

◆ Figure 5.7. **PC penetration rates in US households, by employment status, October 1993**
Persons aged 18 and over



Source: US Bureau of the Census (1993b), *Computer Use in the US*.

◆ Figure 5.8. **Computer penetration rates, by residential location**
Share of households with access to a computer



1. For Sweden, data refers to persons aged 16 to 64.

Source: Australia: Australian Bureau of Statistics (1996b), *Household Use of IT*.

Canada: Statistics Canada (1996b), *Access to the Information Highway: Canadian Households*.

France: INSEE (1996), *Conditions de vie des ménages*.

Sweden: Statistics Sweden (1995), *Computer Habits Survey*.

have a modem. In Canada, for example, twice as many urban households as rural ones have a modem (13 per cent vs. 6.5 per cent). The higher cost of accessing the Internet with a modem in rural areas may contribute to this difference.

- Computers are not evenly spread across regions. In Canada, for example, only the three "richer" provinces (out of ten) are above the national average, while in Australia, the penetration rate in the Australian Capital Territory (ACT) is more than 12 percentage points above the national average. In the United States, the penetration rate in the west is clearly above the national average, while it is below it in the south. Regions with major cities generally have a higher PC density than others. The greater Copenhagen area in Denmark is a case in point, as is the Stockholm/Sodertalje region in Sweden, where homes are twice as likely to have a computer as homes in remote rural districts (36 per cent and 18 per cent, respectively).

All these factors are interrelated in their effect on individuals' access to computers. In particular, an NTIA study shows that in the United States the rural poor and rural senior citizens have the lowest computer and modem penetration of all households (NTIA, 1995).

Households that lack computers are an indicator of potential demand. Furthermore, their characteristics provide valuable information as to where policies/support may be needed to improve the likelihood that those who need assistance in connecting to the information highway may get it. The principal reasons given by those not having a computer and/or a modem include lack of use or interest, as well as cost. Home computing still represents a significant investment for many households.

For individuals who do not have a computer at home, public libraries and other community centres possessing ICTs may constitute points of access to the information highway in many countries. In Denmark, for example, 23 per cent of the population had access to the Internet via libraries in their own municipality.

3. HOUSEHOLD USE

Accessing the information highway requires not only access to a computer and a modem but also knowing how to use them. Computer literacy is there-

fore an important determinant of use and is highest among higher income groups and younger users. Surveys that cover the use of IT at school and work as well as in homes show that the leading computer users are those who use computers on a daily basis in their jobs and find uses for them in their homes as well as households with school-age children. The work and study needs of persons in the household are among the principal reasons for buying computers.

Examining the use of home computers reveals how residential users choose to integrate them into their daily activities, including work, learning, entertainment and shopping. Home computers are actually used for a wide variety of purposes. The most frequent uses involve computer games,² educational activities, word-processing, record-keeping, and work-related activities (Figure 5.9). Uses that have gained importance in recent years include desk-top publishing, newsletter creation, working at home, and activities requiring the use of network services such as electronic mail, connecting to bulletin boards or to databases as well as connecting to a computer at work. These uses focus on access to information rather than on conducting transactions.

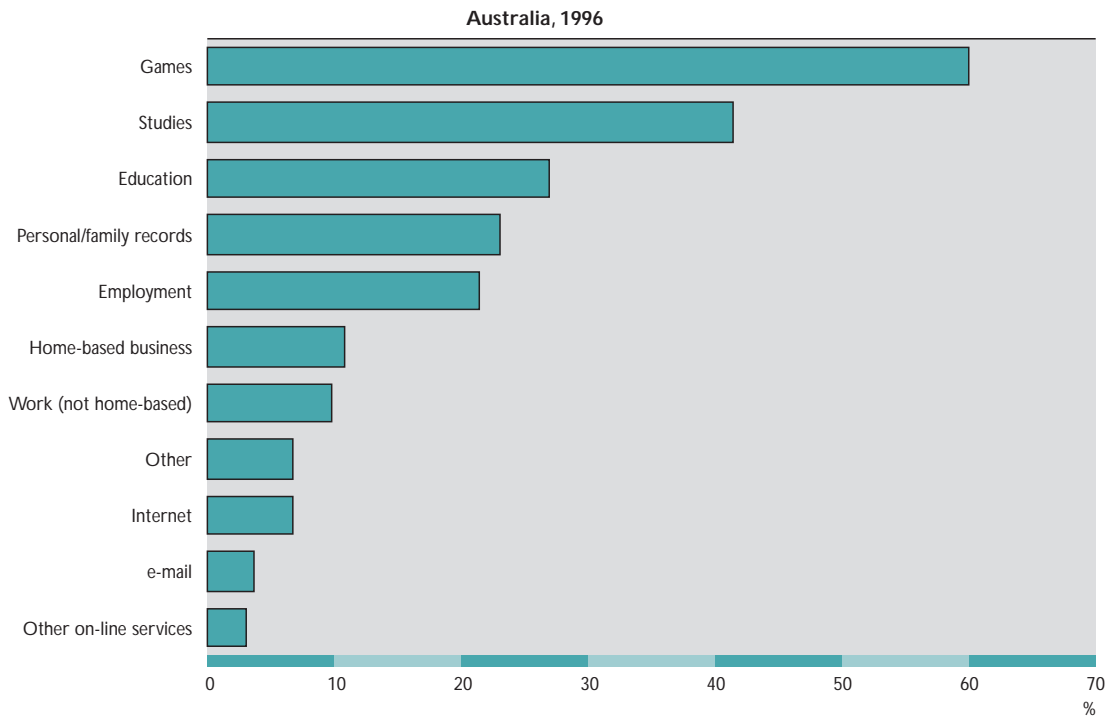
A major purpose of PC use in homes is education. This confirms that ICTs offer learning opportunities beyond educational institutions and that availability of computers at home is an important component of lifelong learning (see Part II). This means that the disparities in home ownership of computers discussed above may have considerable consequences for educational achievements.

The existence of a home-based business in a household is a significant motivation to acquire a home computer, as demonstrated in the case of Australia, where 46 per cent of such households had computers, compared to 30 per cent of all households, and 20 per cent of households without a home-based business. Households with a home-based business were three to four times more likely to have a modem. In the United States, a rather small share of users used computers to run a home-based business in 1993, only 5.5 per cent compared to 11.4 per cent in 1989. More than 28 per cent used home computers to work at home and 8.6 per cent to connect to their computer at work.

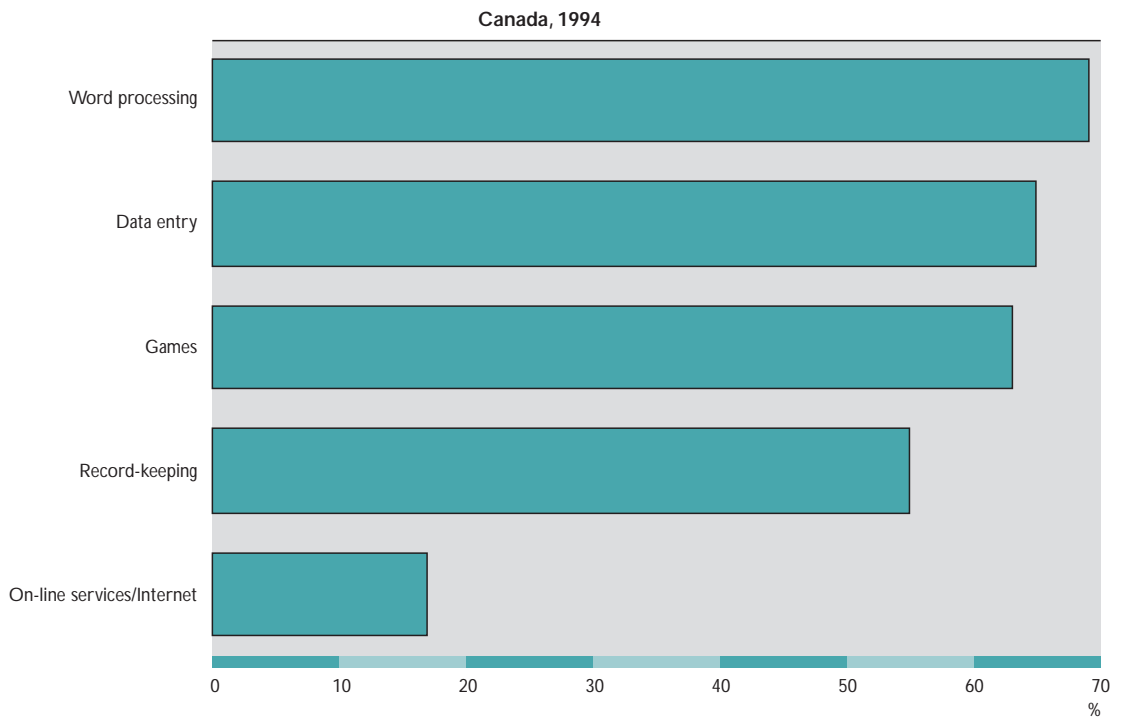
Usage habits of PC/modem users in accessing on-line services has become an important area for policy development.

- In Australia 6.7 per cent of PC users used the Internet, 3.6 per cent used e-mail, and 3 per cent used other on-line services/databases.

◆ Figure 5.9a. *Use of PCs in households*

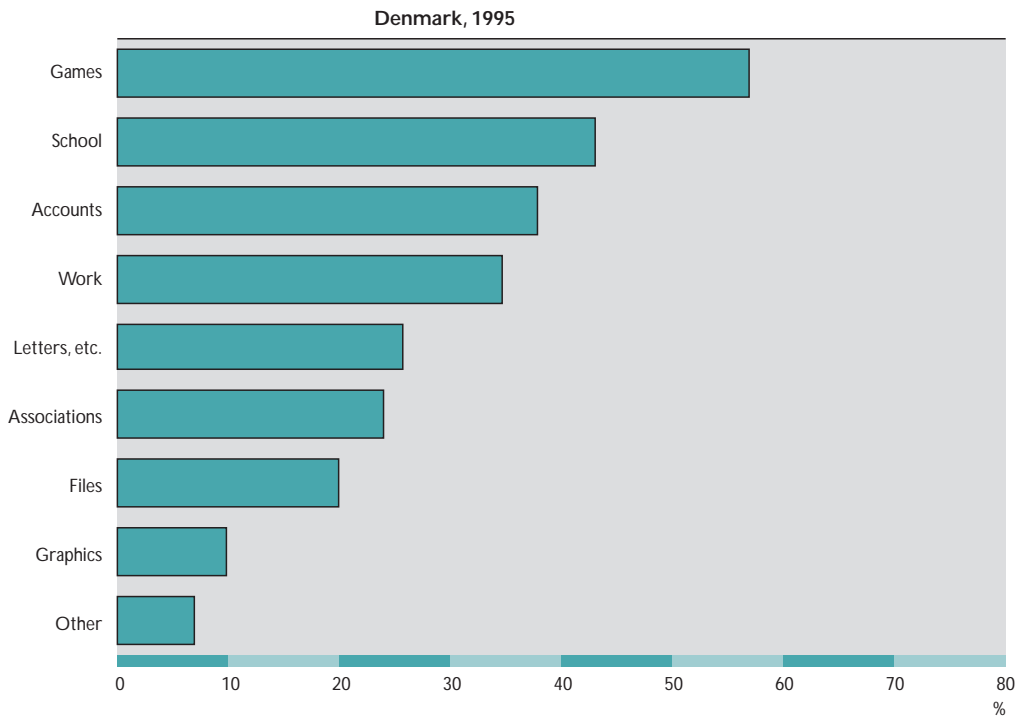


Source: Australian Bureau of Statistics (1996b), *Household Use of IT*.

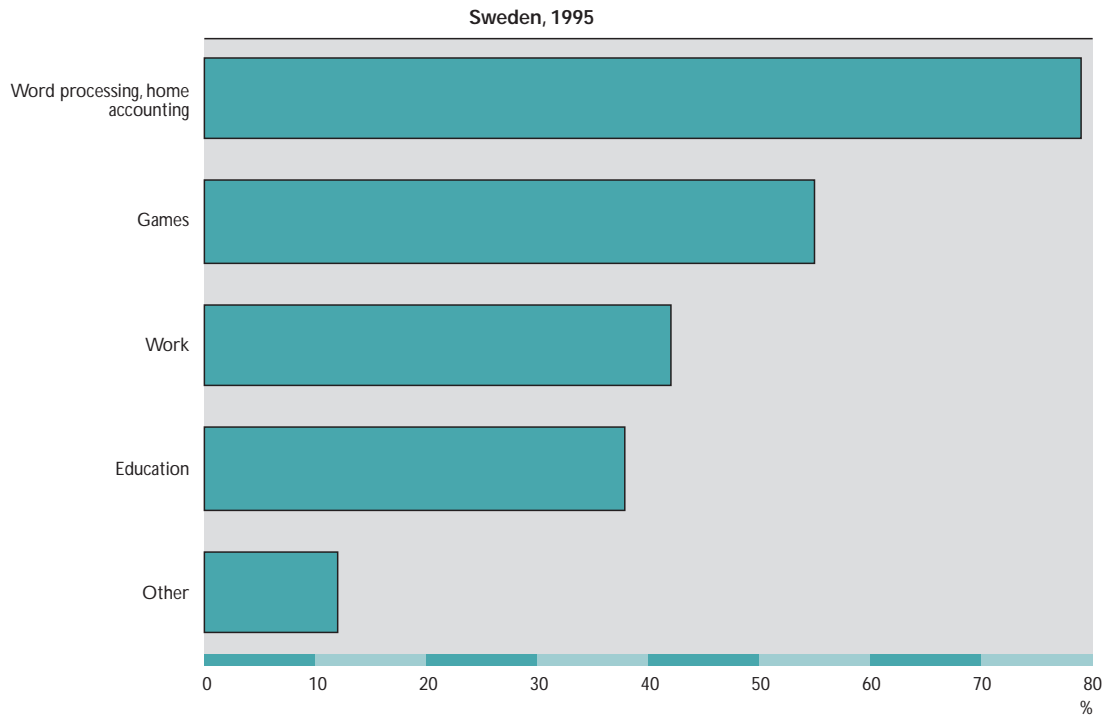


Source: Statistics Canada (1996b), *Access to the Information Highway: Canadian Households*.

◆ Figure 5.9b. *Use of PCs in households*

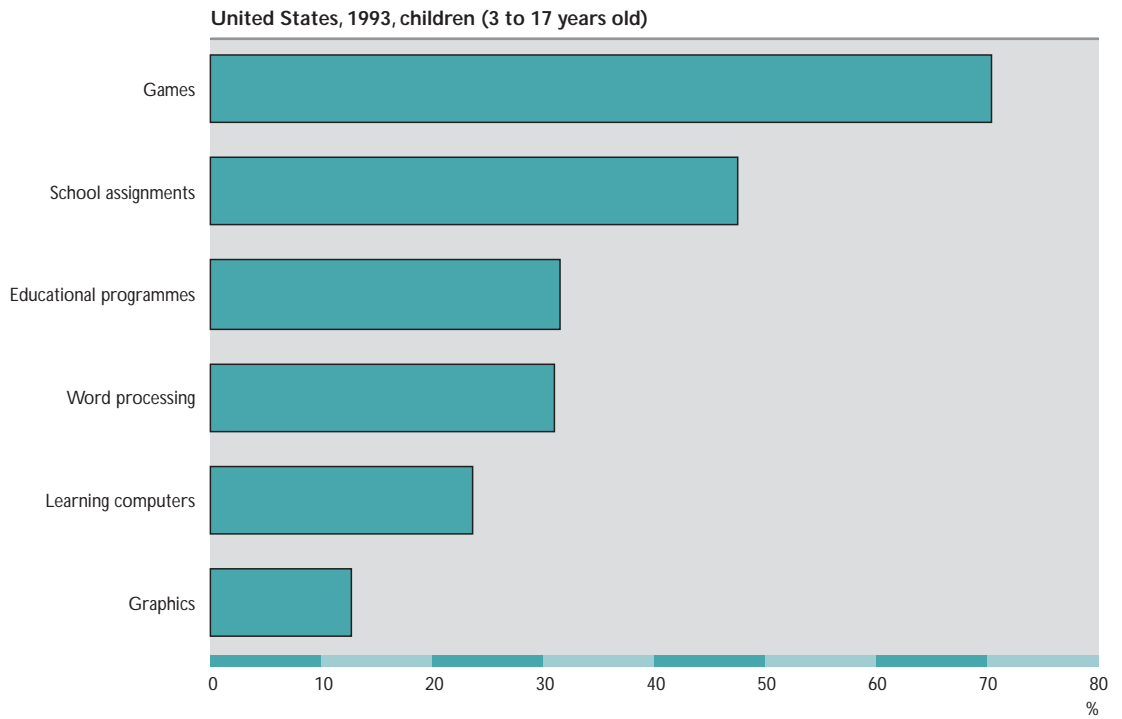


Source: Danish Ministry of Research and Information Technology (1996a), *IT in Figures 1996: 23 Pictures of the Info-Society*.

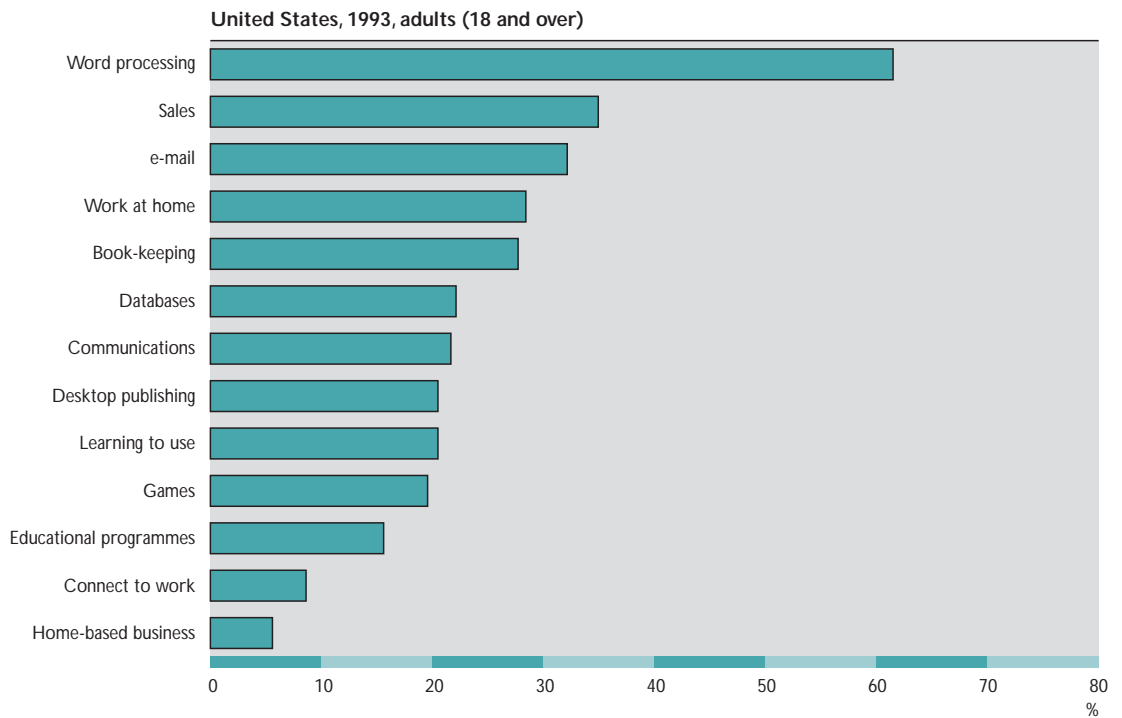


Source: Statistics Sweden (1995), *Computer Habits Survey*.

◆ Figure 5.9c. *Use of PCs in households*



Source: US Bureau of the Census (1993b), *Computer Use in the US*.



Source: US Bureau of the Census (1993b), *Computer Use in the US*.

The age distribution of Internet users was as follows: 11 per cent aged between 5 and 17; 18 per cent between 19 and 25; 38 per cent between 26 and 40; 28 per cent between 44 and 55; and 6 per cent over 55 years.

- While 17 per cent of persons aged 16 and over in Canada and the United States had access to the Internet in August 1995, only 11 per cent had actually used it in the previous three months. Only 44 per cent of these had accessed it from home. The time spent on the Internet averaged 5 hours and 28 minutes per user per week, or 35 minutes per week per person (Statistics Canada, 1996b).
- In Canada, only 17 per cent of people who used a computer in 1994 used it to access on-line services or the Internet. This figure seems low when compared to the 34 per cent of home

computers that have a modem and highlights the importance of looking at actual use in addition to penetration rates.

- In Sweden, almost 9 per cent of those aged 16 to 64 who used computers at home used them for accessing external databases, bulletin boards, or the Internet.
- In the United States, the groups that are the most disadvantaged in terms of computer and modem penetration are the most enthusiastic users of on-line services that facilitate economic betterment and empowerment. Low-income, minority, young, and less educated computer households in rural areas and central cities appear to be likely to engage actively in searching classified ads for employment, taking educational classes, and accessing government reports on-line (NTIA, 1995).

NOTES

1. The penetration rate is an indicator of technology uptake. It must be interpreted with care however, as it is affected not only by the various characteristics of households and individuals to which it relates but also to the evolution of the total number of households.
2. More than 50 per cent of users play games in Australia, Canada, Denmark, Sweden and the United States (children only).

Part II

SPECIAL FOCUS

IT-RELATED POLICIES

INTRODUCTION

As information technologies have become more ubiquitous, policies directed towards information technologies in OECD countries have broadened from “technology push” programmes focused on the development of information technologies to include “demand pull” policies that support the use and application of IT. (See Appendix in Part IV for profiles of many OECD Member countries’ IT policies.) In short, it is evident that more comprehensive IT policy strategies are being adopted, often as part of an overarching information infrastructure initiative. In many cases, this has meant expanding policies to address some of the impacts these technologies have on work, culture and communities. Possibly the clearest example of this shift is the development of programmes to use IT to improve the delivery of government services.

National programmes for developing information infrastructures are concerned with public services and administration as well as private sector applications.

According to a national poll commissioned by the Public Information Exchange in the United States, demand for public information appears to outweigh demand for commercial information. Less than 10 per cent of those polled were interested in electronic shopping or video games, while more than 40 per cent were interested in health care. The level of interest in news, consumer, and education information was similar. Education courses accounted for more than 35 per cent of demand (MacLennan Ward Research, 1994).

Governments need not only respond to this demand, they also need to use electronic information systems to satisfy their internal needs for information. Given their size and breadth, how they respond will play a key role in defining the shape of the electronic services market. While considerable attention has been paid to IT policies for technical standards, intellectual property laws, or funding for new technological advances, government’s role as user of the information infrastructure will also have a large impact.

Box 6.1. The Information Technology Agreement

At the meeting of the World Trade Organisation in December of 1996 in Singapore, an agreement to eliminate tariffs on Information Technology products was forged that would phase out tariffs on a wide range of information technology products including software, computers, semiconductors and telecommunications equipment. Tariffs would be reduced to zero in a series of four steps: July 1997, January 1998, January 1999 and January 2000. (See <http://www.wto96.org/media/13ipirita.html> for a copy of the agreement.) It is estimated that the existing average tariff level on IT products across the US, EU, Japan and Canada is roughly three per cent and that the elimination of these tariffs would save \$172 million a year for companies operating in the US and the EU alone.* It was decided that in order to avoid the “free rider” problem, a “critical mass” of participants that represent 90 per cent of the world trade in these products must be party to the agreement by April 1997. Several participants expressed confidence that this threshold had already been achieved.

Although the exact impact of this agreement on the IT industry and IT users is unclear, it seems likely that the elimination of tariffs on IT products will increase the sales and diffusion of IT products in high-tariff countries. It is also likely to lead to some readjustment of the industry as IT-producers move out of high-tariff, high-cost where they had located to avoid the tariffs.

* Friedman, Alan, “Trade Ministers Agree on Global High-Tech Accord”, *International Herald Tribune*, 13 December 1996, p.1.

The general broadening of IT policies is accompanied by a trend in government to forge co-operative relationships with industry, whereby governments, rather than trying to direct the course of the IT industry, play a moderating role, working with industry and important users to set standards, engage in R&D, and undertake diffusion exercises.

Beyond strictly IT-related policies, it is becoming clear that the broader regulatory environment significantly affects the development of IT. Policies involving restraints on trade, the regulation of key sectors that provide and use IT, such as telecommunications, finance and retail trade, as well as labour policies that hinder the reorganisation of businesses and the reallocation of resources have important effects on the

sale, use and impact of IT goods and services. In many countries, these regulatory frameworks are being examined with an eye towards liberalisation. The recent trade agreement on eliminating tariffs on information technology products is a clear example of this trend (see Box 6.1).

This section of the Outlook first provides an overview of public sector use of IT. It summarises incentives and potential benefits of electronic information services (EIS), EIS applications in OECD countries, current barriers, and common elements of successful implementations. It then surveys Member country policies for using information technologies to further lifelong learning.

GOVERNMENT USE OF ELECTRONIC INFORMATION SYSTEMS

Electronic information services (EIS) include the electronic delivery of “services” that make it less costly and easier for the internal administration of governments and for the public to: find out what government services are available and identify their location; obtain information and documentation on regulatory and legislative developments and on government programmes and projects; expedite the processing of requests for information; and file government documents, such as tax returns or customs declarations.

Incentives for governments to adopt EIS fall into three categories: enhancement of governmental services, cost savings, and demonstration effect as a major user of IT.

Enhancement of services. Delivering services is recognised as a core business of government in most OECD countries, and it is increasingly acknowledged that electronic means can improve service delivery. Governments are examining various applications, such as telemedicine, distance education, on-line and off-line government information, electronic data interchange (EDI) and electronic delivery of government benefits. As governments make greater use of EIS, greater public participation in the governmental process may be possible, as in the UK “open government”, the Canadian “blueprint”, or the US “reinventing government” concepts.¹ IT can help governments respond more quickly to citizens and businesses, facilitate interaction, and thus increase citizens’ participation in community and/or political issues. IT can help to increase accountability, productivity and reduce fraud, and help reduce the cost of programmes.

Demonstration effect. Government adoption and use of EIS is an important way to support the development of information infrastructures, stimulate demand, and provide incentives to invest in broadband infrastructures (Mansell and Tang, 1994). By becoming leading users of IT applications, governments can set an example and show the benefits of

these technologies and applications to society as a whole.

Cost savings. The principal argument for government adoption and use of EIS is the perceived cost effectiveness of these services. Recent studies of the impact of computers on the productivity of US federal government agencies conclude that the agencies where computer assets per employee grew 10 per cent faster than average experienced 2.5 per cent faster growth in labour productivity and 6 per cent slower growth in unit labour costs (Lehr and Lichtenberg, 1996).

While it is generally accepted that electronic delivery saves resources and improves services to the public, such benefits are not guaranteed. In some cases, “IT has an overall reputation for being over budget, behind schedule and disappointing in terms of achieving objectives” (OECD, forthcoming). A review of available cost data and feasibility studies indicates that:

- Many small-scale decentralised electronic delivery systems, such as automated telephone response systems, electronic filing, computer bulletin boards, and compact disks, can be cost-effective.
- Large-scale delivery systems, such as electronic transfer of benefits and electronic kiosks, require considerably higher levels of inter-programme, interagency or interdepartmental co-operation and co-ordination to be cost-effective.
- While quantifying savings is difficult, it is widely believed that electronic delivery potentially offers considerable savings to service recipients and providers, especially when the value of their time is included, as the use of computer bulletin boards and electronic kiosk trials have demonstrated. It is important, however, to specify clear, measurable objectives, so that projects concentrate on the end results, rather than the technical means used to achieve them.

- Easier access to EIS may increase demand for services, and this, in turn, may increase the cost of delivering further services. However, most analysts argue strongly that, in the long term, government dissemination of information through electronic means should result in savings rather than costs.
- The largest potential financial benefits of electronic delivery are probably the indirect ones resulting from: first, a restructuring and streamlining of government programmes and agencies or departments; and second, the creative use of electronic delivery to improve the general public welfare, including social, economic, health and educational conditions (US Congress, OTA, various years).

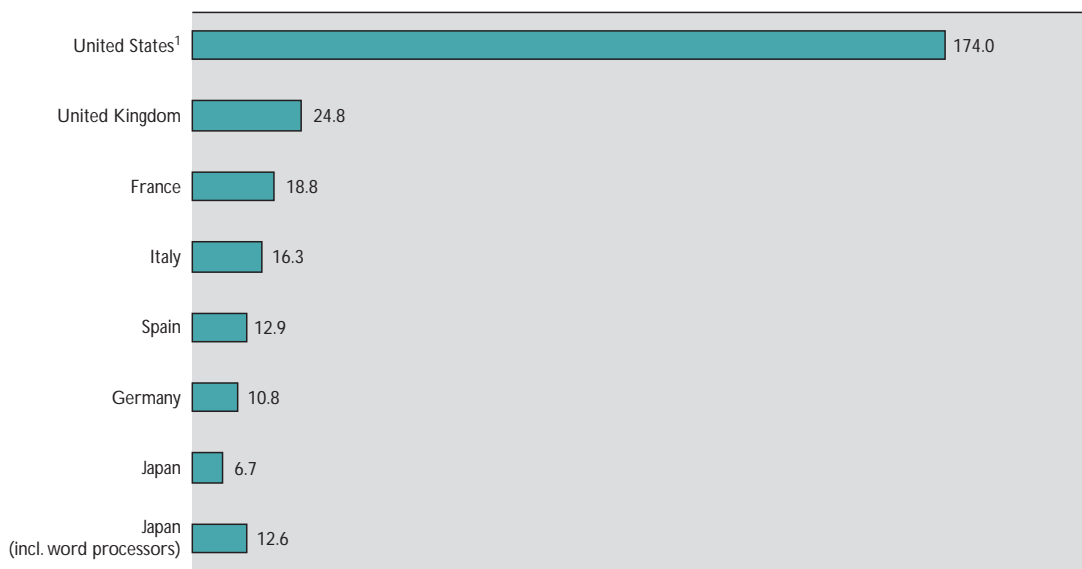
1. EIS APPLICATIONS IN OECD COUNTRIES

While benefits of EIS are difficult to measure accurately, belief in the beneficial effects of government adoption of EIS has led to a surge in the use of electronic information services throughout government (Figure 7.1). Some of the larger activities are described below.

General information about government activities. Nothing is more important to a democracy than ready access to information and to government operations. Thus, it is not surprising that governments have used electronic information services extensively to make their activities more accessible. Information on voting records of elected officials, announcements of public hearings, budgets of various departments, and directories of public agencies and employees are available in a number of OECD countries. Increasingly, public documents such as major “white papers,” draft legislation, and statistical information are available on-line (see Box 7.1).

Electronic benefits transfer (EBT) is a way to improve the integrated delivery of payments for several social service benefits and to simplify the process of issuing and redeeming benefits. EBT uses automated financial transaction processing and card access technologies to deliver benefits electronically to recipients. Recipients use bank-operated automated teller machines (ATM) and point-of-sale (POS) terminals at retail locations to obtain their benefits. EBT substantially reduces costs to government agencies, recipients, and intermediaries such as participating retailers and financial institutions (see Box 7.2) and is likely to decrease fraud.

◆ Figure 7.1. **Number of PCs and terminals per 100 public administration employees, 1993**



1. The US figure is 1992. Of 174 units, terminals account for 101 and PCs for 73. It excludes NSF and DOE due to their unique positions concerning the Internet and government laboratories. The figure would be 204 if these were included.

Source: Lehr and Lichtenberg (US); EITO, 1994 (Europe); Office of General Affairs, National Personnel Authority (Japan).

Box 7.1 Access to government information in Denmark, Portugal and the United States

The Danish State Information Service has established an electronic key or information guide to schemes and functions of all public institutions, with instructions on how to locate and access them. Electronic bulletin boards to provide the public with information on central government press releases, newsletters, legislation, and publications are to be established. Similarly, the National Business Register, with public data on all companies, was scheduled to begin to be electronically delivered at the beginning of 1996.

Portugal has recently introduced a new system, Interdepartmental System for Information for the Citizen (INFOCID), with the aim of providing citizens with a single source of information on their rights and duties, a complete listing of all government services and their location, and a description of the procedure citizens must follow to obtain these services. Access to the system is provided through a network of 60 ergonomically designed, touch-screen-activated multimedia kiosks: the number will reach 400 in 1997-98. An Internet version of the system was launched in 1995 (OECD, forthcoming).

Use of bulletin boards and on-line databases for US government information has grown sharply over the last decade. More than 40 federal organisations operate bulletin boards, which can be accessed through a modem or the Internet, as part of their information dissemination activities. Fedworld BBS is operated by the National Technical Information Service and provides easy access to a vast range of government information sites, including digital libraries, more than 130 federal bulletin boards, and documents such as Presidential speeches, reports, and legislative proposals. More than 50 organisations of the federal government were listed as database producers in a 1992 directory of on-line databases (OTA, 1993b). There are 176 publicly available federal databases.

The use of electronic commerce by governments can be used to reduce the transaction costs and inefficiencies associated with government's economic activity as large consumer, intermediary and seller. In its simplest form, a purchase order is transmitted electronically to the vendor who in turn transmits an invoice electronically; payment is made through electronic transfer of funds. More sophisticated applications include the electronic dissemination of invitations to tender, distribution of catalogues, despatch of orders and confirmation, delivery, invoicing, accounting, and the registration of payments. Ultimately, public procurement systems will probably adopt the continuous acquisition and life-cycle support (CALs) system, which was initially

developed for defence procurement. At present, CALS involves the electronic delivery of technical documents, requirements, specifications, etc., but it is expected to be used increasingly for concurrent design and engineering (see Box 7.3).

Transportation. Many OECD countries expect increases in urban motorway travel of approximately 50 per cent by the year 2005, while the road supply is expected to increase by only 6 per cent. As a result, delays can be expected to rise by 400 per cent. Governments are deploying information systems to ease congestion and make travelling safer and more convenient. To date, information systems have mainly been used for relatively simple tasks, such as alerting motorists to upcoming hazards, providing naviga-

Box 7.2. Canadian use of EBT

The Canadian government spent C\$ 49.1 million in 1992 in transfer payments to individuals, including income support payments to some 3 million elderly Canadians, child benefits to some 3.7 million families with children under 18 years, and unemployment insurance benefits to an average 1.4 million people a month (Ministry of Industry, 1994). Projects such as the Income Security Programs Redesign will be used to test the electronic delivery of social security payments and services, such as Canada Pension Plan, Old Age Security and Guaranteed Income Supplement, family allowances, the refundable child tax credit and unemployment insurance. Federal-provincial co-operative projects are also being worked out to provide convenient delivery of services such as training, employment and counselling; this should help reduce duplication of effort and save millions of dollars.

Box 7.3. **The United Kingdom's electronic procurement project: PURSUIT**

The PURSUIT (PURchasing and Supply: Unified Information Technology) project is a major government initiative, supported and funded by most large spending departments (HMSO, 1992). Its goal is to design a procurement system which the government hopes will be accepted as a national standard, based on best purchasing and supply practice. If successful, PURSUIT will not only improve the management of government procurement practices, but will also be beneficial to UK industry. It involves the design of a core specification for purchasing information and control systems across government and specifically aims to reduce cost and procedural duplications through an integrated IT system (D'Adderio *et al.*, 1995). Its modular design will enable user departments to adopt parts of it to complement their present systems and procedures.

tional information or automatic toll collection. As the technology progresses, new applications are being tested, including dynamic route guidance, dedicated lanes equipped for automated travel, and collision avoidance systems using radar in order to double or triple capacity and drastically reduce accidents (see Box 7.4).

Health. A recent Danish analysis found that about 30 per cent of total work time in hospitals is devoted to registration and administration, while direct patient treatment and care accounts for only 16 per cent. The remaining 54 per cent is spent on planning, management, transport, stand-by arrangements, etc. (Danish Ministry of Research and IT, 1995). Similar statistics exist for the United States, and it is thought that potential savings from EIS could range from 0.5 to 3.6 per cent of administrative expenses for health care or from \$5 billion to \$36 billion annually (OTA, 1995a, p. 11). The main uses of information systems for health care are to store

patient records, to automate financial records and billing procedures, and to provide medical services to remote areas through telemedicine. In addition, governments are using EIS to improve health services by providing access to diagnostic information and easing the reporting burden associated with review of drug, biological and medical device applications (see Box 7.5).

Science. In many countries, advanced electronic information systems were first deployed in the field of scientific research, which is often largely performed by publicly funded universities, laboratories and quasi-government research institutes. Governments have used networked systems to open up access to high-performance computational resources, link researchers, allow access to digital libraries and scientific databases, improve scientific education and facilitate collaboration at domestic and international level. As the technology evolves, governments are placing some research facilities "on-line", thereby

Box 7.4. **Japanese traffic systems**

The AMTICS (Advanced Mobile Traffic Information and Communication System), is an integrated traffic information and navigation system run jointly by the Ministry of Construction and the Ministry of Posts and Telecommunications. It transmits traffic congestion information from a traffic control centre to an in-vehicle navigation system by using the down-link part of a new radio data communication system called Teleterminal (a two-way digital cellular radio communication system). The static information system uses an in-vehicle compact disc system (CD-ROM) and CRT display terminals to display road maps, local traffic regulations, location of parking lots, hospitals and petrol stations, as well as tourist information. The dynamic information is transmitted by the Teleterminal system to provide real-time information on traffic conditions, weather and accident warnings, as well as parking space availability. The in-vehicle equipment detects the position of the vehicle itself by distance and directional sensors and displays the vehicle's position on the road map shown on the screen. This vehicle location system uses a map-matching method and a correlation function between the trajectory and the road map. The project was launched in April 1987 and a pilot experiment was undertaken in Tokyo in 1988. A wider demonstration of AMTICS was carried out in Osaka in 1990 (OECD, 1992c). FM radio teletext broadcasts began in 1996.

Box 7.5. Using smart cards for health information in France

France uses smart cards in many economic sectors, including health care. Experiments with health cards include insurance cards, medical cards, emergency cards and health professional cards. In 1989, the *Caisse nationale d'assurance maladie des travailleurs salariés*, the national health insurance administration which administers the primary health insurance for 80 per cent of the population, began experimenting with the Vitale/SESAM card to replace paper insurance claims forms. The experiment currently involves about 14 000 residents of Boulogne-sur-Mer who are insured by the social security system. Encoded on the smart card is the card-holder's name, social security number, birth date, and information about the extent of coverage and payment under the beneficiary's insurance. To protect the security of information contained on the card, it also contains a confidential code that the card-holder must enter into the reader at each medical visit. The second stage of this experiment will expand the cards to additional cities. It is hoped to cover the entire nation by the year 2000.

allowing remote access not only to state-of-the-art computer facilities, but also to unique scientific instrumentation such as electron microscopes and synchrotrons as well (see Box 7.6).

Education. Governments have used electronic information systems in the field of education to provide distance learning, disseminate lesson plans and curriculum materials, and use IT in the classroom as a new teaching tool. To this end, they have launched initiatives to digitise libraries, acquire equipment, train teachers, and develop electronic educational materials (see the next chapter).

The areas mentioned above are among the first to use EIC. However, as IT becomes more widespread, as citizens' expectations increase, and as governments become more accustomed to electronic information systems, further applications will be developed. Experiments are now under way to use EIS for voting, paying taxes, and conducting surgery.

2. EIS ACCESS CHANNELS

Government initiatives to set up EIS may take various forms, including on-line and off-line

databases, the Internet, computer bulletin boards, CD-ROMs, teletext, audiotex and videotex services, electronic mail (e-mail) and fax-based services. Although the computer, rather than the television, appears at present to be the preferred medium for electronic delivery of public information and services, the variety of potential points of access suggests the need to ensure that opportunities for developing alternative networks remain sufficiently available. A wider choice of delivery mechanisms will better guarantee universal access to the government services offered through EIS. Access to electronic delivery can be divided into several categories.

The home. The home is clearly the most important point of access. However, home computer and modem penetration is very uneven in OECD countries, so that home access will require a broad array of applications, including not only the computer but also more prevalent technologies, such as audiotex (telephone and television) or interactive television services (see Part I, Household Usage). Alternatively, governments can take steps to ensure access to computer-based services in local libraries, schools, town halls, or community centres.

Box 7.6. The US supercomputer centres

In 1985, the National Science Foundation created four supercomputing centres whose primary mission was to "provide a stable source of computing cycles for a large community of scientists and engineers. A second objective was to educate and train students and researchers from academia and industry to use and test the limits of supercomputing in solving complex research problems". In addition to being a research facility for computer scientists, the centres are widely used by nearly all branches of science: quantum physics (phase transitions), materials science (nanomaterial predictions), biology and medicine (crystallography), engineering (ultrahigh-strength steel), Earth sciences and the environment (climate simulations), astronomy (black hole collision dynamics). Based on CPU hours, use of the centres increased at an average of 72 per cent annually between 1986 and 1994 (NRC, 1995).

Schools, colleges, universities and libraries.

Access to services delivered directly to educational institutions and libraries can satisfy the “computerless” home consumer and serve as “tutorials” or “practice runs” to familiarise students and the public with the use of EIS. The success of such services lies in their user friendliness, the existence of good directories, and availability of sufficient hardware.

Businesses and hospitals.

More businesses than homes have computers, and many services can be delivered directly to the office. Electronic data interchange (EDI) is particularly useful for business transactions such as billing, customs clearance, procurements, and regulatory filings. International EDI standards, such as the UN EDIFACT, have been adopted by many governments, but OECD governments need to make greater use of EDI services (CCTA, 1994). Special steps can be taken to give small and medium-sized businesses access to electronic services through existing small business assistance programmes and extension centres.

Stores and banks.

Electronic benefits transfer can be used to deliver public assistance or other benefits (social security, pension, and unemployment payments) to the public via automated teller machines and point-of-sale terminals in stores. An OTA report claims that “electronic benefits transfer helps to reduce theft and fraud in benefit programmes, as well as reduce paperwork, delays, errors and the stigma sometimes attached to paper cheques, stamps and coupons issued by government for social security payments”(OTA, 1993b).

Neighbourhood electronic kiosks.

An electronic kiosk is an “information dispatcher”, through a computer that combines text, sound, video, and graphics to provide services in a central location. Kiosks can be used for transactions, such as paying utilities accounts. In the United Kingdom, the local authorities in Manchester, for example, are experimenting with “employment opportunities” kiosks in an effort to expedite job searches in the area.

Community one-stop service centres.

Government departments and agencies can co-ordinate efforts to deliver services to the public in a “one-stop” location. This produces economies of scale and more effective delivery of services. If a single location proves unworkable, departments and agencies can resort to desktop video-conferencing, for instance, to establish a “virtual” one-stop centre, but this requires a high degree of co-operation and co-ordination.

Mobile or remote access. The government can deliver services to those living in remote areas, where a community one-stop service centre might be too costly, through cellular telephones, satellite receivers or laptop computers. Although the range and quality of the services offered might be limited, access to services would still be faster. Such centres could also serve as grass-roots educational facilities.

3. BARRIERS TO EIS

A coherent strategy for implementing electronic delivery of government services is a *sine qua non* condition of success. Several key barriers to successful and equitable electronic delivery of government services and information to the public have been identified.

- Because of the complexity and scope of EIS applications, there is a possibility that overlapping or competing initiatives might work against improvements in service delivery, productivity and public services. Integration is likely to be necessary to achieve economies of scale (OTA, 1993b), and significant amounts of time and effort will have to be invested in harmonisation and standardisation.
- Information overload is also a problem. It is one thing to make public services available electronically, but it is another to find the appropriate service on the bulletin boards. User friendly navigation systems are therefore important.
- Costs of electronic service delivery can be high. They include initial costs for hardware, wiring, equipment, initial training, and retrofitting, as well as the desired software. Ongoing annual costs consist of, among others, network support and depreciation and replacement costs for hardware, software and equipment. Also, fixed and usage charges for telephony and/or data lines to the Internet can be considerable. It is not certain that electronic service delivery is cost-effective, that is, that it provides the same level of service at less cost or more service at the same cost. US findings indicate that, to be cost-effective, large-scale technology applications require quite high levels of co-operation and co-ordination (Rothstein, 1995).
- Legal issues such as privacy protection, security of network systems, intellectual property protection, etc., are potential barriers. For

instance, computerising student records raises questions of legality. In France, implementation of smart card services in the health-care sector has been hindered by concerns about the confidentiality of card systems and by difficulties in persuading physicians, administrators, and patients to keep information and medical records on cards or in computerised form (OTA, 1995a).

- If EIS is to succeed, the rate of penetration of computers (or other access technologies) must accelerate in most OECD countries. Dependence on computer networks for electronic delivery must be reduced, and alternative approaches, such as telephone and mass media (television) services, should be investigated. In this context as elsewhere, it is necessary to reduce the wide (and increasing) disparity between the “haves” and the “have-nots” and to implement programmes to train the computer-illiterate.

4. REQUIREMENTS FOR SUCCESSFUL IMPLEMENTATIONS

Experience has shown that the benefits of information technology are not automatic and that organisation and management are more important than the technology itself. An overall strategy or vision is needed in order to define objectives, issues to be addressed, and priorities and to decide how to reduce costs and/or improve services. Sectors involved must realise that providing public services through EIS requires identifying and promoting the information agenda throughout government and that fragmented, short-term planning is detrimental to, or might thwart, the development of a well-formulated policy (Bellamy and Taylor, 1994).

Successful implementation of EIS is likely to entail significant reorganisation of the participating agencies. The benefits of automation can largely be nullified if the technology is simply overlaid on old ways of doing business, so that the costs of the latter are still incurred (OECD, 1992c). Recent work using very detailed data on US federal agencies suggests that widespread adoption of information technologies is beginning to have a significant impact on productivity and unit labour costs (Lehr and Lichtenberg, 1996).

If EIS is to be implemented successfully, efforts must be made, some of which have been suggested

by recent surveys of electronic service delivery in OECD countries.²

- Existing information management systems must be restructured and redesigned to take advantage of appropriate and relevant advanced communication technologies. Outdated technology applications may need to be replaced. To cope with institutional change, opportunities for departmental and interdepartmental adjustments and training and for interdepartmental co-operation and co-ordination should be offered.
- A concerted “public relations” campaign should precede the introduction of EIS. It should include: instruction and training for public education; outreach activities to gain user involvement in developing customer-oriented systems; developing “electronic road maps” to help the public locate relevant services; and information on costs (to allay fears of increased charges for such services).
- If electronic delivery of government services is to be effective on a large scale, public access must be facilitated (direct dial-up from the home, school, office and libraries, electronic kiosks, community one-stop centres, etc.) The public needs to know that such services exist and how to obtain them, and must be able to afford them. Governments may have to consider offering financial support for the installation of computers in community centres, schools and libraries. Moreover, EDI costs can be a barrier for small businesses, and government and industry will have to provide extensive training.
- The concept of “universal service” may need to remain flexible so as to encompass, if necessary, various modes of electronic delivery of public services and information.
- Interoperability of network systems is important, in order to ensure end-to-end connectivity between government departments or agencies and public users. As proprietary systems can hinder interoperability, open systems using commercially available standardised equipment and software should be adopted as a common delivery platform.
- Innovation and partnerships within government need to be encouraged. Joint public-private sector projects should be sponsored, and leadership should be promoted at all

levels. Experimentation should be fostered, since, in the long term, diversity may be less costly than selecting or focusing on a “winning” technology at the outset.

Governments in OECD countries generally argue that the production, dissemination and use of information will benefit their economies, make them more efficient and competitive, and improve the quality of life for citizens. As they attempt to harness IT for better management, dissemination of information, and electronic delivery of public services, OECD countries that are less familiar with a culture favouring the wide distribution of public information may need to consider reconciling their less open practices of information sharing and dissemination with the realities of an environment in which EIS are becoming more widespread. In general, it is clear that governments can learn from one another as they experiment with this new method of delivering services. The G7 Ministerial conference on the Information Society held in 1995 identified a number of areas where international co-operation could be fruitful (see Box 7.7).

The transition to electronic delivery of services suggests the need to rethink government use of IT. Governments need to have a clear vision of their goals in this respect. They need not be overwhelmed

by the notion of the “information superhighway”, as existing communication infrastructures can adequately deliver many government services. Existing communication infrastructures are under-utilised, and mass media, such as broadcast or cable television, may be viable alternative modes of electronic delivery.

Delivering services electronically requires an unprecedented degree of co-ordination and co-operation between government departments and agencies. Equally important, governments need to be “catalytic, community-owned, competitive, mission-driven, enterprising and decentralised”, and keep abreast of the capabilities of IT (Bellamy and Taylor, 1994). Successful and equitable implementation of electronic delivery of government services relies primarily on “user demand”. This will result from a combination of factors: knowing what services are available and how to access them, how user friendly and affordable they are. Finally, given the fiscal constraints faced by all OECD governments, industry participation and collaboration should be actively sought for developing applications and providing public information and services.

It is clear that governments are recognising the potential benefits of using IT for improved delivery of

Box 7.7. **The G7 Information Society Initiative**

In an effort to build international consensus on issues such as access to networks and applications and interoperability while establishing productive co-operation, a series of pilot projects were selected on the basis of the capacity of the activity to provide a forum for exchanging lessons learned, to serve as a vehicle for making the concept of an information society clearer to citizens, and to help integrate key stakeholders: business, academia and government. On this basis, 11 projects were selected:

1. Global inventory
2. Global interoperability for broadband networks
3. Cross-cultural education and training
4. Electronic libraries
5. Electronic museums and galleries
6. Environment and natural resources management
7. Global emergency management
8. Global healthcare applications
9. Government on-line
10. Global marketplace for SMEs
11. Maritime information systems

Source: Prerost, Sandra (1996), “Overview of Government Initiatives – National and Multinational”, presented at Workshop No. 5: Government Responses to the Emerging Information Society, 22-23 October, Seoul, Korea.

public information and services. What is not clear, despite ambitious government blueprints and plans, is the degree to which governments have the “political stamina” to provide adequate financial resources

to realise them. If the results of public opinion surveys are any indication of what the majority of the public wants, then governments need to maintain the momentum and allocate the necessary resources.

NOTES

1. For the United Kingdom, see Bellamy and Taylor (1994). For Canada, see Ministry of Treasury (1994). For the United States, see Gore (1993) and Clinton and Gore (1993). See also Osborne and Gaebler (1993).
2. Among these reports are OTA (1993b), Mansell and Tang (1994), Ministry of Industry, Canada (1994), and Ministry of Research, Denmark (1995).

ICT AS A TOOL FOR LIFELONG LEARNING

1. INTRODUCTION

Today, knowledge and skills are at the forefront of policy debate in many OECD countries, and experts both inside and outside the OECD have emphasised that success – for individuals, firms, and nations – requires the capacity to adapt to changing conditions by renewing, reconfiguring and redeploying assets. For the individual, this implies being able to learn continuously – in educational institutions, the workplace, and the home – from early childhood through retirement.

This chapter examines information and communication technologies (ICTs) as a tool for lifelong education and training. It focuses on the technologies involved and on policies to foster their use from the earliest years of education through upper-secondary education, for teacher education and training, and more generally for adult education.

Section 2 describes the economic and social context that has led to changes in the qualifications required for employment and the ensuing need for lifelong learning. Section 3 discusses how ICTs can help meet this need. Section 4 presents an overview of relevant Member country policies. Section 5 reviews assessments of the success of these technologies and policies. Finally, Section 6 draws some conclusions.

2. KNOWLEDGE AND SKILLS FOR THE NEW ECONOMIC CONTEXT

The new economic context

OECD economies have become “knowledge-based” economies in which knowledge in all its forms plays a crucial role in economic processes, including growth and job creation (see OECD, 1996*b*). Individuals with more knowledge get better-paid jobs, firms with more knowledge are winners in their markets, and nations endowed with more knowledge are more productive. This is why individuals, firms and nations are increasingly investing in knowledge.

Among the developments that have helped to bring knowledge and skills to the forefront of policy debate are the growing deployment of ICTs, the changing nature of work, ongoing globalisation and trade liberalisation, growing cultural and ethnic diversity, as well as the ageing of the population (see OECD, 1996*c*).

The increasing use of ICTs provides the knowledge-based economy with a new and different technological base, the essence of which is greater memorisation and storage, speed of transmission, and easier manipulation and interpretation of data and information. The impact of ICTs on economic growth and competitiveness is expected to flow from such enabling and empowering effects. However, the move to widespread and intensive use of ICTs raises many “mismatch” problems, as those who adopt them must to some extent “forget” old patterns, learn new habits, and establish new forms of organisation.

A prerequisite for success: the ability to adapt

Firms’ success in this respect is increasingly determined by their capacity to adapt to changing conditions. Their strategies for achieving the requisite flexibility and adaptability for producing and distributing goods and services are associated with shifts in the demand for labour and thus in the qualifications required of the workforce. Studies of the skills required of the workforce reveal the increasing importance of a variety of “qualifications”, attributes, and behavioural characteristics. The need for broader scientific literacy and mathematical understanding and greater personal responsibility and initiative, in addition to specific workplace skills and competencies, has been stressed repeatedly. Workers now need to be able to work with resources, acquire and evaluate information, understand complex relationships and systems, and use a range of changing technologies.

In 1995, the European Roundtable of Industrialists stressed the importance of well-rounded individuals with broad rather than deep knowledge, trained

to learn how to learn and motivated always to learn more. Some studies have identified the growing importance of foundation skills (verbal and quantitative), communication and teamwork skills (speaking, listening, and organisation), problem-solving and creativity skills, and motivational and self-development skills, while others have indicated that some employers rank attitudes and communication skills ahead of factors reflecting specific knowledge and job competencies.

Such changes involve both an upward shift in minimum qualifications and a shift towards qualifications that do not necessarily correspond to traditional formal degrees and diplomas. The mismatch between the knowledge and skills provided by educational systems and those in demand in a changing labour market points to the need for changes in the learning process. Success in school, the workplace and everyday life now depends on learning new and more effective ways to access, evaluate and use a variety of information sources.

The need for lifelong learning

Today's children need to be prepared for a life in which they will change jobs or job responsibilities frequently and will be regularly retrained as work environments evolve. This preparation must take place in classrooms which bring together students from diverse backgrounds and cultures. In the past, the young received education over a fixed period in preparation for work and life. In the new knowledge-based economy, however, continuous re-education will be the norm, so that skills remain relevant, individuals employable, and firms able to adapt and compete.

It is also necessary to meet the various and broad-ranging instructional needs of today's adults. An exclusive focus on initial education will only replace workforce skills at a rate of 2-3 per cent a year. In addition to enabling those in the labour force to obtain the training required for a continuously changing work environment, this means providing those who lack foundation skills a chance to catch up. Many adults need higher levels of literacy in order to function effectively in society, find employment, or be retained as jobs change. Educational efforts aimed at such adults can have important intergenerational effects as well by increasing the likelihood that their children will be better educated.

Patterns of firm-sponsored training are already changing, notably in firms which view training as part of more comprehensive changes in business strategy, technology, and organisation. Firms that are moving towards more flexible forms of work organisation, for example, are more likely to plan the development of their human resources. Firms are, in any case, often in the best position to deliver the most relevant training in areas of strategic economic importance. Changes are also taking place in the means of providing training and, more broadly, in the way in which learning occurs, particularly with respect to the use of formal and informal methods and the use of specific employee development strategies.

It is important to note however that participation in job-related continuing education and training is closely linked to previously attained levels of education. Current hiring practices indicate that the minimum qualifications required by firms may be creeping up to completion of upper secondary education or apprenticeship training to ensure that employees have the basic competencies for filling the lowest-level jobs as well as a foundation for more specific training. Since educational disadvantages early in life are likely to persist, access to and quality of education, particularly in early childhood, are extremely important.

Three related issues need to be addressed in order to make lifelong learning a reality for all. The first is to improve basic education, so that all learners, young and old, obtain the academic and vocational qualifications they need for work and further learning. The second is to facilitate the passages between learning and work, especially the transition from school to work. The third is to rethink the roles and responsibilities of all partners, including governments, in implementing and financing lifelong learning for all (OECD, 1996c). It is to the first two of these that ICT can contribute the most.

3. USING ICT FOR LEARNING

ICT provides one means of building tomorrow's learning society. While technology cannot furnish all educational opportunities, it has become an essential learning tool. Information technologies, especially when combined with communication technologies to form information infrastructures, facilitate access to and extend the availability of educational resources. They help to develop the skills required in the workplace and make available new methods of instruction.

Technologies available and in development

IT hardware

Use of personal computers (PCs) in schools has risen considerably in many countries since the early 1980s. Detailed US surveys show that children's access to computers at school rose from 28 per cent in 1984 to over 60 per cent in 1993 (US Bureau of the Census, 1991, 1995). Computers are used for instruction, simple drills, or amusement (Table 8.1). Children also use PCs at home for instructional purposes, as do many adults. In Japan as well, access to and use of computers has increased, as demonstrated in particular by the rising percentage of elementary and lower secondary schools with computers for instructional use (Table 8.2). Although schools are seldom included in systematic surveys of computer use, several OECD countries have estimated the number of PCs per student in schools in the early 1990s (Figure 8.1).

The network computer, which has only recently been brought to market, may be of particular interest to schools. It is cheaper and easier to use than a PC

and may constitute a simple way to exploit the Internet. Another device which may be relevant for learning in the more distant future is the electronic book being developed by researchers at MIT, which looks and feels like an ordinary printed book but uses "digital" ink particles. It will be able to download text from databases on the Internet, and once the text is in memory the reader will be able to display its pages by pressing a button on the book's spine ("Developments to Watch", *Business Week*, 18 March 1996).

Software

Widely available software tools, such as text processors, spreadsheets, electronic mail, and network browsers, which were developed for commercial markets, are also used for educational purposes. More and more educational software, which provides important and structured sources of information and opportunities for practice, has become available in recent years. To realise the full educational potential of computers, however content software that reflects national educational standards is needed.

Table 8.1. **The use of computers for learning in the United States**

	Percentage		
	1984	1989	1993
Children (3 to 17 years old)			
At school ¹	28.0	46.0	60.6
At home	15.3	24.2	31.9
Educational programmes	..	..	31.5
School assignments	..	39.5	47.4
Learning to use computers	..	24.9	23.7
E-mail	..	0.5	0.9
Games	..	84.3	70.3
Word processing	..	24.8	30.9
Adults (18 and over)			
At school ¹	30.8	43.6	53.8
At home	9.1	17.3	25.6
Educational programmes	..	..	15.7
School assignments	..	12.5	11.8
Learning to use computers	..	19.5	20.6
E-mail	..	5.3	32.2
Games	..	44.1	19.6
Word processing	..	61.6	61.5
At work ²	24.6	34.8	43.2
Educational programmes	..	..	4.0
Learning to use computers	..	5.2	4.1
E-mail	..	5.3	9.2
Word processing	..	14.3	19.1
Communication	..	9.0	13.6

1. Percentage of those enrolled.

2. Percentage of those employed.

Source: US Bureau of the Census (1991, 1993b).

Table 8.2. **Schools with computers for instructional use in Japan**

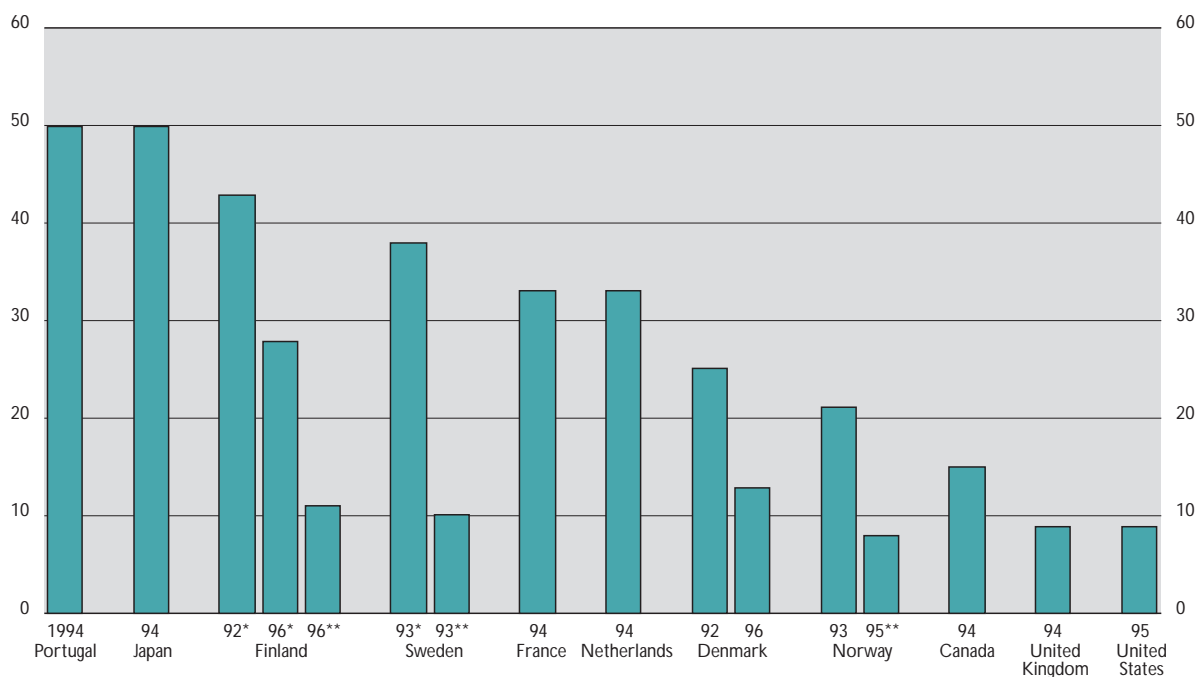
	1983	1986	1989	1992
Percentage of schools with computers				
Kindergarten	0.32	0.64	1.43	2.79
Elementary	0.58	4.32	24.09	51.28
Lower secondary	3.09	17.59	50.48	89.24
Upper secondary	56.38	86.43	87.27	89.20
Average number of computers per school				
Kindergarten	0.00	–	0.01	0.09
Elementary	0.01	0.13	0.75	2.06
Lower secondary	0.04	0.53	2.55	11.82
Upper secondary	2.36	10.87	21.15	32.26

Source: Ministry of Education, Science and Culture.

CD-ROMs can be an important source of information in libraries and in the classroom. The technology is increasingly interactive, is able to represent images, and can be used by young children. Together

with asynchronous transfer mode (ATM) technology and compression techniques, CD-ROM technology has contributed significantly to the development of the multimedia market. In the corporate market,

◆ Figure 8.1. **Computer penetration in schools**
Average number of students per computer



* Primary and lower secondary schools.

** Upper secondary schools.

Source: Canada: Industry Canada (1994a), *Educational Opportunities on Canada's Information Highway*.

Denmark: Danish Ministry of Research and Information Technology (1996b), *The Info-Society for All*.

Finland: National Board of Education (1996), *Education and Informatics*, National Report Finland.

Norway: UNESCO (1996), *National Report on NIT in Education in Norway*.

Portugal: OECD and Ministry of Education of Portugal (1994), *Report of the MINERVA Project Evaluators*.

Sweden: The Swedish Agency for Administrative Development (1995), *The Swedish market for Electronic Information Services*.

France, Netherlands, United Kingdom, Japan: European Commission (1996), *Educational Software and Multimedia*.

United States: US Congress, Office of Technology Assessment (1995b), *Teachers and Technology: Making the Connection*.

training applications are a major use of multimedia. Network access to multimedia material on CD-ROM may also become increasingly common.

Computer-based integrated learning technologies offer extensive instructional activities, cover a range of subjects and grades, and are used to teach core academic skills. Such software is typically housed on a central "server" that is linked to 15-30 network computers. In some cases, specific lessons can be automatically loaded into each student's computer on the basis of an assessment of that student's previous accomplishments and current learning needs. Others require intervention by teacher or student to move to higher levels. All systems provide formative feedback and diagnostic records for both students and teachers (Becker, 1992).

Computer-based training uses software to provide information, simulate situations and processes, and interact with the learner. This may include knowledge testing. The new media learning materials (NMLM) comprise computer software and course content, including multimedia and interactive programmes, applied to electronics-based training products such as computer-based training, intelligent computer-based training, intelligent tutoring systems, and expert systems tools. Most such software is written for microcomputers, either in stand-alone mode or in networked environments. The spread of NMLM follows the increase in desktop computing power, sophisticated presentation software, CD-ROM technology, and broadband networks (HRDC, 1996).

Interactive video (IV) can integrate full or partial screen moving pictures with text or graphics, and the user controls and interacts with this material through a computer. Although IV is not fully digital, it closely

resembles the distance learning and training applications that may become available over information infrastructures (HMSO, 1995b).

Telecommunications networking

Telecommunications technologies, including computer network systems, give geographically dispersed learners and teachers access to knowledge resources scattered throughout the world and allow them to ask questions, discuss ideas, and receive quick feedback (Table 8.3). Telephones and modems offer learners and teachers basic two-way communication. Modems allow computers to communicate electronically across telephone lines by converting digital computer signals into analogue format. Local-area networks (LAN) and wide-area networks (WAN) provide connected computers means of accessing shared digital communications. The Internet is a set of interconnected networks and the protocols that allows computers on these networks to communicate. The protocols also include a large and growing list of services that can be provided or accessed over the Internet. At present, it is mainly a narrowband network used for conveying electronic mail and messages and accessing remote sources of information, but it can also convey graphics, audio and video. The range and quality of the functions available depend on the capacity of the connection, the speed of the modem, and the power of the user's computer.

Television/video can be used for instruction via direct broadcast, cable television and satellite (distance learning). Direct broadcasting systems can bring satellite television into the classroom and offer the possibility of video conferencing between institutions with access to equipment to transmit and

Table 8.3. **Access to selected telecommunication capabilities in public schools in the United States, 1994**

Telecommunication capabilities	Schools with access	Percentage				
		Administrative offices	Teacher workroom	Classrooms	Computer labs	Library/media centre
Any type	75	71	15	40	55	62
Broadcast TV	70	36	31	83	41	84
Cable TV	74	31	24	70	39	85
Closed Circuit TV	25	49	31	94	59	89
2-way video w/ 2-way audio	6	27	14	63	21	61
1-way video w/ 2-way audio or computer link	10	28	14	58	36	67

1. Percentages do not sum to 100 because many schools reported access in more than one location. Location estimates are based on those schools with access to each type of telecom capability.

Source: US Department of Education (1994), National Center for Educational Statistics, Fast Response Survey System, "Survey on Advanced Telecommunications in US Public Schools, K-12", FRSS 51.

receive. Remote sensing satellites can also bring new information into the classroom. Interactive video resources such as camcorders, video-disks and CD-ROM are also used for instructional purposes.

Impacts of ICT on learning

Access to educational resources

ICTs have the potential to remove many of the temporal and spatial constraints on access to information and knowledge for all learners (distance learning), including those with disabilities. In addition, learning materials based on ICT greatly improve the quantity and quality of learning resources.

The new media open up new means of access to public and private information of all types and provide new opportunities for working with information and cultural commodities. Their use for initial publication reduces the time between production and availability. Moreover, data and texts available electronically can be constantly updated and amended and are readily available. They can be transferred to any place at any time within seconds. Teachers and students can thus access a greatly expanded range of educational material on the network or off-line.

ICTs enable educational institutions to offer a more diverse curriculum and to reduce their dependency on local teaching resources. They have the potential to reach populations of learners that have traditionally been underserved. Television via satellite, for example, can offer students in remote locations classes that their schools cannot provide because of small student numbers or the lack of specialised teachers. They open up impressive learning opportunities for the disabled, thanks to computer-based applications such as word processing for those who cannot hold a pencil to write or speech synthesisers for those who cannot communicate orally.

Teachers are also learners, and ICTs can enhance teacher preparation as well as train them for using technology. ICTs can provide post-training support to teachers, as well as give them access to new ideas, master teachers, and other professionals beyond their school setting, in both formal and informal courses and enrichment activities.

ICTs also offer more and more possibilities for reducing the separation between school and the home and between school and work. As computers become more widely available, ICTs can encourage organised learning in increasingly varied settings. This more direct and more flexible education is par-

ticularly valuable for adult education and training. It is very attractive to sectors such as the environment industry, engineering and agriculture, where work is often performed at many sites or in remote areas. On-site training and skills upgrading are much cheaper and more efficient than transporting employees to distant training sites.

Support for the learning process

Computers offer alternatives to established educational methods by creating an environment in which students learn by exploring, thereby benefiting from the fact that they understand and remember better what they have discovered themselves than what they have merely been told. As learners seek answers using information technology, the teacher becomes a resource and a guide, helping students refine their own questions and assisting in the search for answers. While a shift from teacher-centred methods and materials to student-centred ones can be beneficial to all, it would be particularly useful for non-average pupils. Special education students may work on a more equal basis with their classmates when a computer speaks for them, gives them big print, or adjust to their difficulties. When students work individually, their progress can be measured in terms of their own advances rather than with respect to the group as is generally the case today.

Because motivation affects what is retained, and because computer-based activities are motivational, ICTs offer a learning environment that may help reduce drop-out rates and increase overall academic achievement. They may also help raise adults' awareness of lifelong learning and assist them in addressing their individual problems and needs, for example, in making choices of learning routes or planning future careers.

Because computer-based ICT activities are interactive, immediate responses to learners' input as well as corrections can be provided, thereby augmenting the potential for self-teaching, freeing learners to devote more energy to exploring other issues, and releasing teachers from routine testing. The self-directed nature of these technologies also makes them particularly attractive for training professionals.

Electronic classrooms support the social process of learning and help to create an environment in which students and teachers interact and are more creative. The computer becomes a vehicle for sharing work, a meeting place. Working groups formed around the computer prepare for a world in which most

problems are addressed by teams. (Wallis, 1995). These technologies also provide new possibilities for personal development, for example by allowing learners to take time to answer questions of interest to them beyond the classroom setting.

A concern in this respect is the danger of software systems that would replace individual authors and teaching styles with approaches developed by bureaucracies or large teams and which might limit real choice. Inflexible and unimaginative software could crush the spirit of inquiry. The personalisation of education also places great demands on teachers, who need to be able to follow the progress of individual students and to identify their sources of confusion and their receptivity to different pedagogical strategies. This is difficult to do for 20 to 40 students per class or for 100 or more students a day.

Support for skill development

Studies suggest that certain configurations of hardware and software, used with particular populations of children and under the supervision of competent teachers, contribute to meeting specific instructional objectives. Students who use ICTs efficiently develop the kinds of skills and competencies that many reform panels have viewed as essential for all high-school graduates (Table 8.4). Technological tools also help teachers structure, organise and enhance activities that facilitate the development of these skills.

For example, computer-assisted instruction (CAI) for drill and practice to master basic skills such as

arithmetic in elementary schools, word processing to develop writing skills by easing the physical burden of writing and revising, and database management systems, which encourage students to define a problem and break it into its component parts, have proven to be effective supplements to traditional instruction, in addition to contributing to acquisition of the computer skills that are necessary in an increasingly technological world.

Computer simulations, educational games, databases and other software also help train students to break down problems and find strategies for solving them. Computer simulations help students gain a deeper understanding of complex scientific concepts in mathematics and science where experiments are not feasible or are dangerous, by providing them, for example, with microcomputer-based laboratories for visualising phenomena or a frictionless world in which the laws of Newtonian physics are more apparent. They can also be effective in social studies, by motivating students to play, for example, the role of world leaders or of citizens of other countries.

Familiarity with technology is important for individuals who need to work and live in a society that is increasingly based on these technologies. Enterprises need labour capable of using and developing new information services in order to stay competitive. An increasing number of future jobs will be in professional, clerical, sales and administrative careers where computer literacy is essential, and individuals will increasingly need to use these technologies to carry out their daily activities. Schools already constitute an important source of training for household users in countries where attitudes to new technology

Table 8.4. **Impacts of ICTs on education in Sweden, 1995**

Type of impact	Percentage believing impact will be great or fairly great	
	School principals	Pioneers
On students		
Ability to work independently	87	97
Ability to co-operate	45	66
Subject knowledge	78	84
Ability to search for factual information	92	97
Ability to analyse and solve problems	73	81
Preparedness for working life	87	84
Involvement in society	63	60
Influence on teaching	47	75
On teachers		
Choice of materials	72	86
Co-operation with each other	46	63

Source: Statistics Sweden, 1995, *Use of Computers and Databases in Sweden*.

Table 8.5. **Source of computer training in Australian households where computers are frequently used, February 1996**

	Households (thousands)	Percentage of households where computers are frequently used
Computer training from supplier	271	13.8
Computer training from employer	920	46.9
Computer training from a commercial organisation	287	14.6
Computer training from a primary or secondary school	1 427	72.8
Computer training from a TAFE college	465	23.7
Computer training from a university	416	21.2
Computer training from a adult community education course	179	9.1
Other	1 062	54.2
Total number of households where computers are frequently used	1 960	
Total number of households	6 645	

Source: Australian Bureau of Statistics (1996b), *Household Use of Information Technology*.

are positive, like Australia (Table 8.5). Using ICTs for learning results in familiarity with these technologies and encourages use.

4. CURRENT APPROACHES TO EXPANDING THE USE OF ICT FOR LEARNING

Broad government policies and support

Education is a major area of government responsibility. In 1992, about 12 per cent of all public expenditure in OECD countries went to education. Primary and secondary education received an average 7.9 per cent of all public spending, with outlays varying between 5.4 per cent and 9.6 per cent. Overall, OECD countries spent 6.1 per cent of their collective GDP to support their educational institutions, with an average of almost 4 per cent for primary and secondary education and a range of between 2.6 and 5.1 per cent (OECD, 1995). Maximising the educational outcomes of such large expenditures and ensuring that the entire population has the knowledge and skills needed for participation in knowledge-based economies is receiving increased priority.

While ICTs may provide new educational opportunities, they may also, like any new invention that is expensive, scarce and hard to use, create or amplify divisions between haves and have-nots, at least at the outset. Authorities in many Member countries have been trying to deal with the use of information technology in education for more than a decade.* Primary and secondary schools have been a primary focus of

policies that are intended, at least in part, to avoid or remove such divisions and ensure that all have the opportunity to participate in the information society (Issues in Science & Technology, "Wired Classrooms", 1996). They are the foundation on which a lifelong learning culture may be built and where the new technology for learning can be most successfully introduced.

More recently, governments have made the integration of ICT into education a priority and reflected this in their national plans for education. Authorities in several countries have attempted to meet the challenge of making technology a central component of instruction. It is a major goal of Denmark's new Primary and Secondary School Act. In Finland, the National Education Board has made information technology skills a part of the basic general education curriculum; in the first ten years of schooling, as well as in vocational education, students will learn to use computers and the most common software applications and understand the potential of using IT as a learning tool for different subjects.

Norway's *New Information Technology* (NIT) programme, which is part of the National Plan for 1996-99, calls for activities in five areas: using NIT to learn, learning to use NIT, technical issues related to infrastructure, teacher training, and organisational needs owing to the small number of speakers of Norwegian and the consequences on markets, publishers, funding, and competencies (Box 8.1). Most of the funding comes from schools and various levels of

* The following discussion is based on a number of documents emanating from national authorities con-

cerned with such issues. They are listed among the references at the end of the book.

Box 8.1. **Some activities in Norway's NIT plan**

R&D on the pedagogical use of NIT, especially by teacher education institutions and other educational research bodies.

Use of NIT to remedy girls' lack of interest and competence in IT.

Using students' knowledge of NIT as a resource.

NIT for the disabled (e.g. adapted keyboards and switches, special software and teaching methods).

NIT for teaching environmental awareness (e.g. study of satellite pictures).

The Norwegian Internet Bookstore (place Norwegian texts on the Internet; a research project to present five Norwegian authors in multimedia format).

Electronic learning aids (develop material based on Norwegian social and pedagogical traditions; encourage publishers to develop CD-ROMs and to translate or adapt existing ones, generally from English).

Certification of NIT competence using a test developed by the Norwegian Computer Society (DND) for general computer literacy, in co-operation with similar European organisations, covering areas such as word-processing, spreadsheets, graphics, general NIT knowledge, etc.

New curriculum for teacher education to integrate NIT into teacher education.

Access to global networks for all schools.

Use of libraries to help ensure equal access to computer, software and network services.

government, and Parliament budgeted an additional Nkr 33 million in 1996 for these activities. Nkr 5 million have been set aside for special purposes related to IT for primary schools. In addition to contributions from the budgets of state-owned and co-operative bodies such as teacher education institutions, resources have also been attributed to teacher training in view of the introduction of a new curriculum in primary and upper secondary schools.

The Revised National Curriculum, introduced in England and Wales in 1995, requires that, where appropriate, IT is used to enhance teaching and learning and to develop pupils' IT capability. Since 1988, the government's grants programme has supported £187 million of expenditure on IT equipment and teacher training in curriculum use of IT. Total IT expenditures in schools has been four to five times this amount.

The US National Plan for Technology in Education, "Getting America's Students Ready for the 21st Century" was released in June 1996. It follows from the 1994 Goals 2000: Educate America Act which directed the Secretary of the US Department of Education to develop a national long-range plan to improve student achievement through the use of technology in education. Under this plan, all teachers should have the training and support they need to help students learn to use computers and the information superhighway, all teachers and students

should have modern multimedia computers in their classrooms, every classroom should be connected to the information superhighway, and effective software and on-line learning resources will be an integral part of every school's curriculum.

Specific initiatives

This section provides examples of specific initiatives being implemented in Member countries by types of goals and in alphabetical order by country. It is by no means all-inclusive. A wide range of ministries and departments may provide support for technology in education. In the United States, for example, federal support comes from sources as varied as the departments of Agriculture, Commerce, Defense, Energy, Interior, and Labor in addition to Education, as well as from the Federal Communications Commission, the High Performance Computing and Communications Program, the National Aeronautics and Space Administration, and the National Science Foundation.

Furthermore, governments cannot fully integrate technology into education on their own. In ensuring that schools, classrooms and establishments have access to IT or training, alliances and partnerships among school districts, state and local government agencies, and the business community have been an alternative and/or a complement to new government

programmes. Such partnerships are needed because it is unrealistic to expect governments to finance full-fledged integration of technology into every classroom, especially at times of fiscal constraint. It has been estimated that to hook up all 80 000 US schools would cost \$10.2 billion, plus the cost of classroom computers, training for teachers, and the purchase of software (Issues in Science & Technology, "Wired Classrooms", 1996). The project may also require shifting resources from traditional categories, applying for grant money, requesting corporate or foundation grants, as well as soliciting business donations and contributions from parents' organisations.

Developing and deploying IT

In the 1980s, many European countries began to provide at least one computer to each primary school and larger numbers to secondary schools thereby ensuring some consistency in the availability of hardware in schools. In the context of broad plans such as France's *Informatique pour tous*, Italy's *Piano Informativo Nazionale*, the Netherlands' *Poco*, Portugal's *Minerva*, Spain's *Atenea*, and the United Kingdom's *Microelectronics*, authorities sometimes launched invitations to tender for software packages or for finished products. Finland also made substantial technology investments for education. Since then, both these countries and others have continued to acquire hardware and software with public support. Although many programmes still focus on providing computers and software to educational institutions, emphasis on multimedia capability is increasing.

- Canada's Computers for Schools (CFS) programme brings together educational institutions, communities, business, and all levels of government to channel surplus computer equipment and software to Canadian elementary and secondary schools. All usable donated equipment is tested, refurbished and delivered to recipients free of charge.
- In application of the new legislation on primary and secondary schools, Denmark's General IT Initiative will promote the use of IT from the earliest classes. Students will be able to bring their own computers, and computers will be provided those who do not have one. Local councils are estimated to have purchased 6 000-7 000 PCs for primary and lower secondary schools and will increase this number to 12 500 by 1999 in order to have one up-to-date computer for between five and ten students.

The Ministry of Education promotes the development of teaching materials that integrate IT and of a market for high-quality software.

- The Finnish government has supported the production of domestic software for use in schools for more than ten years, but it is only recently, with the use of multimedia software and CD-ROMs, that these programmes have spread beyond vocational institutions, which have made the greatest use of CAI. There are currently ten CD-ROMs in Finnish and another ten are being developed with the support of education authorities.
- In France, the Ministry of National Education has since 1988 provided indirect support to producers of educational software by compensating certain publishers of vocational and teaching software packages which are sold to educational institutions at a low price.
- In Italy, the Ministry of Education initiated an action plan to equip 20 per cent of primary schools and 30 per cent of secondary schools with multimedia equipment and software between 1995 and 2005.
- The Japan Development Bank gives low-interest loans for computer rentals for education purposes. These loans arise from a plan to enhance the deployment of personal computers in education, initiated in fiscal 1994. In addition, Japan's Educational Software Development and Promotion Project (ESDPP) aims to improve students' creative, cognitive and communication abilities. Catalogue information, demonstration programmes, and test versions of commercially available education software are made available in a database to support developers, teachers and students and to promote use of such software. The Centre for Information Infrastructure provides an environment conducive to the creation of practical educational software and multimedia programmes.
- Portugal's MINERVA project was launched on an experimental basis in 1985-86 to carry out research on ICTs and to introduce them in primary and secondary education both by teaching about them and by using them to support the teaching/learning process for various subjects. An integrated project, it also aimed to educate teachers and teacher trainers and to develop educational software. Participating schools were required to apply for admission

and to provide a plan of proposed activities, teacher profiles, and resources required. The project terminated at the end of the 1993/94 academic year.

- The UK CD-ROM Initiative in Primary Schools has an annual budget of ECU 6 million for two years for purchasing multimedia PC stations and CD-ROMs for teaching purposes. There are also private sector initiatives to alleviate the shortage of expertise and cash in schools. In the context of the Community Learning Utility, based on various US initiatives, schools or learners pay for material on the basis of use, with software and curriculum packages selected and supplied by a community-based utility through a not-for-profit foundation. In another pilot, CRT Group, a training and recruitment company, provides hardware, software and, where appropriate, personnel to schools, with the aid of partners in the IT sector, as a commercial proposition.
- Research, development and demonstration activities of EU programmes such as Information Technologies and Telematics Applications provide next-generation ICT platforms and experimental multimedia services. The MEDIA 2 and INFO 2000 programmes stimulate the creation of multimedia programmes that can be used for educational purposes. The Community Structural Funds or financial aid from the Trans-European Telecommunications Network may also be tapped for deploying educational multimedia.

Providing content and networks

The early focus on hardware did not yield the expected results, and over the years, attention has turned to the opportunities offered by networking, to the use of information technology, and to the role of teachers. Access through cable to networks and/or satellite television is available in a number of European countries, Australia and the United States. The use of interactive video has also been explored in France. However, schools do not yet have consistent access to electronic communication networks, and many governments have taken action to encourage reasonably priced access for educational institutions, students and staff. In some cases, specific education networks have begun to be developed. In others, authorities have attempted to leverage university and research networks by linking them with establishments providing primary and secondary education.

The functions supported through connections to networks differ, and various partnerships have also been established.

Many public authorities and non-governmental organisations are also currently developing, or planning to develop, special materials for schools. These will be offered either off-line on CD-ROMs or on-line via the Internet or the school computer network. Large companies are increasingly interested in the potential of information technology for vocational learning. IBM, for example, is poised to make a considerable investment in developing commercially available multimedia learning material for people wishing to earn national vocational qualifications.

- Canada's joint federal and provincial School-Net programme will ensure that every Canadian school and library is connected to the information highway by 1998.
- Denmark's national education network is the basis for developing and using a large number of IT applications for education and administration. By the end of 1995, it linked all vocational and commercial schools in addition to higher education institutions. Upper secondary schools and adult education centres were being connected in 1996. The connection of lower secondary schools, begun in 1996, will be achieved by 2000 at a cost of DKr 180 million.
- Germany's Council for Research, Technology and Innovation had recommended the development of a high-speed network for universities and research institutes (155 Mbit/s as a backbone and 34 Mbit/s for local connections) which would be open to schools (64 Kbits/s). Launched in autumn 1996 for an initial duration of three years, Schools on Line is a major joint initiative of the Federal Ministry of Education, Science, Research and Technology and Deutsche Telekom, for which the latter has earmarked DM 35 million. Its objectives are to provide general and vocational schools with access to telecommunications networks and on-line services and to integrate the use of new media in learning, teaching, and assessment. It will concentrate on developing and testing teaching materials and on training teachers. The Federal Ministry is providing DM 80 million over three years to expand the high-speed network and has offered schools low-cost access via the German research network.

- In Japan, the 100 School Networking Project is an ongoing pilot project initiated in 1994 to obtain practical information on the use of networks for education. It is a part of the ESDPP and is executed jointly by the Information Technology Promotion Agency and the Centre for Educational Computing (Box 8.2). In addition, Apple Media Kids, a joint project of Apple Computer and the Centre for Global Communications of the International University of Japan, has enabled students from 14 elementary and junior high schools to communicate with each other. Participation was expanded to 200 schools in fiscal 1995. Also, the Konet Plan of Nippon Telegraph and Telephone Corp. (NTT), Japan's telecommunications giant, will provide 1 000 schools with equipment to connect to the Internet. NTT will offer each school ¥ 300 000 in equipment, including a high-speed connection through an integrated services digital network circuit.
- While the Netherlands has no specific programmes to promote IT in education, the national research network SURFnet, jointly owned by PTT Telecom and the SURF Foundation, a co-operative organisation of academic industrial research institutions, has offered its services to teachers and students. Universities and most schools for higher vocational education are using them. Other vocational education and secondary education institutions are increasingly being connected. The BVE-net public sector project, initiated in 1995 as part of the national action programme "Electronic superhighway – from metaphor to action", provides IT services to vocational and adult training institutes and will receive ECU 20 million over a four year period. Plans are being developed to provide Internet access and information services for education and administration to all primary and secondary education institutions.
- Sweden's National Agency for Education has a school computer network, *Skoldatanatet*. The Agency and museums are developing databases primarily intended for teaching local history, and several publishers have announced new series of CD-ROM teaching materials.
- The UK industry-led Schools on Line initiative to connect about 50 schools to the Internet was launched with government support in March 1995. It will enable schools to gain experience using networks and assess the educational benefits. Members of the UK Cable Communication Association plan to connect any school passed by cable to their network free of charge.
- The Telecommunications and Information Infrastructure Assistance Program (TIIAP) of the US Department of Commerce provides grants to public schools to speed up the flow of information through the application of advanced communications technology. The TIIAP has accelerated the pace of connecting public institutions and has stimulated private sector investment. The government has thus leveraged \$24.4 million in federal funds to provide a total of \$64.4 million in demonstration projects. Also, in addition to administering grants and loans to assist rural and remote communities, including schools, to develop

Box 8.2. **The 100 School Networking Project**

A client server system was installed in 100 elementary and secondary schools throughout Japan and is linked to the Internet. It is intended for use in shared learning, information exchange, and conferencing and enables students to access and send information to libraries and schools throughout the world.

Participating schools have set up home pages and carry out work of their choice, such as translating works in foreign languages into Japanese, researching a topic such as acid rain, or broadcasting information from an observatory to the local TV station via a reflector so that they can observe phenomena at home in real time. Many schools have expanded the system to include previously available PCs. While activities were limited to raising awareness among and use by teachers and to information exchange through e-mail in 1995, in 1996, they were to be extended to the broader community, to student use, and to joint projects at international scale.

their communication infrastructure, the US Rural Utilities Service will provide 52 public school systems with two-way interactive video services. In another initiative, Bell Atlantic is helping the Library of Congress digitise its holdings and make them available on the Internet and is building "distance learning networks" in Maryland and Delaware to connect public high schools, community colleges, and public universities to a fibre-optic video-conferencing network. In California, Pacific Bell is connecting schools to the Internet as a private initiative ("Wired Classrooms", 1996).

- The Global Learning and Observations to Benefit the Environment (GLOBE) Program, initiated in 1994 by the United States, joins students, educators and scientists in an international science and environmental education network with state-of-the-art technology. Students in more than 200 schools made environmental observations at or near their schools and shared their data through the Internet in 1995.
- The European Commission will install Network Education Training and Use-NETY to provide information on national contacts for EU programmes such as SOCRATES, LEONARDO and Youth for Europe III. In the context of the Action Plan for a European education initiative (1996-98) adopted in October 1996, the Community will encourage the interconnection, at the Community level, of established regional and national school networks. It will also stimulate the development and dissemination of content of European interest for educational products and for the development and electronic networking of multimedia resource centres. A working group will examine ways of producing and disseminating audiovisual and multimedia content.

Focus on teachers

Teachers' skills, like those of other professionals, need to keep up with the new technologies and developments related to their jobs. Their professional development is particularly important, as it affects not only their own future but that of their students. Since integrating IT into teaching requires teachers to become experienced users of IT, educating and training teachers to integrate IT into the curriculum is of vital importance. As noted in the following section,

however, many fewer resources have been devoted to this issue.

- Denmark plans to provide substantial parts of supplementary teacher training via IT-based distance-learning in an attempt to make all teachers personal users of IT. The Ministry of Education is reforming teacher training to give teachers more opportunity to raise their level of competency in IT, which is being integrated into all basic, continuing education, and refresher courses.
- In Finland, the government supports teacher training of long duration (five weeks) provided in universities. Such training provides pedagogical skills in using IT and skills for training other teachers in the same local area. The programme will cover one-tenth (10 000) of all teachers, the first 1 600 of whom were trained in 1996. The Finish IT Centre for Schools provides training for trainers in modern communications and information technologies.
- Télé-langues is an autonomous distance-learning training system for foreign language teachers in France. It provides them with the skills necessary to analyse video documents and enables them to select videos from foreign television for integration into their secondary and high-school teaching programmes. Much of the training takes place in an institutional setting to encourage teachers to work together with other teachers enrolled in their own schools and with colleagues from other institutions. Flexible arrangements allow trainees to advance at their own pace and establish lines of communication between groups. The experimental phase of the project began in March 1994 and was to be evaluated in 1996.
- In Sweden, active teachers will be encouraged to use IT in teaching, and, starting in 1998, every new teacher will have to be knowledgeable about and experienced in using IT as a teaching tool. Furthermore, a national resource centre will connect universities and municipal resource centres to promote the development of teacher competencies in producing new teaching media.
- The Open University in the United Kingdom is developing a postgraduate certificate of education for teachers through a network linking 1 100 students and their tutors and university staff via loaned computers and modems; already in place are e-mail, bulletin boards,

electronic conferencing, electronic file transfer. The Department for Education supports a pilot project in rural Northamptonshire that uses distant tutorial facilities and e-mail telephone links for in-service science training of teachers in six primary schools.

- The US government funds the Educational Resources Information Clearing House Service to which educators across the country may send questions by e-mail and receive responses within 48 hours. Every week, 200 questions on issues ranging from lesson plans to educational techniques come in, and on-line information (sample lesson plans, answers to frequently asked questions) is accessed more than 15 000 times (White House, 1996). For programmes such as the NSF's Teacher Enhancement Program, it is up to grantees to decide about technology-related training.
- In European Community programmes, training activities will be stepped up and exchanges of teachers from European schools will be encouraged. A network of training centres for teachers and trainers will make it possible to disseminate good practices at the European level.

Broad support for ICT use

- The Office of Learning Technologies of Human Resources Development Canada (HDRC) establishes partnerships with a wide range of stakeholders to support innovative projects that stimulate the use of ICT for education, to assess effective practices, to develop databases and links to others through a Web site, and, with partners and developers, to facilitate demonstrations of learning technologies at locations across Canada. Programmes such as the New Media Learning Strategy for developing computer-based learning materials are also part of Canada's support to the information technology and telecommunications industry's contribution to economic growth and the well-being of all Canadians. In addition, British Columbia's Education Technology Centre provides educators with seed funding to stimulate the use of technology in the classroom through Technology Development Project grants.

- In 1995, Denmark appointed a committee on the pedagogical possibilities of the school network. It provides guidance on the use of IT by publishing a technical and educational guide for local decision makers as well as information on technical developments. The Ministry of Education has launched several initiatives to raise awareness of the existence and supply of teaching aids, including IT, as well as of national and international support schemes. It is also training 20 regional consultants who will help school libraries evolve into educational service centres able to demonstrate the use of IT to search for, process, and present information. It has also gathered information on 100 projects carried out in the context of Infotech in Education and Janus: School Subjects and Data Processing for presentation to secondary schools in 1996 and 1997. One result of the Learn IT project, launched to support efficient implementation of the new legislation on primary and lower secondary schools, has been examples of ways of integrating IT into teaching; these are provided to schools via the Internet and on CD-ROMs. In 1996, the National Centre for Technology-supported Learning provided DKr 11.5 million for 28 projects ranging from the use of IT in teacher training, to the potential of IT for training apprentices, to the establishment of a network for teachers of foreigners and Danes who lack general school competence or suffer from dyslexia.
- In Finland, networks involving 30 educational institutions are being used to develop open and flexible study practices for vocational education and training. Projects planned for 1996 focus on adults, with distance learning at the upper secondary school level and opportunities for using networks to take examinations. On the basis of the Finnish Ministry of Education's Information Technology Strategy for Education, a development programme, Help make Finland an Information Society, was launched in early 1996 to support education and research to meet the demands of the information society. The programme, scheduled to run to 2000, includes projects for developing classroom practices that make the best use of IT and for developing Finnish multimedia programmes and study materials for use in a networked environment. Government support to schools for PC purchases and

extension of information networks will reach Mk 100 million.

- A broad German programme, Innovations for the Information Society 1997-2001, will address issues such as education and training, basic technologies for multimedia systems, and the future of multimedia.
- In the Netherlands as in Norway, plans to introduce training in the use of information technology applications and provide a so-called "driver's licence for the information superhighway" are being developed.
- The US Technology Learning Challenge challenges communities to form partnerships among local school systems, students, colleges, universities, and private businesses to develop new ways to use technology to improve the quality of learning experiences for all. Grants focus on integrating innovative learning technologies into the curriculum and federal funds help to establish local consortia committed to school reform and technology integration. In fiscal 1995, 19 grants were awarded. The objective of the US Department of Education's Regional Technology Consortia Grant Program is to help state and local educational agencies, teachers, and administrators to integrate advanced technologies into the K-12 grade classrooms, library media centres, and other educational settings, including adult literacy centres. The consortia are establishing and conducting regional activities for professional development, technical assistance, and information resource dissemination to promote the effective use of technology in education. US mathematics teachers use a computer network to discuss the teaching techniques presented in the Mathline Project videos sponsored by the Public Broadcasting System. The Star Schools Program, initiated in 1988, addresses educational needs for students and, to a lesser extent, teachers, through emerging applications of technology. In California, IBM has a \$25 million project to link technology to educational reform in ten school districts. Local initiatives that involve parents and the community also help introduce and integrate technology into education. Linking student homes to schools to facilitate teacher-parent conferences, along with teacher training and the application of innovative technology, helped turn one troubled school

into an excellent one ("Wired Classrooms", 1996).

- The EU education and training programmes, SOCRATES and LEONARDO, are helping to spread the use of multimedia in educational institutions and to promote exchanges of experience in integrating technology into education. The Commission will improve the availability of information on educational opportunities provided by new technologies by linking Internet sites and databases which provide information on going projects and on educational multimedia and audiovisual resources in Europe, to create a platform for the exchange of information accessible on the Internet. It will also use traditional media to inform those without access to electronic networks.

Distance learning

- A project of the Danish Ministry of Education on technology-supported education will establish a development centre and an experimental fund. The focus will be on adult education and vocational training.
- In Finland, Freenet, which provides educational telematic services for students, their parents, and teachers, is operated by the Helsinki University of Technology.
- Japan's Ministry of Education launched a pilot project in distance learning using multimedia in 1995. The project aims to use digital switched lines to connect schools in remote areas to schools in big cities, giving the former access to classes held in the latter.
- The Open University of the Netherlands set up the Interactive Learning and Course Development Environment (ILCE) project to deal with the economic, educational and technological problems raised for the development, production and exploitation of learning materials (text-based and multimedia) for distance education. The project is concerned with the design and production of materials and a delivery system for selecting specific materials for students and their delivery in printed and/or electronic mode (OECD, 1996d).
- In Sweden, the Committee for Distance Education and Training will propose measures to promote recourse to distance education and training principally for higher and adult educa-

tion. The government has allocated SKr 45 million for grants to higher education and SKr 40 million to adult.

- British Telecom has been working for many years on distance learning in collaboration with schools and universities. Some 4 000 schools use BT's on-line database service, Campus 2000, which was to be enhanced in 1995 and provide Internet access. Projects such as ACTOR at Ulster University are making distance teaching by video-conferencing available to minority groups in remote locations.
- The US Rural Utilities Service Distance Learning and Medical Link (DLML) Grant Program for improving education and health care for rural residents provides hundreds of students attending rural schools in 28 states with access to previously unavailable courses. Distance learning projects of the Department of Education's Star Schools Program have helped improve instruction in mathematics, science, foreign languages, literacy skills, and vocational education for under-served populations through partnerships that develop, construct, acquire, maintain and operate telecommunications audio and visual facilities and equipment, develop and acquire educational and instructional programming, and obtain technical assistance for the use of such facilities and instructional programming. More than a million students and their teachers in 50 states and territories participate. The US Internet Access Project is part of DARPA/ITO research on networking systems. The objectives of the project pertaining to urban public schools focus on distance learning and the benefits of Internet-based distance-learning technologies using off-the-shelf hardware, software, and network components. The project compares the delivery of Internet services to schools via cable-TV and via conventional high-speed data lines and promotes use of Internet-based distance-learning technologies in certain universities

Support for training

- In Canada's Office of Partnerships for Advanced Skills, the Ontario government, universities, HRDC, and private sector partners collaborate to meet industry needs for upgrading employee skills and knowledge. The Office helps make universities more aware of indus-

try training requirements and promotes the use of leading-edge technologies for training.

- Finland has carried out or has under way several small experiments on networked training, some of which took place within the framework of the EU Telematics Programme. The EU LEONARDO Programme has also approved five Finnish projects on the educational use of multimedia and IT.
- Germany's Council for Research, Technology and Innovation has recommended fostering open-mindedness towards new technologies via information, discussion and opinion-building processes and has promoted the establishment of training centres for skills.
- In the Netherlands, the Fund for Interactive Multimedia Production for Vocational Training (FIMMBO) has brought together manufacturers such as Philips and basic training schools since 1993.
- In Switzerland, MIGROS took a technological approach to employee training because computer-assisted on-the-job learning, in small groups with colleagues and superiors, is considered the most effective form of adult education, particularly when learning is centred on practical considerations and problem solving. Various companies use ICTs to provide newcomers to the firm structured knowledge about the firm, its corporate culture, its ways of working, and technologies used on the job; they may also use ICTs to provide all employees with up-to-date information, to reinforce the company culture, or to provide answers to specific questions. Silicon Graphics, for example, introduced a Web tutorial about the company for newcomers and used the Web to provide information to all employees about an on-going merger with Cray Research. Companies also use ICTs to train clients who buy technological solutions or infrastructures or to offer courses in non-technological areas.
- The United Kingdom is looking at how to make advice about the use of technology and flexible learning available to employers, especially in small enterprises, and to their suppliers of training. The government is considering the use of existing sources of advice about business and training such as the Training and Enterprise Councils (TECs). Pilot projects have also helped demonstrate to TECs the possible

benefits of flexible learning in terms of cost savings, higher penetration of target client groups, and achievement of national vocational qualifications. Some enterprises have been using technologies such as multimedia for a number of years (Box 8.3).

- The US Department of Defense has a long and successful record of using simulations to train pilots, tank drivers, missile crews, maintenance personnel and a variety of other specialists. The US Army has found that a very successful use of its M-1 tank simulator was to permit a team of tanks to practice working together in difficult tactical situations. Good-year has successfully used simulators to train repair crews, and the insurance industry has used video representations to train students to respond to a variety of situations. Such training has helped identify at an early stage students who are ill-suited to the job (Mill, 1994).

Support for adult education

- In Canada, the HDRC has a mandate to promote lifelong learning for continuing skill development. It also focuses on functional literacy in an effort to help Canadians to meet the challenges of the emerging information society. Its recent Standardised Training for Alberta Practitioners in Literacy Education (STAPLE) project is an interactive multimedia programme for literacy workers, co-ordinators and volunteer tutors. Speech Assisted Reading and Writing (SARAW) teaches basic literacy skills to adults with disabilities that affect the
- ability to communicate; first implemented in British Columbia in 1992, it is being introduced across Canada.
- In Switzerland, PRONET is a training programme designed to help women acquire the necessary skills for information management. The goal of the organisers is to permit participants to concentrate on subjects which interest them the most by using network technologies to access information available on the Internet. Participants have shown a preference for e-mail and the World Wide Web.
- The UK Open for Learning programme offers access to learning, through the public library system, to individuals who return to learning and must fit it around other commitments. It has enabled 90 per cent of library services to set up at least one flexible learning centre in a local library. The centres attract 2 000 new users a month and involve co-operation between libraries, TECs and further education colleges. A Learning and Technology Committee has also been set up to examine the use of LANs and WANs for adult education. The Bytes for Belfast project is exploring use of the Internet to improve communications skills and provide information on training opportunities for unemployed school leavers.
- In order to raise public awareness of the need for lifelong learning, the European Commission proclaimed 1996 the European Year of Lifelong Learning. By mid-1996, about 200 projects, including pilots, conferences, media events, and promotional activities had been launched, some with an IT component. A

Box 8.3. A multimedia training application

British Airways (BA) has used multimedia to train cabin crew since 1992. It developed its software in-house in order to enlist the help of cabin crew. By 1994, it had eight applications. Most were refresher courses run on PCs situated at BA offices around the world as well as at an open learning centre in the building where the crew reports for duty. There were also mandatory courses, such as those that prepare crews for the annual safety equipment procedures test required by the Civil Aviation Authority.

Despite the time and effort required to develop applications, the team clearly saw the value of multimedia for training: learners appreciated the interactivity which livened up the course, kept their interest, and helped them retain the information.

In late 1994 the team was preparing for the next step: networking the PCs so that applications could be installed and upgraded remotely, and the training department could keep track of the use of the applications (Mill, 1994).

White Paper, "Teaching and Learning: Towards the Learning Society", encourages the acquisition of knowledge with the help of multimedia. It also proposes treating investment in training on the same basis as capital investment, notably for taxation. The objective of Learning in the Information Society is to speed up the deployment and diffusion of common multimedia platforms for learning, the development of high-quality content, teacher training, and exchange of information through a European School Network. This new initiative will help increase the synergies between national initiatives. An action plan will be prepared by October 1996.

5. ASSESSMENT OF RESULTS ACHIEVED WITH ICT IN LEARNING

Faced with deciding whether to make large investments in an information infrastructure for education, policy makers and taxpayers will want to know whether it is worth the expense. They need to know, for example, to what extent the content on the information superhighway can help learners, whether increased communication possibilities, such as additional telephones for teachers or e-mail connections, will really improve parent-teacher communication, or whether new personnel will be needed to support teachers who have just been trained in technology use in order to enhance the instructional capabilities of investments in technology. They will also need to know whether these efforts achieve their goals.

The effectiveness of ICTs for education and training has been examined in various contexts and compared to existing methods of instruction. There are fewer assessments, however, of the impact or efficacy of policies relating to the use of information technology as a learning tool.

Evaluation of technologies

Studies have consistently demonstrated that computer-assisted instruction is equivalent or superior to conventional instruction and may markedly improve achievement and attitude.

- According to research based on small trials in one or a few settings, computer- and network-based technology can significantly improve educational outcomes if it is appropriately used. The limited research on schools that make full-scale use of technology is promising but as yet inconclusive. It remains to be seen

whether these results are sustained as increasing numbers of schools acquire similar levels of technology (Rand, 1996).

- A US review of 24 evaluations of educational technology (five in basic education, the rest in specialised technical subjects) found that, compared to conventional instruction, new technologies could cut learning time by 25 per cent. In one programme for adult basic literacy, educational technology allowed the average student to gain one grade level in reading and math in 21 hours instead of 150.
- While the introduction of new training technologies to a firm can cause conflict by blurring traditional responsibilities and lines of communication, it can also lead to fundamental rethinking of the way a company does business and significant productivity gains, according to the preliminary findings of the Delta Centre, a non-profit Canadian corporation that evaluates instructional technologies. Earlier US findings also indicate greater effectiveness: Federal Express reported a 50 per cent increase in the learning rates of agents in training and McDonnell Aircraft a 33 per cent increase in efficiency in teaching computer-aided design (Mill, 1994).
- A study of the use of technologies for training in SMEs, commissioned by the HRDC, examined the effects of introducing new training technologies in 37 leading Canadian companies. It clarified some of the factors at work in effective training and some barriers to the use of technology-based training.
- A Canadian study of new media learning materials showed a potential 50 per cent reduction in training costs as a result of their use. Predicted annual savings of C\$223 per employee in the industrial sectors covered translate into an increase in labour productivity of 0.5 per cent. For the whole economy, the reduction in labour cost would be C\$2 billion and could lead to the creation of some 9 500 new jobs (HRDC, 1996).
- Distance learning appears to be as effective as classroom learning for adult learners and advanced high-school students. These findings are based on new technologies, including fibre optic and computer-network systems, which provide advanced and specialised courses to students and training to teachers, allow interaction between distant learner communities,

bring experts and information to the classroom, and enable geographically dispersed learners and teachers to ask questions, discuss ideas, and receive quick feedback.

- In Australia, case studies of the use of video conferencing, satellite and data networks for the training of staff in the tourist industry had positive impacts on students. In the case of video conferencing, remote students were proactive in raising questions and initiating discussion on the sessions's topics, student participation increased, and better exam results were reported than in face-to-face classes. Lecturers' re-evaluation of the structure of the course and consideration of more effective means to convey a concept in the more limited number of hours of contact possible compared to a traditional classroom contributed to these positive results.
- Preliminary indications on the educational value of Internet connections, currently being explored in the United Kingdom, are that it lies in the opportunities it provides both teachers and learners to develop information handling skills, experience with electronic communications, and general network literacy. However, there are concerns about the cost of telephone access to the Internet and the need to avoid unsupervised student access to objectionable materials.
- Evaluation of the first year of a Welsh initiative to provide satellite receiving equipment to secondary schools found increased motivation, improved linguistic skills and a greater sense of immediacy and relevance through access to live images. Most used were remote-sensing satellites which collect information about the surface of the earth and the atmosphere for geography and direct television broadcasts in a range of languages for modern foreign languages. The potential for other subjects is being explored.
- Students using interactive video take more responsibility for learning, have a longer attention span, and develop conceptual awareness; however, teachers need considerable time to become familiar with the material and plan lessons, and issues and materials that do not require specific action by pupils tend to receive less attention. A review of 28 studies of newly introduced video-disk training systems used by US corporations and the military

found that achievement improved in over 60 per cent of cases, user attitudes improved in 56 per cent, and training time dropped in 80 per cent (20 per cent reported mixed results) (OTA, 1988b).

- According to an analysis of the results of 30 evaluations in the United States (Becker, 1992), integrated learning systems technology has had a moderately positive effect on student achievement. The findings confirm that computer-based activities motivate students, and that students enjoy them. Some learning gains, as well as an increase in attention levels and personal responsibility for learning, were also reported as early outcomes of some UK pilot projects. Teachers also benefited from smaller teaching groups and more personal contact, as half classes alternately used the technology.
- The US Writing to Read programme has consistently increased learning rates of kindergartners and first graders, and an advanced system designed to teach literacy skills to adults has consistently increased measured grade levels by two to three years during a 20-week course (OTA, 1988a).

Findings in favour of technology are useful to the extent that they are timely. Measuring effectiveness is a complex issue, and the combination of the typically slow pace of careful research and rapid advances in technology may mean that by the time a technology is assessed, it is already obsolete. The results may no longer tell interested parties what they need to know to plan for the use of technology for education and training.

Some policy evaluations

In Finland, the development programme introduced by the Ministry of Education has helped change attitudes and has led many schools to revise the ICT content of their curricula. In Northern Ireland, however, the Education and Training Inspectorate and independent sources both indicate that schools are not finding it easy to offer all pupils appropriate opportunities for using IT in the curriculum. Some IT skills students learn in primary and secondary schools are not used as often as they might be to enhance performance in various subjects (HMSO, 1995).

In Portugal, the MINERVA project has achieved several goals despite a small number of computers,

about one per fifty students, unevenly distributed among participating schools. In addition to fostering acceptance of computers as educational tools (many teachers now own computers), evaluators found that the project fostered further engagement and exploration, helped students bridge gaps of time and geography and understand the natural world through research projects, helped them learn to work in teams, served students with special needs, and catalysed a broader pattern of change. The project achieved these results with a balanced mix of national guidance and local initiative, active involvement by universities, strong emphasis on human resource development, and the initiation of a MINERVA culture in the schools and resource centres involved.

A key factor in the success of the MINERVA project was the emphasis placed on developing human resources, especially through teacher training, rather than on equipment. Encouraged by their training, teachers able to define their own projects put in much more time than the released time allotted, and their enthusiasm raised their productivity. The project generated a nationwide community of teachers, trainers, and researchers with extensive knowledge of educational ICTs. Many teachers involved in the MINERVA project are participating in programmes to equip schools and train teachers. Participation in the programme was voluntary; this avoided a waste of resources that might have occurred if teachers were unable or unwilling to use the computers. The next step will be the elaboration of a global policy to avoid the proliferation of unrelated and temporary projects (OECD and Ministry of Education of Portugal, 1994).

In the United States, equity among schools in terms of availability of technology, is not a major

issue, according to surveys carried out several years ago (Rand, 1996). Past federal, state and local funding, and policies appear to have mitigated extreme differences in the average availability of computers among poor, minority, and special-needs populations. Federal compensatory education programmes have supported the acquisition of substantial technology for schools serving disadvantaged populations. This finding does not imply however, that the overall level of ICTs is adequate.

A review of US federal support for teacher training and technology reported that teacher issues have largely been neglected, and an insufficient share of funds for technology have gone for teacher training. School districts devote at most 15 per cent of funds to teacher training (OTA, 1995a). Most programmes that support teachers' use of technology are small (under \$10 million), and such support is optional. When the review was written, there was not a single programme devoted exclusively to technology-related teacher training, although some programmes made such training mandatory for one funding cycle. The report recommended spending a larger share of funds on training teachers in the use of IT (Box 8.4). Other barriers include lack of time, inadequate training options, rigid scheduling, attitudinal barriers, and multiple demands on staff development time.

Assessment of the current situation in school use

Although CAI is as effective as or superior to conventional methods, and although authorities in Member countries have supported the deployment of ICT in education for many years, the classroom revolution foretold decades ago has failed to materialise. Overall, the school system has not kept pace with the rest of society in terms of IT use, even

Box 8.4. Teacher training

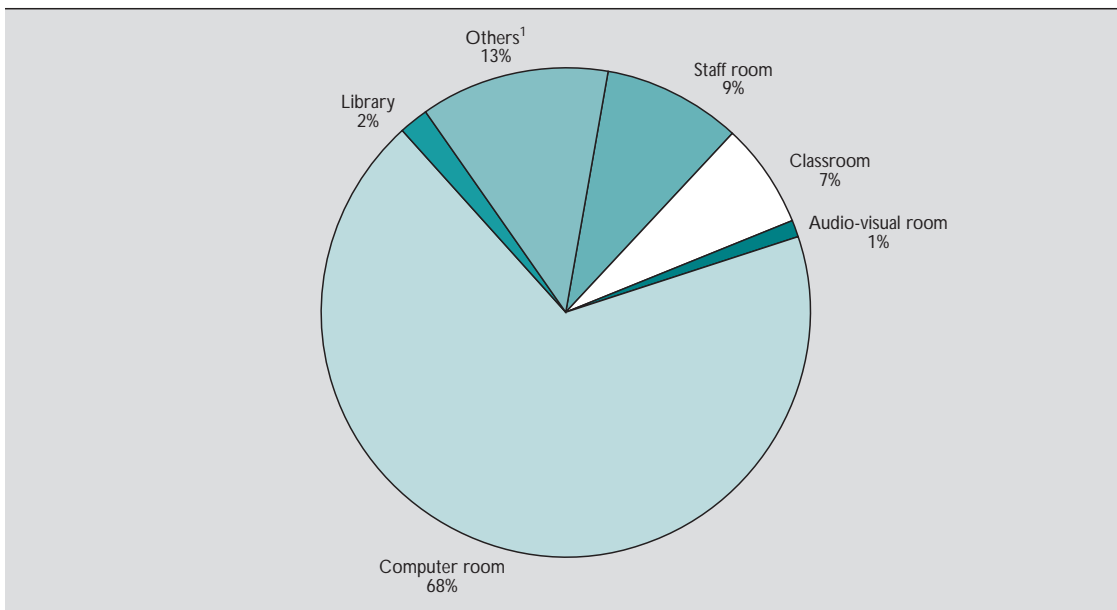
IT can help students learn but only if educators know how to make use of the technology. This has hardly been the case. Teachers are learners, too. They undergo pre-service training, and follow courses, workshops, and other forms of in-service training to fulfil recertification requirements, learn new instructional methods, or keep up with changes in their specialities. Teacher training has typically involved a short in-service course on a specific topic in which a large group of teachers are gathered together for an "injection" of training or a "cascade" type of training where schools make formal arrangements within schools for well-trained teachers to train their colleagues. These are not appropriate ways to encourage teachers to use technology. Training using hardware and software, curriculum-specific applications, and follow-up support are all necessary, as is information on how to integrate technology into classroom instruction, choose software, and organise classes to derive maximum benefit from technology.

though equipment has been deployed, advanced (regional) communication networks are progressing, and projects in open and distance learning and multimedia materials are under way. Even in the United States, where the IT penetration rate in schools is relatively high, computers are used in only a few schools to make the world's storehouses of knowledge immediately accessible to students or to bring history, geography or science alive on screen.

There may be several reasons for this. The benefits of IT for education will come from putting the computer in the classroom as a resource for all studies rather than in a computer lab where it is treated as a source of technical skills, as has often been the case (Figure 8.2). Currently, computer penetration in schools is insufficient to meet such needs (Figure 8.1). ICT equipment levels still differ from school to school and some equipment is obsolete. Too little of the equipment now in schools can be connected to the information highway and access to electronic information networks is inconsistent. ICTs are expensive for massive deployment in education, and money and knowledge about products are limited.

Successful deployment and use of ICTs in the classroom still largely depends on highly motivated, pioneering principals and teachers. Although the lack of appropriate teacher training and experience was identified at the beginning of the decade as a major problem for effective use of IT in education, most policy discussions and technology initiatives in the area of IT and education have tended to focus on hardware and software acquisition and students' access to technology (OECD and Portuguese Ministry of Education, 1991). Computer literacy is still generally low among educators: the majority lack the necessary training, some lack an appreciation of ICTs and their classroom potential. Old habits also die hard, and there is some scepticism about the suitability and effectiveness of computer-based materials, which is reinforced by important variations in IT acquisition policies, for example, between language studies and other subjects. While the reform of national core curricula provides a good basis for using ICTs, their actual applications are ultimately in the hands of individual schools. It may also be noted that co-operation between educational institutions in using teaching resources is quite rare.

◆ Figure 8.2. *Location of client computers connected to the Internet in Japanese schools, 1995*



1. "Others" includes clerical room, passway, broadcasting room, advisory room, health room and others.
Source: 100-School Networking Project.

In terms of applications, there may be a specific market failure. In most countries, the computer and software industries have little incentive to develop products for cash-starved public education systems, and this has retarded the use of ICTs in education and training (Adonis, 1994). Production of electronic information products has also been limited by the size of certain markets and language areas. Even when learning software exists, and may be shared, few schools have the computers to run multimedia programmes or the resources to support complex school-wide networks (although they can increasingly connect to existing ones). This has limited the use of telecommunications services and information networks, where available, and even where adequate hardware exists, it is not fully utilised (Table 8.6).

More broadly, education is not viewed as something that happens via interrelated learning in homes, classrooms, communities, workplaces, and through the media. IT has been used more to automate models of presentational teaching than to make effective models of learning-by-doing affordable and sustainable. Educational innovation has been impeded by psychological, organisational, political and cultural barriers set up by all stakeholders. Calculations of the cost and productivity of educational technology have largely been framed in the context of school budgets

rather than the larger economic context of issues such as international competitiveness, workforce productivity, the cost of crime and of welfare, and citizens' more complex responsibilities. Teachers and school administrators, overwhelmed by current responsibilities, lack the support systems necessary to rethink their roles (Rand, 1996).

6. LESSONS LEARNED

Building an education and training system that incorporates new ICT skills requires nothing less than major changes in attitude, teaching and learning styles, education-business partnerships, education funding formulae, and community-school relations. Some lessons on the fundamental elements of successful deployment, drawn from experimental implementations in schools and more extensive experience in adult learning, are provided below.

Increasing the use of technology in education will require a commitment to research and the development of powerful curriculum products, tools and telecommunications resources which are beyond the capability of individual actors in the public and private sectors. Without appropriate incentives, the market for educational technology products may not be

Table 8.6. **Barriers to acquisition or use of advanced telecommunications in US public schools, 1994**

	Minor or no barrier	Moderate barrier	Major barrier
Lack of or poor equipment	32	20	48
Inadequate hardware upkeep or repair	56	21	23
Lack of instructional software	50	29	21
Software too complicated to use	79	16	6
Too few access points in building	28	21	52
Telecommunications equipment not easily accessible	37	25	39
Telecommunications links not easily accessible	42	22	36
Variability of telecommunication rates from service providers	64	16	20
Problems with telecommunication service provider	80	10	10
Lack of time in school schedule	33	32	35
Lack of technical support or advice	43	32	25
Lack of or inadequately trained staff	31	32	37
Lack of teacher awareness of ways to integrate telecommunications into curriculum	26	39	35
Not enough help for supervising student computer use	48	28	24
Lack of administrative support or initiative	69	17	14
Lack of teacher interest	61	31	8
Lack of parent or community interest	78	17	5
Lack of student interest	92	6	2
Funds not specifically allocated for telecommunications	19	18	63

Source: US Department of Education (1994), National Center for Educational Statistics, Fast Response Survey System, "Survey on Advanced Telecommunications in US Public Schools, K-12", FRSS 51.

promising enough to interest the private sector. Firms see a role for government in facilitating R&D on educational content based on new media, possibly through R&D and technology tax credits. Educators need to work closely with industry, research centres, and universities to ensure that they develop programmes that are practical, useful and relevant.

Governments can also play an important role in supporting the adoption of learning technologies, notably the new media learning materials. They could become model users of these technologies and also support their broader adoption by industry by informing key industries about their availability and benefits. They can also encourage the use of communications technologies by educational institutions with more affordable tariffs, a course of action that is being considered in some countries. The concept of an education rate has been launched in the US, guaranteeing free Internet access to all US schools and libraries by the year 2000. Rural and remote areas must be also served adequately and at reasonable cost by communication networks. A good example is in Nova Scotia, Canada, where a special education tariff has been established for telephone and television.

Technology deployment should continue and should be guided by educational rationale. Integrating technology into the curriculum is essential if technology is to be truly effective as an educational resource. Technical standards for hardware and software are needed, so that platforms for the tasks at hand are appropriate. Educators should also seek the help of corporations and the community for deploying technology. Opening the technological resources of schools in order to provide adult continuing education would allow these resources to be used more fully.

The choice of technology is important. It depends on the particular purpose and situation, but should also be reasonably accessible, robust and affordable, rather than "leading-edge". In any case, the cycle of renewal in educational institutions will never be able to keep up with improvements in the technology.

While technology acquisition is very important, the most difficult and expensive issues involve people. Investments in technology should be accompanied by substantial investments in human resources. Most of the cost of applying technology to learning lies in enabling people to manage and use it, in raising awareness of its possibilities, in ensuring training, and in restructuring organisations. What is interpreted as resistance to technology, especially by adults, is frequently a reaction to inadequate consultation, poor implementation, lack of training, information and support (OECD, 1996*d*).

In the case of teacher training, systemic support by principals, other administrators and the community at large is also needed. Training, technical support, and time to learn to use the technology are essential. In the United States, the allocation of a minimum of 30 per cent of technology budgets to teacher training has been recommended in some cases. While pre-service training should necessarily include, for all teachers, an introduction to the pedagogical use of computers, the main problem remains the retraining of those already in service. Teachers need to participate in training programmes that not only provide technical knowledge about computers but also show them how computers can best be used in the classroom. In addition, they need a vision of the technologies' potential, opportunities to apply them, just-in-time support, and time to experiment. Finally, various teacher training and support strate-

Box 8.5. **Implementing technology for education**

Develop nodes where expertise in various technology applications can be developed and shared.

Train master teachers who serve as a resource for colleagues.

Provide experts from staff, such as librarians, computer co-ordinators or volunteers from business, parent and student groups.

Give each teacher a computer, training, and time to develop personal confidence and expertise.

Train administrators to serve as technology supporters and guides within their school and jurisdiction.

Establish resource centres, ideally with easy access through on-line services.

gies must co-exist, as there is no “best” way to use or to train teachers to use technology (Box 8.5).

The teacher learning experiences that are currently lacking are those that take place mainly in the classroom. More co-operation between higher-education institutions and schools is necessary so that teachers, their educators, and researchers work together. This collaboration should continue throughout the school year. It would also benefit institutions involved in teacher education, as schools may well be better aware of the pedagogical uses of IT (OECD and Portuguese Ministry of Education, 1991).

Teachers also need ready access to technology. After learning to use technology in a workshop, teachers must have the technology available in the classroom and be able to use it at home to explore how it can help them do their job. Follow-up support and coaching are as essential to effective staff development as the initial learning experience. Teachers need to be able to count on technical assistance and support once they return to their classroom.

From pioneering to broad-based use

Experience with educational technology has shown that providing schools with educational technology and teachers with technical training is only half the story. It does not necessarily result in widespread major gains in learning outcomes or student

motivation, even though isolated examples of innovation have been very successful (“Wired Classrooms”, 1996). The challenge is to reap the same benefits in schools that are less technology-rich or have teachers who are less enthusiastic and energetic than the pioneers. The other half of the story involves changing attitudes and mental structures.

Governments may need to exercise leadership in articulating the value of integrated, technology-based teaching and encourage the use of technology as a path to achieving educational goals. They can encourage people to change their mental models of teaching and learning in many ways. They can help parents recognise that the changes they see in the workplace have dramatic implications for their children’s education. They can help teachers who are frustrated by conventional classrooms to envision alternative forms of instruction. They can help the corporate sector to see that employee attitudes that are valuable for the knowledge-based workplace are best inculcated through learning partnerships among parents, communities, businesses, the media and schools. They can also raise awareness of the benefits of IT for education so that the educational community and taxpayers understand that technology is essential to meeting their objectives for student learning and co-operate to reallocate funds to technology and/or increase funding in order to integrate technology into education (Rand, 1996).

Part III

CONGESTION ON THE INTERNET: GROWING PAINS OR MELTDOWN?

Extensive use of the Internet network and a sharp rise in the number of connections has significantly changed the network's shape and performance. Originally the domain of scientists working on military-funded or related research in the United States, the Internet is now accessible in virtually all the world's countries and to the public at large. Its architecture allowed for this quick expansion, but potentially difficult problems arise as new uses of the Internet such as the World Wide Web (WWW) become popular. Instances of diminished quality and a general decline in user comfort have been noticed. As a consequence, the popular and trade press has suggested that a "traffic jam has hit the information highway".¹ Some foresee this problem worsening as new applications such as video, which make even greater demands on Internet resources, become common.² While the Internet is privately managed and still rather embryonic, governments have an interest, as with any infrastructure, in ensuring that the market adequately supports and maintains its operation.

This chapter of the *Outlook* aims, first, to describe the problem and to try to determine whether the problem is temporary or more lasting; it discusses recent trends in Internet supply and demand and examines traffic density. Next, it looks at the impacts on the development of the network and the services it provides by examining the causes of mismatches in supply and demand. Finally, it sketches out potential solutions to some of the problems. The analysis focuses almost exclusively on the United States, as it is the only large OECD country where the Internet operates in a largely unregulated environment and is extensively used. The US experience may be a harbinger of things to come as Internet use expands in Japan and Europe and as these regions engage in regulatory reform of their telecommunications sectors. Some aspect of the US situation, such as flat-rate pricing for local telephone calls, are undoubtedly somewhat atypical. Nevertheless, many of the changes affecting the supply of and demand for

Internet services in the United States are likely to take place around the world.

1. RECENT TRENDS IN INTERNET SUPPLY AND DEMAND

To understand the current and likely future supply of Internet resources and demand for Internet services, it is essential to understand two things. One is the structure and design of the Internet. The other is how its use has changed, and is likely to change in the future.

The origins of the Internet

What is now the Internet began in the late 1960s as a project of the US Department of Defense's Advanced Research Projects Administration (DARPA). DARPA wanted to link the Department of Defense, defence research centres (government laboratories and universities), and the Department's contractors. The network, initiated in 1969, was called ARPANET and had four linked mainframe computers. As a result, the Internet's basic characteristics reflect the early needs of the US military and the research community:

- The desire to optimise transmission *speed*. Since the network would inevitably have segments consisting of low-speed telephone lines, the protocol had to be designed so that the maximum use of available bandwidth could be obtained.
- The need for a system that would allow *universal access* by a wide variety of computers, operating systems, local networks, and communication mediums with different technical standards.
- The need for *survivability*. If war broke out and part of the network was damaged, it would be necessary to route transmissions around the damaged portion so that messages reached their destination.

- The need for *high-quality* communication, since distortion of the signal could corrupt the transmitted data or scientific files.
- Lastly, as “a network of networks”, the protocol had to remain simple so that it would be easily understood by all users.

TCP/IP (Transmission Control Protocol/Internet Protocol), a packet-switching communication protocol, was selected to meet these needs. One of its principal features is that it breaks every message up into a series of separate packets consisting of two main segments: the “header” (primarily the source and destination addresses) and the “payload” (the data). A header is 20 bytes long and the payload can vary from 12 to 65 536 bytes (Garfinkle, 1996). A single page of standard e-mail text has about 2 500 bytes or from 8 to 16 packets.

The user sends a message via a modem (short for modulator-demodulator, see Glossary in Part IV) which converts bits into waveforms; these pass through the phone system or a local area network (LAN) to a host or Internet service provider which converts the message into packets. The size of the packet will depend on the type of message. For TELNET, the average packet size is 75 bytes, for e-mail sent via smtp (Simple Mail Transfer Protocol) the average tends to be 160-165 bytes. The packets flow from the Internet service provider (ISP) to a computer called a router; the router selects the most efficient path for each packet to the next router en route to its final destination. It does this by consulting a routing table containing a complete map of the current network structure (there are currently about 40 000 routers). Depending on usage and the status of various downstream routers, the most efficient path might very well involve a different route for every packet that makes up the message (a phenomenon called “fluttering”). In many cases, the best path has little relation to the geographical distance being spanned (see Box 9.1).

After the packet leaves the router, it typically flows across a “backbone” which is, in most cases, a fibre-optic trunk line and through several more routers. Depending on the route, the packet may cross from one backbone to another; the points where backbones intersect are called network access points (NAPs). When the National Science Foundation (NSF) transferred management of the Internet to private firms, there were only four NSF-chartered NAPs in the United States, but that is changing as private operators open up additional NAPs, called Metropolitan Area Exchanges (MAEs), and as “private peering

arrangements” (for the exchange of packets between two firms) are struck. Finally, the packet arrives at the destination’s ISP, where it waits until all the packets arrive, at which point they are reassembled into the message. Once complete, the host or ISP sends the message to the final user.

Congestion on the system is a function of many factors, but most simply it depends on the number and size of packets and the capacity of the infrastructure across which they are travelling. This capacity is measured in terms of bandwidth or the number of bits that can be transmitted across a particular channel (copper wire, coaxial cable, radio spectrum or fibre-optic) per second; congestion can occur at any of the points that connect a user to the final destination.

The Internet’s protocol for communicating differs significantly from that of conventional telephone calls. The most fundamental difference is that when a user makes a phone call, an end-to-end circuit is opened, and kept open, between the origination and the destination of the call. Even if there is a silence in the conversation, the line cannot be used by somebody else. The Internet, on the other hand, is “connectionless”: there is no end-to-end set-up, and packets share a line with many other users. While packet switching is a very efficient and frugal method of communicating and one which satisfies most of the needs of its original military mission, its shortcomings become apparent as larger numbers of users engage in a broader range of uses.

The evolution of Internet demand

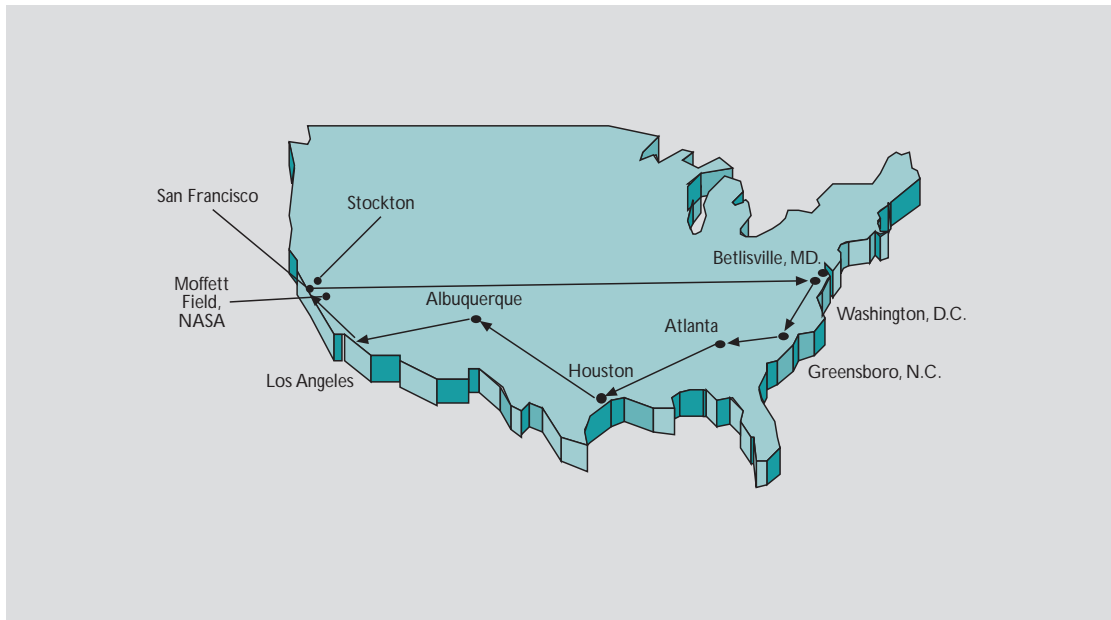
Two factors are driving the evolution of the Internet: a dramatic increase in the number of users and a qualitative change in the manner in which the Internet is used.

As Figure 9.1 shows, Internet users have been growing at a steady exponential rate for the past decade and a half, leading some to predict over a billion users by the year 2000 (Negroponte, 1996). Whether this prediction is accurate or not, there is no question that the Internet has experienced explosive growth. These growth dynamics echo the pattern inherent in “network economics”: when enough people are part of the network, it suddenly becomes economically attractive for all potential users to join, so that there is a sudden growth in demand.

- Between August 1981 and May 1982 (the two first available surveys) the average increase was 2.5 new hosts every month.

◆ Box 9.1. *From The Washington Post to the White House*

The graph tracks an e-mail sent by Rob Pegoraro, a reporter for *The Washington Post*, to the White House, four blocks away, in September 1995, using the command `tracert`



```

twp.com% tracert whitehouse.gov
Tracert to whitehouse.gov [198.137.241.30], 30 hops max, 38 byte packets
 1. pds1.p1.digex.net (199.34.33.2) 20 ms 0 ms 20 ms
 2. ebola-reston.digex.net (204.91.197.1) 0 ms 0 ms 0 ms
 3. strep.digex.net (204.91.99.2) 0 ms 0 ms 0 ms
 4. mono.digex.net (164.109.202.7) 20 ms 20 ms 0 ms
 5. enss230.digex.net (164.109.1.1) 20 ms 20 ms 0 ms
 6. t1-3.cnss59.Washington-DC.t3.ans.net (140.222.59.4) 20 ms 20 ms 20 ms
 7. mf-0.cnss56.Washington-DC.t3.ans.net (140.222.59.222) 0 ms 0 ms 0 ms
 8. t3-1.cnss72.Greensboro.t3.ans.net (140.222.72.2) 20 ms 20 ms 40 ms
 9. t3-0.cnss104.Atlanta.t3.ans.net (140.222.104.1) 40 ms 40 ms 40 ms
10. t3-2.cnss64.Houston.t3.ans.net (140.222.64.3) 60 ms 60 ms 60 ms
11. t3-0.cnss112.Albuquerque.t3.ans.net (140.222.112.1) 80 ms 80 ms 80 ms
12. t1-0.cnss19.Los-Angeles.t3.ans.net (140.222.19.2) 120 ms 120 ms 120 ms
13. t3-2.cnss8.San-Francisco.t3.ans.net (140.222.8.3) 120 ms 140 ms 120 ms
14. t3-0.cnss144.t3.ans.net (140.222.144.1) 140 ms 160 ms 120 ms
15. ICM-FIX-W.ICPNET (192.203.230.16) 120 ms 140 ms 120 ms
16. sl-stk-5-H2/O-T3.sprintlink.net (144.228.10.21) 120 ms 120 ms 120 ms
17. sl-dc-6-H1/O-T3.sprintlink.net (144.228.10.1) 120 ms 100 ms 120 ms
18. sl-dc-F0.sprintlink.net (144.228.20.3) 240 ms 100 ms 100 ms
19. sl-eop-1-S0-T1.sprintlink.net (144.228.72.66) 100 ms 120 ms 100 ms
20. whitehouse.gov (198.137.241.30) 120 ms 120 ms 120 ms.
twp.com%

```

Comments (and explanations):

- Each line represents a computer encountered on the packets' path.
- The numbers in parentheses (e.g. 192.203.230.16 in line 15) represent the IP address of each computer; names such as `Whitehouse.gov` are only used by humans.
- The three numbers (e.g. 120 ms 140 ms 120ms in line 15) refer to the time needed to reach the computer. Because the message was divided into three packets, there are three figures. The 6 000-mile path followed by the packets to go from the *Post* to the White House "a 10-minute, four-block walk" took 60 milliseconds and went coast-to-coast.

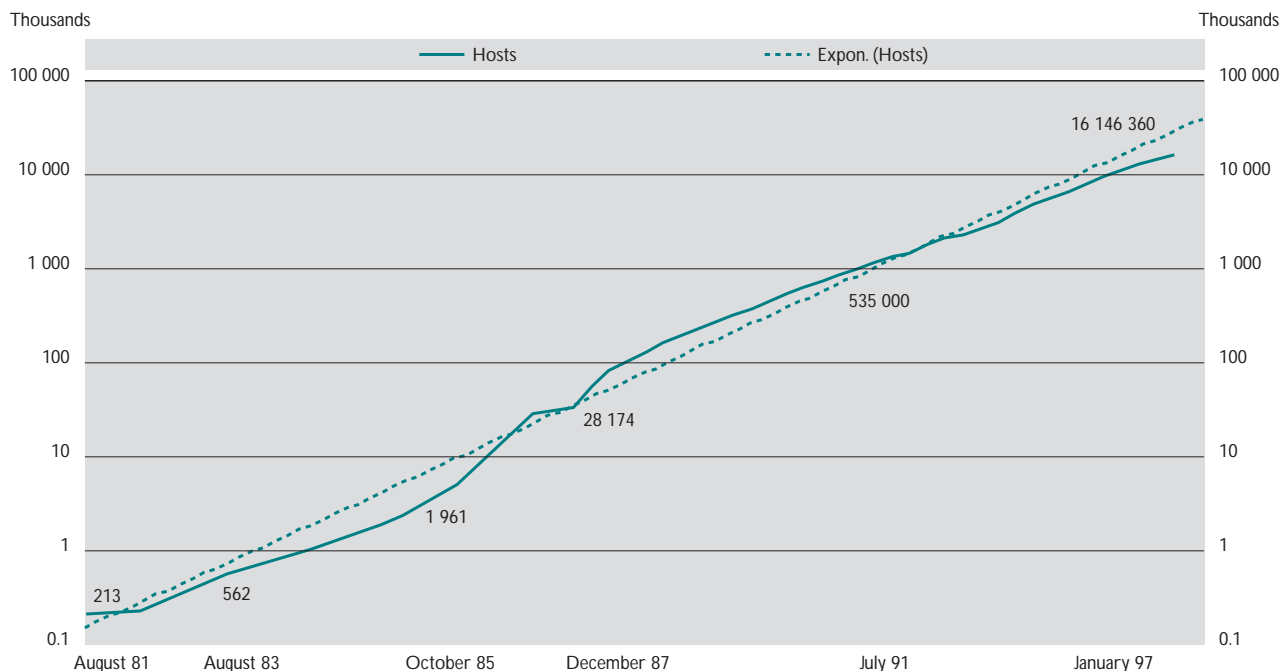
Steps 1 to 5: "digex.net" refers to Digital Express located in Beltsville, MD (see map), the *Post*'s Internet access provider.

Steps 6 to 14: The packets go through the Advanced Network & Services (ans.net) one of the nation-wide backbones.

Steps 15 to 19: The message is passed from one router to another until it gets to Sprintlinks, another backbone, used by the White House as a connection to the net.

Source: Pegoraro, Rob (1995), « The Medium is the Mess », FFWD, *The Washington Post*, September.

◆ Figure 9.1. *Trend in world host names (August 1981-January 1997)*



Source: Network Wizards, February 1997.

- Between October 1988 and January 1989 the average was 6 000 new hosts every month.
- Between the two last surveys, in July 1995 and January 1996, the average increase was about 470 000 new hosts a month.

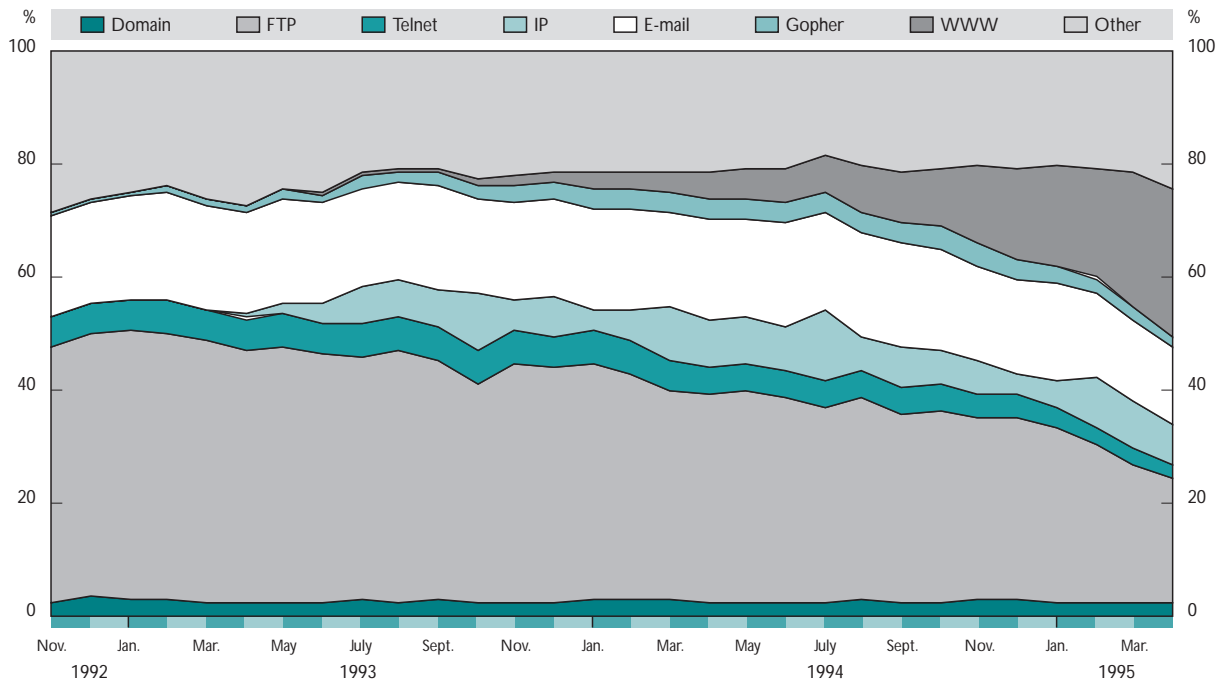
Such markets tend to arrive at maturity quickly, and it may be that the US market is close to saturation. While the growth rate may subside in terms of absolute numbers of new users, even a small increase on such a large base is significant.

At the same time, as the user population has grown and evolved, so has use of the Internet. There has been a significant shift away from applications requiring relatively little bandwidth, such as text file transfers (using the file transfer protocol – FTP) and e-mail, to new applications, such as the World Wide Web, which involve graphic user interfaces, high-resolution pictures or audio clips and demand substantially more bandwidth (Figure 9.2). This is an essentially normal evolution; as the number of users increases, less sophisticated users join the network and demand for more “user-friendly” applications such as graphic user interfaces (GUIs), pictures, and audio increases.

Another indicator of changes in the use mix is reflected in the shift of domain names from .edu (universities and academic applications) and .gov (government agencies) to .com (commercial applications and households) (Figure 9.3). Because commercial users demand more entertainment and advertising, they make more use of bandwidth-consuming applications such as audio, video and graphics. As a consequence, the number of packets or of bytes going through the Internet is increasing even faster than the number of users: NSFNET estimates that growth in hosts is about 6 per cent monthly while it is about 11 per cent in terms of packets processed (MacKie-Mason and Varian, 1994). This means that surveys of the number of hosts or users only hint at the actual flow of data on the Internet.

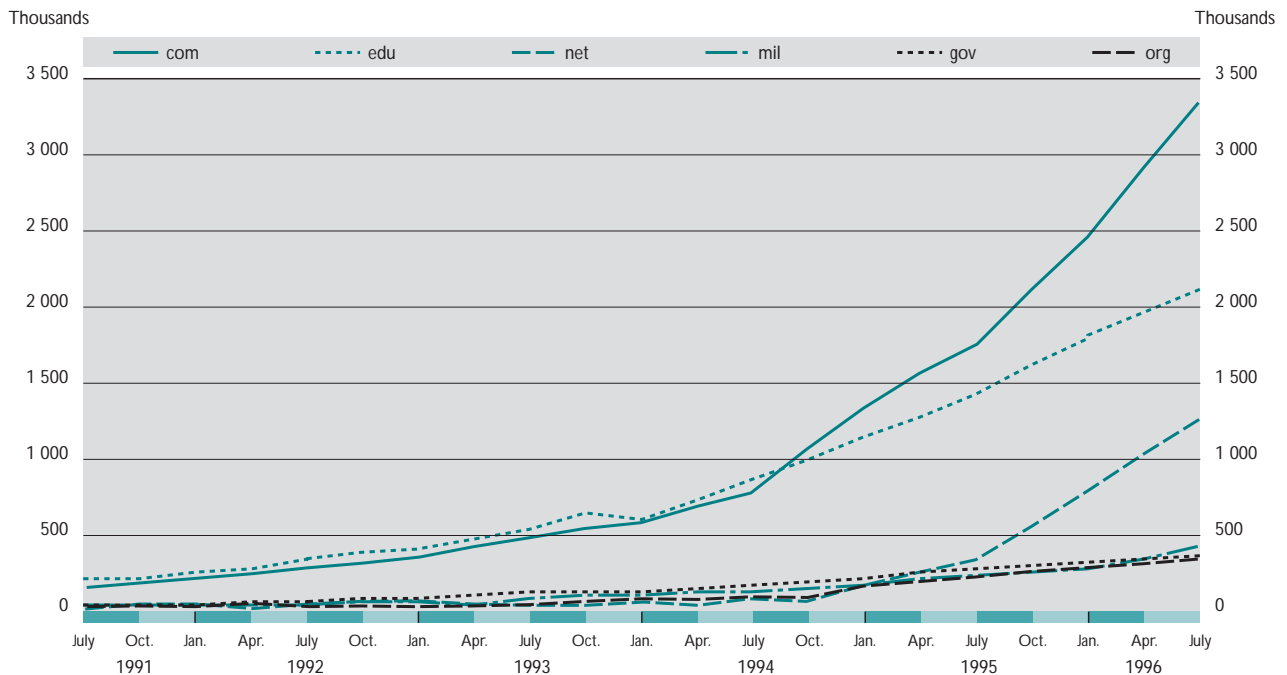
This shift in demand requires an increase in bandwidth that is not always available in the current infrastructure (Barron, 1996). For example, high-speed backbones are based on a technology that runs at 155 million bits per second (mbits/sec), but access to such technology is prohibitively expensive except for a handful of users. More commonly, access is through a T1 line at 1 mbits/sec and, increasingly, T3

◆ Figure 9.2. *Trends in use of the different ports*



Source: Merit, September 1996, <http://nic.merit.edu/nsfnet/statistics/>.

◆ Figure 9.3. *Shift in the mix of users*
Number of hosts by domain names



Source: Merit, September 1996, <http://nic.merit.edu/nsfnet/statistics/>.

lines at 45 mbits/sec. The most common connection (about a quarter of users surveyed) is at 28.8 thousand bits per second (kbits/sec) (GWU, 1996).

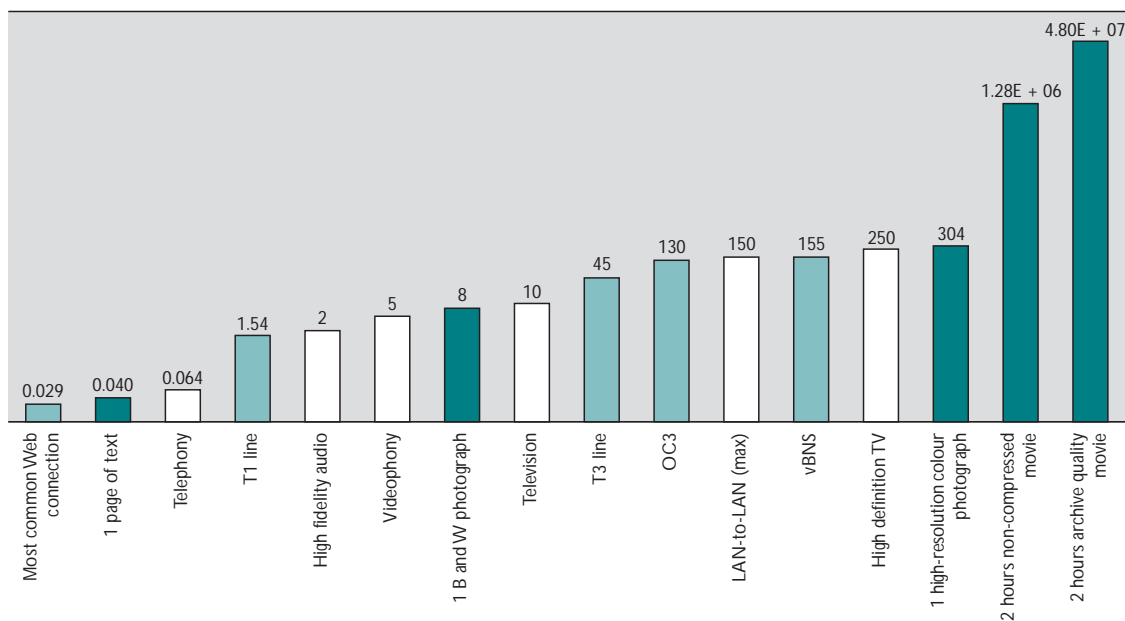
Figure 9.4 compares these means of access to current uses of the Internet. Black bars represent the storage requirements for different applications (a page of text requires 0.040 megabits of memory and two hours of a non-compressed movie, 1 280 000 megabits. White bars represent the bandwidth needed for some applications (high-fidelity audio requires 2 mbits/sec of bandwidth). Grey bars represent the capacity provided by a variety of different technologies (a standard T1 fibre-optic line is capable of delivering 1.28 mbits/sec). It is possible to obtain quick access (less than a second) to a high-resolution black and white photograph, but it requires assigning a T3 line to a single user. With a T1 line, there is a delay of about eight seconds. If many people use the same T1 line and want to download a high-quality photo, congestion is likely to occur. Home users accessing the Internet with a modem hooked to a telephone line can spend over ten times longer downloading a film than watching it (Sprout, 1996). High-definition television, on the other hand,

is simply not accessible with available technology. In short, if demand is for high-fidelity audio and video but if supply is over a 28.8 kilobit modem hooked to a T1 line shared by many users, the result will be congestion.

Changes in supply

This is hardly a static market: as demand has increased, so has supply. Capacities of public telecommunications operators (PTOs) and private firms are regarded as strategic information and are not made public, so that it is impossible to assess what part of the infrastructure, if any, is under-utilised. Nevertheless, the evidence seems to suggest that in some cases available capacities are under-utilised. Figures available both for trans-Atlantic and trans-Pacific connections show that capacity is far ahead of demand (OECD, 1996e). However, the senior vice president of MCI, Vinton Cerf, warns: "With transoceanic traffic growing by 100 per cent per year, finding capacity on the available undersea cables is increasingly difficult" (*InfoWorld*, 1996b). At national level, evidence of sufficient capacity seems to go in the

◆ Figure 9.4. *Memory or bandwidth requirements/capacity of various Internet applications (mbits/sec.)*



same direction, although systematic information on the subject is very scarce. Table 9.1 shows that deployment of fibre-optic cable throughout the OECD region has been significant recently. Studies undertaken for Japan by the Ministry of Posts and Telecommunications (MPT) (Hatta and Takeuchi, 1995) and for the United States by the Federal Communications Commission (FCC) showed that capacity outruns demand.

In the recent past, the capacity of the Internet has been upgraded and augmented. When the NSF created NSFNET in the mid-1980s, the backbones moved at the then unbelievable speed of 56 kbits/sec; in 1987, the speed rose to 1.5 mbits/sec through T1 lines; in 1991, it rose again to 45 mbits/sec through T3 lines. Most recently, under its current "Internet 2000" programme, MCI (which carries 40 per cent of the world's Internet traffic) has tripled its capacity by switching to OC-3 lines, which can transmit 155 mbits/sec, and it plans to upgrade them in the very near future to OC-12, thereby increasing speed by a factor of four (CNNfn, 1996). If so, the speed of

the Internet backbones will have increased at an average annual rate of over 100 per cent over the last decade.

Work is also under way to expand the number of points (NAPs or MAEs) at which backbones merge to reroute packets. Concert InternetPlus, a joint venture between British Telecom and MCI, proposes first to develop eight hubs around the world, followed by 12 more, so as to avoid the current problem posed by routing most traffic through the United States. Owing to these developments, among others, the Internet's capacity has increased by 30 per cent, according to MCI (CNNfn, 1996).

While the investment in new capacity gives weight to the argument that delays on the Internet are temporary "growing pains" that the market will overcome, users generally continue to perceive a decline in the quality of service (QoS) even as the new capacity is deployed. Scientists, the original users, have expressed the most dissatisfaction, claiming that congestion has made it impossible for them to use the Internet for the purpose for which it was

Table 9.1. **Deployment of fibre optic cable in the OECD area**

	1993	1994	1995	Compound annual growth rate 1993-95	Measure
Australia	-	-	-	-	
Austria	45 298	64 558	92 320	42.8%	Fibre km
Belgium	4 650	-	-	-	-
Canada	3 696 775	3 951 036	-	6.9%	..
Czech Republic	1 408	39 187	90 336	701.0%	Fibre km
Denmark	9 300	10 300	-	10.8%	Km
Finland	164 024	327 416	425 955	61.1%	Fibre km
France	34 000	53 700	-	..	-
Germany	68 400	81 100	86 000	12.1%	-
Greece	2 745	4 615	7 025	60.0%	Cable km
Hungary	-	-	-	-	-
Iceland	156	180	315	42.1%	Km
Ireland	8 600	9 600	11 200	14.1%	Fibre km
Italy	1 333 000	1 719 000	1 964 000	21.4%	Fibre km
Japan	168 300	212 629	-	26.3%	Km
Luxembourg	-	-	-	-	-
Mexico	8 701	16 796	21 610	57.6%	-
Netherlands	12 000	-	-	-	-
New Zealand	-	-	-	-	-
Norway	11 400	12 700	13 800	10.0%	Cable km
Portugal	15 280	99 600	134 128	196.3%	Km
Spain	24 857	29 339	36 041	20.4%	-
Sweden	25 000	-	-	-	-
Switzerland	214 051	-	-	-	-
Turkey	20 700	24 850	28 300	16.9%	Km
United Kingdom	2 300 000	2 600 000	2 800 000	10.3%	Km
United States	7 545 539	9 055 120	10 714 811	19.2%	Fibre miles

Note: CAGRs in bold are 1993-94.

Source: OECD (1997), *Communications Outlook*.

intended (Butler, 1996). They have been joined by businesses, which see the potential of the Internet but consider that the current level of reliability precludes their use of it. For example, US automobile assemblers would like to use it to link together their upstream suppliers, internal production process and downstream distributors but cannot tolerate fluctuations in service when “a 3 minute outage can bring down an assembly line; and after 20 minutes the plant shuts down and the shift is sent home” (NSF, 1996b). Most recently, telephone network operators have joined the chorus, complaining that “the Internet is flooding their networks” and creating problems at their switching centres (Kehoe, 1996). These concerns have created interest in trying to measure QoS on the Internet systematically (Monk and Claffy, 1996), and some firms, such as the three big US automobile manufacturers, are developing their own certification process for Internet services providers (<http://www.aiag.org>).

2. CHANGES IN THE QUALITY OF SERVICE

The problem of measuring Internet congestion

It is very difficult to move beyond anecdotal information on Internet congestion and the impact of congestion on QoS, owing to the nature of packet switching, the volatility of congestion, and the lack of reliable QoS indicators.

The use of packet switching technology makes it almost impossible to analyse bottlenecks: if one router is overloaded, a different path will be used, eventually creating another bottleneck somewhere else. Moreover, given the network's architecture, apparently similar conditions may lead to distinctly different congestion patterns. The network's adaptability can thus result in “rolling congestion” which significantly reduces the quality of service but is very difficult to track, diagnose and fix.

A related issue is the high degree of variation in QoS in terms of both timing and location. It is widely recognised that congestion peaks during working hours, or “when California comes on line” (Figure 9.5). Yet, researchers have found that the least congested hour on the Internet (00:00 to 01:00) had only 15 per cent fewer connections than the most congested (13:00 to 14:00) (Paxson, 1996). It is also difficult to identify whether a delay is due to a local access problem (a slow PC), too many users from the same group trying to access the same Internet service provider simultaneously, congestion at the router, or overloading on the backbone.

The decommissioning of the NSFNET backbone in 1995 has left the Internet community with no dependable public source of statistics on Internet workloads. The privatisation of network access and management has resulted in fragmentation, and the thousands of current Internet access providers have not organised themselves and agreed on developing a plan for the future evolution of the Internet that takes account of some estimate of changes in demand (Germain, 1996). This is further complicated by the fact that the indicators needed to support such a plan are not readily available (Metcalf, 1996). Recognising the problem, the NSF has convened a workshop on this topic and is funding research to develop indicators of performance, but, for a number of reasons, no consensus has been reached on how data will be collected and used.

- The source of QoS variation may lie in any part of the Internet. As the problem may be at local level, at the NAP, in the backbone, etc., it is necessary to evaluate performance at each of these points.
- A “low QoS” can take different forms: significant delay, packets lost, low average delays but high variability, etc. As these events need not appear simultaneously, different indicators are needed.
- The very notion of QoS can vary. Data currently available, such as flow measurements, looping, and router flapping, identify technical problems that merit the attention of Internet managers, but are of little concern to average consumers who are trying to compare the quality of ISPs.

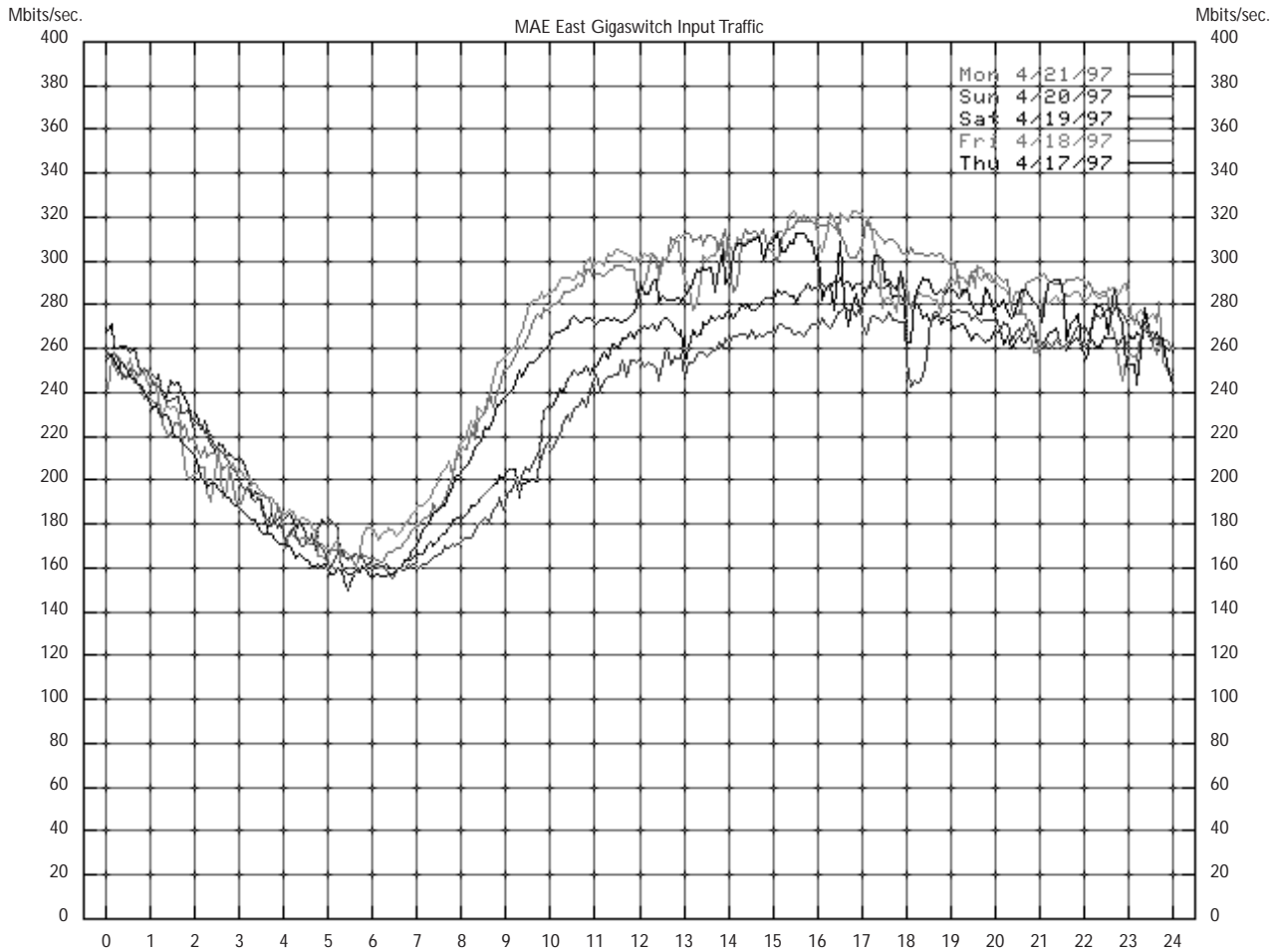
The results of studies measuring Internet congestion

Despite these difficulties, a number of studies have attempted to determine the level of, and the change in, QoS. Each uses a different methodology – dropped packets, delays, router flapping – and in most cases, a decline in the quality of service has been found.

Delays and dropped packets

Aside from measuring actual delays in sending or acquiring information from the network, the degradation of QoS is best observed through the loss of information associated with dropped packets. When routers have to handle many packets simultaneously, some packets are placed in a queue in memory as

◆ Figure 9.5. **MAE East gigaswitch utilisation – five-day composite**
 Five-minute averages of the sum of input traffic over all gigaswitch ports



Source: <http://www.mfsdatanet.com/MAE/east.giga.overlay.html>.

others are routed to the next router on a first-in, first-out basis. Problems arise when the memory buffer of a router becomes filled and newly arriving packets are “dropped”. When a packet is dropped it is not lost – the protocol (IP) registers that a packet has been dropped and retransmits the dropped or damaged packet, thereby generating more traffic and leading to further congestion and possibly even more dropped packets. While applications like e-mail can withstand such delays, they are unacceptable for others, such as financial transactions or real-time scientific experiments. The present lack of QoS guarantees makes satisfying demands for reliable “high-end” service nearly impossible.

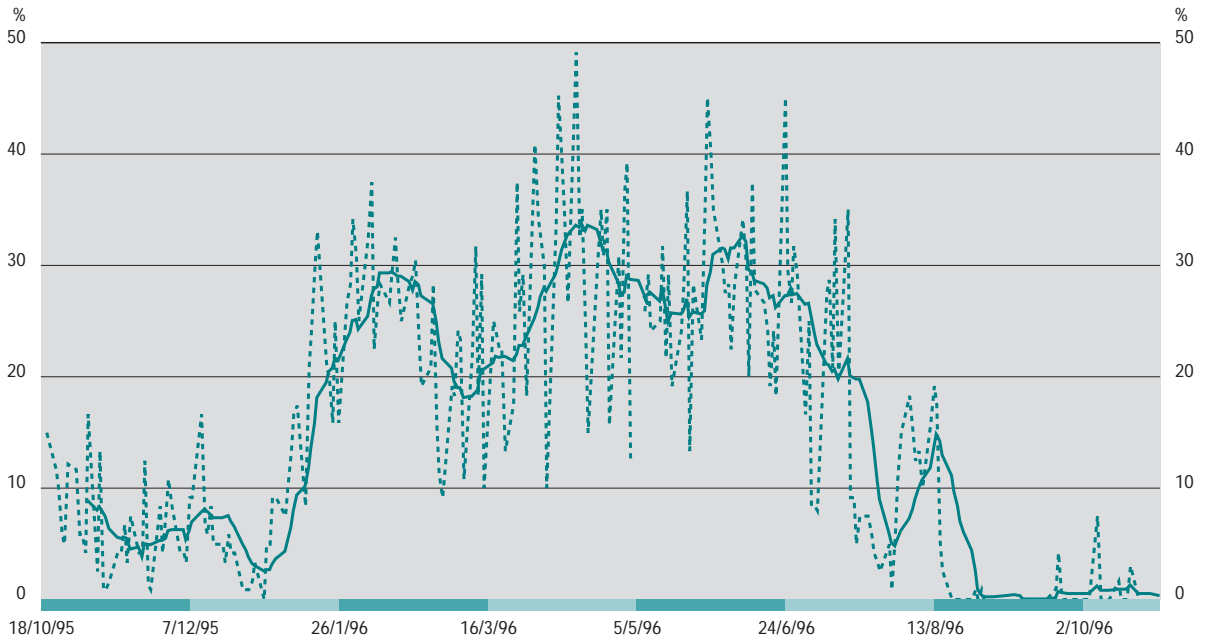
The National Laboratory for Applied Network Research measured the evolution of the QoS at ten

US locations (<http://www.nlanr.net/Viz/End2end>). The same message was sent hourly between the locations, and the time required to transfer the message as well as the volume of information lost en route were recorded for each transmission. The experiment, which was carried out for approximately three months, ended in April 1996 and led to two conclusions:

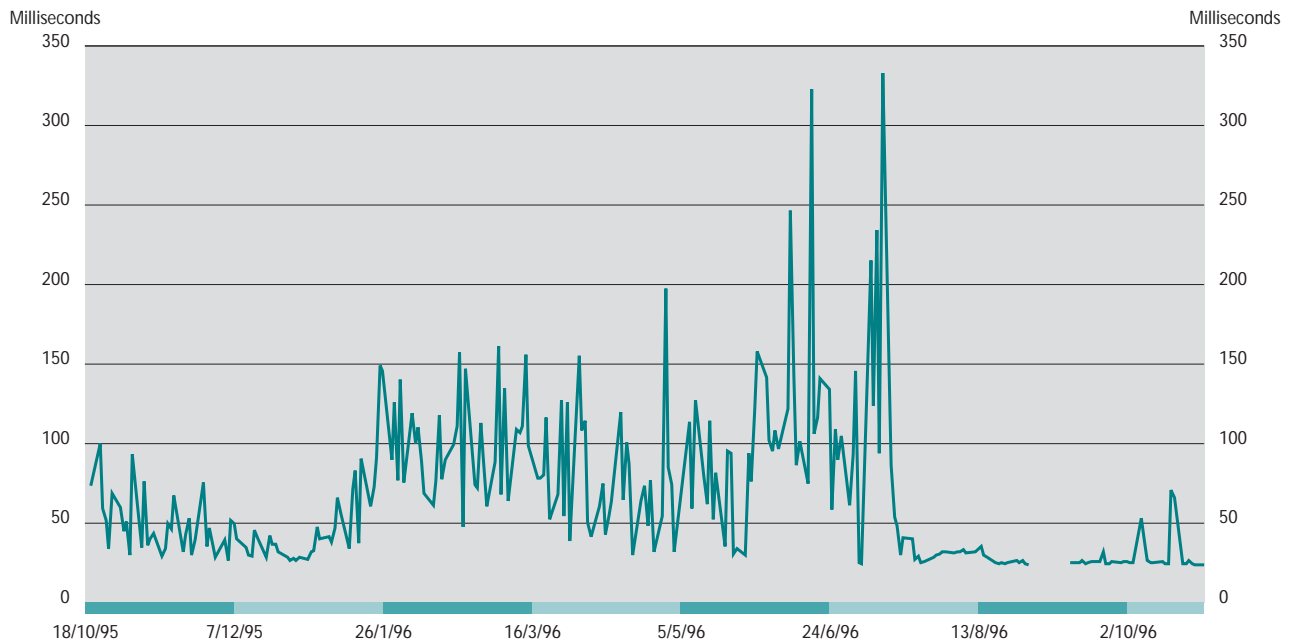
- QoS varies greatly over the course of the day, and the aggregate level of traffic may rise or fall by 40 per cent from one hour to the next.
- While bottlenecks change rapidly, some patterns were associated with particular parts of the Internet. For instance, it seems to be easy to reach Berkeley, in California, from Boulder, in Colorado, whereas QoS is less satisfactory

◆ Figure 9.6. **Packet loss and delay**

9.6a. **Percentage of packet loss**
 Day-to-day data excluding weekend days
 Actual data and two-week moving average



9.6b. **Delay**
 Day-to-day excluding weekend days



Source: The Routing Arbiter (<http://www.ra.net/statistics/trend/delay/aads.192.157.69.250>; raw data are available at <http://www.ra.net/statistics/trend/delay/aads.192.157.69.250.loss0.dat>) last update 10/29/96.

when connections are established from Silicon Valley or Urbana-Champlain, in Illinois. This suggests that some weak points in the Internet topology could be defined and improvements made.

The goal of the Routing Arbiter Project, a Merit/ISI (Information Science Institute) collaboration funded by the NSF, is to provide routing coordination for the new NSFNET architecture. In this context, it evaluated the number of packets lost at NAPs. Figure 9.6 shows the percentage of packets lost from messages between two points during the working week over the last year and a half, as well as the delays incurred. As the MIDS data show, delays vary considerably, but there is an obvious upward trend until summer 1996. On average, about 20 per cent of packets were lost and on particularly bad days losses reached 40 per cent. The data suggest that the network was suffering from overuse and that the QoS decreased over that period. The most recent figures show a sharp decline over the summer months, possibly due to new capacity or to a seasonal decline in use. However, the number of packets lost started to increase again after August.

A relatively comprehensive study examined QoS across a number of different dimensions (Paxson, 1996). Using the "traceroute" command, the study analysed 40 000 end-to-end route measurements between 37 Internet hosts located across the United States and at selected sites in Australia, Canada, Norway, France, the United Kingdom, South Korea, Germany, and the Netherlands. The experiment was conducted in 1994 and 1995 to observe changes as the management of the Internet shifted from NSF to private businesses. Table 9.2 summarises the results for the different problems encountered. The second column gives the probability of observing the problem in each of the two experiments; a "-"

indicates a stable trend while a "/" marks a change. In no case did the incidence of a problem decline, and in several cases increases were significant. Overall, problems doubled. While it is difficult to infer a trend from only two data points, especially for an atypical period, follow-up work using data from the second quarter of 1996 confirms the upward pattern in routing instability (NSF, 1996b).

Routing instability

Much of the pressure on the system is concentrated at the interconnection points where ISPs exchange packets and where the different backbones meet. In particular, as the number of routes on the Internet grows, a problem is arising for maintaining routing stability across the system. The Routing Arbiter Project reports that routing instability is growing at an "exponential rate" and that large levels of routing volatility can lead to a general degradation of service (lost packets, latency, service interruptions) (<http://compute.merit.edu/analysis/routing.html>). One indicator of this instability is associated with routers that turn on and off because of configuration errors, rebooting, software bugs, or severed network links – a phenomenon called "flapping". A flapping router forwards fewer and fewer packets, contributes to congestion, and causes traffic suddenly to stop and start, thereby creating a lurching which further aggravates congestion. While flapping routers can be bypassed by routers with software that recognises the problem, the only comprehensive solution is to update the routing tables to exclude the flapping router. However, this updating procedure diverts routers from their main task of forwarding packets, again contributing to congestion. If the problem were trivial, it could be treated simply as necessary overhead, but Internet core exchanges average about 5 million routing updates daily (<http://compute.merit.edu/analysis/>

Table 9.2. **Changes in Internet routing problems, 1994 to 1995**

Problem	Probability	Trend	Notes
Persistent loops	0.13%-0.16%		Some lasted hours
Temporary loops	0.055%-0.078%		
Erroneous routing	0.004%-0.004%		No instance in second experiment
Mid-stream change	0.16% // 0.44%	Worse	Suggests rapidly varying routes
Infrastructure failure	0.21% // 0.48%	Worse	No dominant link
Outage > 30 sec.	0.96% // 2.20%	Worse	
Total problems	1.5% // 3.4%	Worse	

Source: Paxson, 1996.

routing.html), a trend that is increasing despite the installation of flap-dampening software.

While an exhaustive study on Internet congestion that satisfies all parties does not seem possible, the studies that have been undertaken all indicate that Internet QoS varies considerably, and many have shown degradation over time. In such a fast-moving area, it is not possible to make a firm statement about what will happen on the basis of the past, but it is possible to look at the factors contributing to congestion and at some potential solutions.

3. REASONS FOR CONGESTION

Supply and demand have difficulty reaching an equilibrium in this market because of current market imperfections.

The “tragedy of the commons”

Some of the high growth in users and demand for bandwidth-consuming applications is due to the current pricing structure for Internet services, with most US users paying a flat fee for Internet access. This structure is partly a reflection of the Internet's roots in the scientific and educational community, where the emphasis was on research and knowledge rather than commercial applications, partly a reflection of extreme competition among US access providers, and partly the result of the US tradition of charging a flat rate for local calls. While different rates are in effect for different types of lines (e.g. T1 vs. T3, POTS vs. ISDN), the same price is charged for a given line whether use of the Internet is heavy or light, so that there are no incentives to ration what is in fact a limited resource. This leads to irrational and uneconomical behaviour. (For example, students use video conferencing software, CU-SeeMe, to provide real-time video streams of six different sites around the Monterey Bay region, including the Santa Cruz beach, at <http://sapphire.cse.ucsc.edu/SlugVideo/>).

The lack of clear price signals, combined with a very fragmented industry, creates a situation where there is little co-ordination and where users or access providers do not suffer the consequences of their actions. This situation recalls the “tragedy of the commons” associated with most public goods: as more and more farmers grazed cattle at no cost on “common” (public) land, it became overgrazed and worthless. The same holds for roads, water, and air, for example, where the price (frequently zero) fails to

reflect the costs imposed on others. For example, driving a car pollutes the air, lowering its quality and imposing a cost on others (e.g. respiratory problems). If those who drive cars pay no price for using the air or inflicting respiratory problems on others, they will have little incentive to stop polluting. Only through mechanisms like taxes or regulations will they “internalise” the pollution costs.

The problem of congestion on the Internet is similar. Because the price is low, users have no incentive to economise on its use, and they therefore engage in uneconomical activities. The externalities imposed on other users come in the form of delays or lost (dropped) packets (a type of pollution). While some aspects of the Internet, like the ability of a single user to wreak havoc on the whole system (e.g. a “hacker” shutting down an ISP) are even more prone to the tragedy of the commons, others, like the fact that much of the congestion felt by users is probably local and private in nature or the fact that capacity can be increased, make the analogy tenuous. Thus, it is important to identify the source of the congestion: congestion on the backbone or at the routers is more public in nature while delays associated with users' connections or computers are more private in nature. But as noted above, current information makes it nearly impossible to identify the exact location of the congestion.

Technical problems for differentiating service

To keep the system simple and hold overhead to a minimum, the protocol used for the Internet (currently Ipv4) mainly includes in the “header” of each packet information about the destination of the message. It does not allow for prioritising messages on the basis of users' needs. This made sense when the profile of most users was similar, but today users' needs differ and congestion does not impose the same costs on all of them. Even though some would be willing to pay more to avoid congestion, the protocol makes no provision for this. Currently, the only means of prioritisation is based on the port from which the message is sent. In 1987, because of congestion on the Internet, routers on the NSFNET were programmed to give priority to remote terminal sessions using the TELNET over users transferring file with the FTP procedure. This was dubbed the 1987 priority scheme. Unfortunately, it is very easy to circumvent this scheme simply by switching to the higher-priority TELNET port.

The contribution of market imperfections to congestion

Although the situation is quickly changing in countries such as the United States, some of the congestion observed can be attributed to market imperfections associated with regulations that precluded entry and thus the addition of new capacity. These imperfections take two broad forms: restricting access to the existing communications system and prohibiting systems not previously considered as "communications", such as cable, to offer communication services such as the Internet.

In two-thirds of OECD Member countries, PTOs have been granted a monopoly over the communications system; they therefore control the amount of capacity made available for the Internet. PTOs have an incentive to protect their voice transmissions business from Internet competition by allocating very little capacity to the Internet or charging relatively high prices for access. Comparisons across countries with different regulatory environments suggest that this is in fact the case: in the nine countries with the lowest access charges, only two are monopolies (OECD, 1996*f*). Clearly, market structure has an impact on the price and thus on the rate of connections. Even where the PTO gives independent ISPs access to its facilities, the level of competition is relatively low because it is very difficult to compete in terms of the quality of service to final users when all providers purchase access to the same backbone at the same price.

The second imperfection reflects the technological advance of digitisation, whereby all categories of information and communication become indistinguishable and the logic that separated the different industries erodes. As the regulatory framework and the market catch up with this technological development, significant sources of new capacity are being made available through the integration of local and long-distance telephone, cable television and broadcast television and their respective wired, cellular, broadcast and satellite networks. As this evolution continues, new networks, such as electricity transmission, come on line. Converging to one "information superhighway" could provide scale economies and an integration of services that could have important implications for the structure of the market and competition. For example, Jones International Ltd., a major operator of cable television systems in the United States, has created a new operating unit, Jones International Channel, that has wired captive cable-television franchises with the capability to provide cable subscribers with high-speed access to the

Internet via a combination of coaxial and fibre-optic cable transmitting at speeds of up to 10 mbits/sec in both directions (*New Technology Week*, 8 April 1996, p. 4). In Japan, Sanyo, Mitsubishi and Sharp have all announced plans to produce televisions capable of connecting to the Internet (Reuters, 1996).

4. POTENTIAL SOLUTIONS TO THE PROBLEM OF CONGESTION ON THE INTERNET

Easing congestion can be achieved in one of two ways. The first is purely technical: increase network capacity or make it more efficient. The second is to implement pricing schemes that allow users to reveal information about their needs and thereby make the system more efficient.

Technical improvements

Network technology is likely to change a great deal. Pushed by high demand, research is being undertaken to implement more efficient technologies. These improvements are of four types: hardware solutions that increase the available bandwidth, updating the protocol to support more efficient use of bandwidth, improving the design of applications, and changing the architecture of the Internet.

Hardware

There has been considerable investment in research to improve the capacity of the backbone technology. In three different labs [Lucent Technologies, Fujitsu, and NTT (Nippon Telegraph and Telephone)], researchers have achieved one terabit communications speed (1 trillion bits/sec) through an optical fibre. Each used a different method (*Inside R&D*, 1996*a*). This is 2.5 times the previous record of 400 billion bits per second (gigabits/sec), achieved by NTT last year. (By comparison, an ordinary T1 line can only achieve 1 mbit/sec.) This speed makes it possible to download 100 two-hour movies in one second (*Business Week*, 1996). The technology is predicted to be available for commercial use in five years.

Many copper telephone lines can be updated using a chip called a digital signal processor (ADSL or xDSL for earlier versions). The problem with copper wires is noise, but the noise varies from line to line and from moment to moment. By choosing the least noisy frequency, the ADSL chip can increase the wire's capacity by an order of 1 000 (6 mbits/sec vs. 64 kbits/s), thereby making high-quality video transmission possible, although the speed of the

reverse connection (PC to the Internet) is much slower (640 kbits/sec). This is one solution telephone companies will use to compete with cable-television firms. Another will be to use a second generation of fibre equipment known as SONET (Synchronous Optical Network) which is capable of 155 mbits/sec and can be upgraded to 622 mbits/sec.

Private access to the Internet is also improving, with a move away from copper telephone lines. TCI, the largest cable company in the United States, and Kleiner Perkins Caufield & Byers, a leading venture capital firm, have joined efforts in @Home. A cable system is used to provide Internet service to PCs in homes in an experimental market now being launched at Sunnyvale, California.

Satellite communications are another potentially huge source of bandwidth. Hughes Network Systems has recently introduced a new service, DirectPC, which offers Internet access via a satellite dish; it allows users to download material from the Internet at speeds of 400 kbits/sec, although users cannot send information (Reuters, 1996; Sprout, 1996). Plans are under way to offer Internet access through Iridium's low-Earth-orbiting satellite projects and Teledesic's project, which specifically targets the Internet user. Teledesic users would be able to access varying amounts of bandwidth for high-speed data relays or video conferencing anywhere in the world and would be charged a price that would vary on the basis of bandwidth requested and time spent using it (Kupfer, 1996).

The sharp increase in the capacity of wires and fibre-optic cables and the promise of satellites have shifted the pressure to routers which can only handle a few gigabits/sec at present. Research money is also being directed to this problem. Cisco, which supplies about 90 per cent of the routers sold to ISPs, has plans to develop a 40 gigabit/sec router but is hampered by

the need to provide value-added services such as RSVP (see below) and statistics on each packet (Weinschenk, 1996). DARPA recently granted BBN a contract to develop a multi-gigabit router capable of processing several gigabits/sec of data by dividing the router's functions into three parts: forwarding engines responsible for examining the datagram headers, interfaces responsible for moving the datagram, and a management subsystem that maintains routing tables, etc. This would increase speed by a factor of four to eight (<http://www.ito.darpa.mil>).

As new technologies are developed and deployed, yesterday's "state of the art" is becoming commonplace. Netscape's 1996 system for supporting Internet traffic to its site suggests what the average business might look like in the future (Box 9.2).

Changes in the protocol

Changing the communication protocol standard used on the Internet may be another way to alleviate congestion. The two most promising developments involve deployment of ATM (asynchronous transfer mode) cell-switching and a new Internet protocol, Ipv6, coupled with a new reservation protocol, RSVP.

ATM

ATM is a "cell-switching" technology designed for future high-speed networks. Like TCP/IP, it breaks the data stream into packets to make efficient common use of the lines. The major difference is that ATM, unlike TCP/IP, creates a "virtual circuit" (VC): when a message is sent, a path is chosen and all the cells of the message follow the same path. This has several advantages.

- The standard can be applied to all types of data networks (e.g. telephone, video, Internet) and the International Telecommunications

Box 9.2. Netscape's Web site: a look at the future?

Netscape's Navigator browser registers nearly 80 million "hits" a day on its servers. To accommodate this demand, Netscape has installed three T3 fibre-optic cables from two different suppliers (MCI and Sprint), ensuring Netscape both geographic and technical diversity. Access to Netscape's Web page is provided by 30 servers, each equipped with 128 megabytes of RAM and capable of handling 4 000 connections. To spread the load of the demand for their product worldwide, Netscape plans to develop "server farms" in Paris, Stockholm, Sydney, Tokyo and Hong Kong.

Source: Garfinkle, 1996.

Union (ITU) is promoting it as an international standard.

- Because all the cells (packets) take the same route, the header needs to carry less information (the VC identification number) than an IP packet which needs a complete destination address. This saves on bits in the header and makes the tables of all possible destinations stored in the router smaller and thus faster to read, thereby speeding the routing process.
- An ATM router chooses one end-to-end path for all the cells of a message. While time-consuming, this method supports a higher quality of service: since all cells take the same route, it becomes easier to measure traffic, predict transmission time, and support differentiated levels of service.
- Billing is simpler. It is much easier in an ATM environment to see who originates the message and how long the virtual circuit (VC) stays open.

Currently, ATM networks operate at 155 mbits/sec and can be upgraded to 622 mbits/sec, while Internet backbones not using ATM currently operate at 45 mbits/sec. ATM switches are currently deployed on two of the four NSF-designated NAPs and along the backbone maintained by MCI. When one gigabit communications speed becomes available for commercial use, ATM will be the only protocol able to support it. Finland was the first country to deploy ATM technology widely. It did so in mid-1994. It has the highest concentration of Internet penetration in the world, with 300 000 people connected out of a population of 5 million; this is about twice the penetration rate for the United States ("Finlande number one", *Le Monde*, 24 June 1996). The Finnish example is significant because it is the leading access provider for most European countries. Thus, the era of ATM switching has already arrived for many European Internet users.

ATM is not, however, the solution to all Internet congestion problems. ATM has two shortcomings with respect to the Internet. The first is that ATM was developed for telephone traffic; Internet traffic behaves differently. Telephone traffic is quite predictable over time, with relatively small statistical variance across days, while Internet traffic is "bursty" and fractal (Leland *et al.*, 1993). (A fractal has "self-similar" properties, *i.e.* the shape of the statistical distribution remains the same at all levels of observation.) Thus, unlike telephone traffic, which takes on a predictable, smooth pattern as the level of observa-

tion becomes larger (days or weeks instead of minutes), Internet traffic has bursts that do not fall into a predictable distribution at more aggregate levels of observation. This makes it difficult to optimise a network to handle averages or peaks and undermines the capacity of ATM to ensure QoS. Thus, "MCI turns off ATM's attempt to guarantee QoS in the face of unpredictable traffic" (Garfinkle, 1996).

ATM also suffers from some technical limitations that will limit its use for solving the problem of Internet congestion. In order to send a stream of packets together, an ATM switch must collect all the packets in memory. Given the "bursty" nature of packet traffic, ATM switches will have to have huge memories (*e.g.* 192 megabytes) to buffer the packets, and this will cause their cost to increase significantly (Garfinkle, 1996). In addition, ATM cell switching will be hampered in its ability to ease congestion by the fact that a cell has a set length (53 bytes), unlike IP packets which can vary. Since five bytes are reserved for the header in an ATM cell, roughly 10 per cent of the cell is overhead, a substantially larger portion than for IP. In many cases, the fixed cell length means that not all cells are filled with data, resulting in an overhead rate of roughly 30 per cent (Garfinkle, 1996).

Ipv6 and RSVP

Even if ATM dominates as a switching technology on the backbone, the Internet community will still rely on the TCP/IP protocol as the standard to and from the backbones. TCP/IP (currently Ipv4) is to be improved with the update to Ipv6, scheduled for large-scale implementation at the end of 1996. Among the improvements are an extension of the address length from 32 to 128 bits. This will allow a huge expansion in the number of Internet addresses.

In terms of alleviating congestion, the most important change in Ipv6 is its support of the creation of "tunnels" (see glossary) that will allow the implementation of the Resource Reservation Protocol (RSVP). This can be done by stipulating the same path for each packet of the message, effectively creating a tunnel through which all the packets pass. This will reduce fluttering (rapid changes of the path chosen by routers) and is a good support for RSVP.

Because RSVP allows computers to distinguish between different applications, a user can reserve bandwidth for specific applications such as audio or video transmissions ("streaming" applications), thereby reducing delays and "choppy" transmissions. For example, a conference organiser can request

2 mbits/sec of bandwidth for the next hour from Brussels to San Francisco; the routers will then be informed that they need to keep this amount of bandwidth available for the user. Even if some routers on the path have not implemented RSVP, the average QoS of the connection will be better. The protocol has been running experimentally for the past two years, and more and more routers are implementing it (<http://www.ietf.cni.reston.va.us/html.charters/rsvp-charter.html>). The effect on market structure may be significant, since the price for RSVP service will probably be usage-based.

Mbone

More marginal protocol changes that promise some easing of congestion are also under way. For example, AT&T has developed a virtual network, Mbone (Internet Multicast Backbone), on top of the basic protocol. It sends the same message only once to reach a wide number of final destinations. Designed to broadcast video or heavy memory applications (e.g. an audio stream), Mbone creates a virtual network of tunnels connected to different islands, thereby allowing all packets to flow through one route. Video is then sent to the islands, to which final users connect to receive the video. Thus, rather than sending the video message to individual users (i.e. 100 messages), Mbone only sends the message to the islands (i.e. 10), thereby significantly reducing heavy bandwidth traffic on the Internet backbones, but doing little to relieve local congestion problems. Recent NSF work shows that, to date, deployment of Mbone technology has been unco-ordinated, resulting in many redundant Mbones and "an unnecessary waste of scarce Internet bandwidth resources" (<http://www.nlanr.net/Viz/Mbone>).

Rather than a single protocol, the future is more likely to hold multiple strata of protocols with ATM as the base, Ipv6 operating on top of that, and RSVP as the protocol that differentiates service.

Application-level improvements

As one observer recently noted, "We are running a third-generation Internet but with first-generation apps" (Humphrey, 1996). However, software that optimises the use of Internet is being developed. Since 1990, the World Wide Web has used the hypertext transfer protocol (HTTP) as an application-level protocol that can be used for many tasks (i.e. naming servers and distributing object management systems). Currently, sending a message using

HTTP entails initiating a different TCP session for each object (e.g. embedded graphics or icons) encountered, resulting in a low ratio of web flow to idle time, which is perceived by the user as slowness or congestion (Moskowitz, 1996). The next versions of HTTP (1.1 and 1.2) permit these objects to be "coalesced" into one session, as the information is sent in a row rather than through a number of small connections. This technique, called "persistent connections", should reduce the amount of user waiting time.

Software that compresses messages can decrease the amount of traffic on the Internet. The results achieved from this technique can vary enormously: a typical text file can only be compressed to about half its original size, but an image can be compressed further. Usually each point (pixel) of a picture uses a number to represent a particular colour, but if an area is uniform in colour, the compression software will use one data point to represent the whole field and thus significantly reduce the size of the transmission. New developments such as FLIIT (Fast Lossy Internet Image Transmission), use forward error correction: the receiver reconstructs fragments lost during transmission, so that the compressed message concentrates on the portions of the image with greatest visual impact. In tests over a transcontinental Internet connection where 11.5 per cent of Internet packets on average are lost in transmission, FLIIT took 0.8 second to 2 seconds to transmit, while TCP/IP took 1.4 second to 12.3 seconds (*Inside R&D*, 1996a).

Software such as search engines and personalised news, which download information to the user off-line at off-peak hours, have the potential to smooth out some of the traffic flowing across the Internet. For example, NetCarta's CyberPilot Pro uses maps of WWW sites so that users can browse off-line and then connect directly to pages of interest instead of proceeding slowly from one site to another while on line. The same idea is being applied to software that automatically downloads designated Web pages to file servers, allowing quick retrieval without direct connection during downloading (*Washington Post*, 1996).

Changes in network architecture

Caching or mirroring is a way to decrease the need for access to the network by keeping the most popular addresses in memory. For example, if a Web site located in Europe is very popular, it would be efficient to copy it to Japan for use by Japanese users,

thereby cutting down on the need for connections that span the globe. The solution is technically available for all sites but is impractical for sites such as those with news that are updated regularly. Caching also raises some complex legal issues since cache systems can be seen as infringing copyright protection. It also deprives the authors of the Web site of information about users that may be of commercial significance.

Nevertheless, with some experts estimating that up to 90 per cent of Web traffic emanates from 40 to 50 Web sites, caching is a useful means of easing congestion (*The Economist*, 1996a). The UK network community is trying to reduce the amount of transatlantic Internet traffic by using six Web cache sites in Britain. Since November 1995, a similar system has been in place in Israel, where all university Internet traffic is required to go through cache servers. In the United States, the NSF is developing a cache procedure in collaboration with Digital Equipment Corporation, whereby caches will be placed at six strategic points across the United States and will be extended internationally as other countries and regions (New Zealand, Australia, England, and Africa) participate.

Latent demand

As promising as these technical solutions to Internet congestion are, and some have even predicted a glut of bandwidth in the future (Gilder, 1994), their impact cannot be evaluated without considering corresponding changes in demand. So far, the Internet market has been driven by a kind of Say's law: supply has always created an equivalent, or even larger, level of demand. In fact, it is likely that the true level of today's demand is unclear because much of it is latent and will appear when new capacity is available. Recent experience shows that it takes only about six to 12 months for demand to exhaust the latest generation of installed equipment and that it takes anywhere from three to four months to deploy an update (ordering the hardware, laying the fibre, and reconfiguring the system to achieve higher speeds) (Garfinkle, 1996).

For example, as cable television and other high-speed connections are made available, latent demand for radio on demand, distance learning via video conferencing, or advertising video clips will emerge, exhausting the new capacity. A recent survey of traffic at one connection point (Fix-West) showed that while multimedia represented only a small portion of the "conversation" (0.01 per cent), it represented over

20 per cent of the byte traffic during the sample period (<http://www.nlanr.net/NA/learn/survive.html>). Some companies have banned recent products such as PointCast, which provides real-time news and advertising as a screen saver, owing to the demands they make on company networks; new browser features such as Netscape's proposed InBox Direct, which allows tailored HTML (hypertext mark-up language) pages from different publications to be delivered directly to a user's e-mail box, could generate daily transmission of files exceeding several megabytes (*InfoWorld*, 1996a). Even if a small portion of Netscape's users take advantage of this function, there will be a significant increase in traffic.

Other examples of latent demand abound: on-line universities, telemedicine, electronic commerce, home automation and security, traffic monitoring, on-line vending machines, etc. In addition, there is demand from new users coming on-line as cheaper and easier-to-use Internet devices ("appliances") become available or as world demand begins to match that in the United States.

Price-based solutions

Pricing offers a longer-term solution to congestion. An enormous number of variants can be aggregated into two approaches: middlenets and true congestion pricing.

Middlenets

In the short to medium term, the most important price-based solution to congestion will be offered by networks that lie somewhere between the Internet and the intranet, the so-called middlenets (Gurley, 1996). Each middlenet is a community that has formed to uphold certain shared values as an alternative to the norm that prevails outside the community. America On-Line (AOL), for instance, offers its subscribers differentiated content and guaranteed performance within the confine of its networks. It also gives subscribers a simple link to the greater Internet beyond its borders. Another kind of middlenet, the virtual private network, is growing quickly. A firm located in two cities will ask its Internet provider to guarantee a certain QoS between its two sites. Because the access provider can modify the TCP/IP for its internal needs, such a service is feasible as long as the message goes through its network. NSF envisions universities segregating traffic into different classes based on QoS required and routing this differentiated

traffic to different networks (<http://www.cise.nsf.gov/ncr/nsf96-64.html>).

Other examples include the NSF-sponsored vBNS backbone, which connects five NSF supercomputing centres at 155 mbits/sec on an ATM network. The vBNS is intended to provide bandwidth for cutting-edge network applications and scientific research, which have suffered from Internet congestion (Germain, 1996). Citing concerns over congestion, diffusion of responsibility, and the general fear that the Internet will not evolve quickly enough for their needs, several universities are banding together to form another a private middlenet dubbed Internet II (Deloughry, 1996).

A number of access providers provide a two-tier contract. The first tier is for the usual simple connection while the second includes a commitment to QoS. During periods of congestion, users opting for the second tier are guaranteed a minimum QoS level. The scheme's shortcoming is that it only functions within the provider's network, so that such contracts are only useful to users whose traffic mostly takes place within the provider's network. Moreover, during periods of congestion, the first-tier users will have very poor QoS since, during periods of congestion, even less bandwidth will be available to them than would normally be. A broader implication of using middlenets to reduce congestion is that they segment the network, thereby reducing the positive externalities associated with network economies and interoperability of services across the Internet.

Congestion pricing

Reflecting the frustration of scientists who once enjoyed the Internet as a private resource but now must share it with the wider public, Ellen Germain recently wrote in *Science*:

Clever technology may succeed in opening some fast lanes on the Internet for scientific users who need high capacity. But many Internet researchers say that keeping those fast lanes from clogging like the rest of the Internet will also require a pricing structure, so that when the network is congested, bandwidth will go to the users who pay extra for it. Congestion pricing may conflict with the egalitarian culture of the Internet, but the technology for implementing it is within reach. (Germain, 1996)

While this view is open to debate, pricing schemes that, unlike the current flat-fee model,

somehow account for differences in use are at the centre of many of the proposed solutions to Internet congestion. Advocates argue that pricing would make the network not only "smarter" but also more equitable: it is estimated that, currently, 20 per cent of the users account for 90 per cent of the traffic (MacKie-Mason and Varian, 1994). Thus, light users in effect subsidise heavy users. Rather than differentiating QoS through price, information service providers simply offer "best-effort" service to the wider Internet but make no guarantees.

Economic theory suggests some form of pricing based on use to cope with congestion; this would force users to internalise the cost (congestion) they create for others. Given the flexibility of computer networks, a price signal should lead to a more efficient distribution of demand, with low-priority use shifted to off-peak hours, thus easing congestion. Four variations on this basic concept are frequently proposed:

- *Capacity*: This is a flat-rate scheme which has been segmented to reflect access to different bandwidth capacities and is in effect the one in use today; users pay more for a T3 line than a T1 line but do not pay extra for differences in volume. The main problem with this proposal is that it only limits congestion on the user's line; it does little to reduce congestion beyond that point.
- *Volume*: Users pay for the number of megabytes sent and received and receive a discount for off-peak use (Brownlee, 1995).
- *Time*: Users pay for time used. This mechanism provides some incentive to conserve during periods of congestion, as the cost to send a bit increases as the system slows down, but it does little to force users to internalise the cost of congestion since they all face the same marginal cost (more time) during periods of congestion, and there is no mechanism for discriminating between users. A peak-time pricing system would alleviate this problem, but, as discussed above, it is difficult to identify stable peak times.
- *Priority*: In one variant of this scheme, usage pricing would only be applied when QoS drops; at other times a flat fee would prevail. When the system is congested, the packet header would be read to see what bid the user gave to get that packet onto the network at that time (zero would preserve the current flat-fee scheme). The network gateway would sort

bids in descending order and admit those with the highest bids until performance dropped, charging all packets admitted the bid of the packet with the highest priority that was not admitted to the network (MacKie-Mason *et al.*, 1995).

Some industry experts are sceptical of schemes based on usage pricing because of the accounting overhead that would be generated and the complex settlement process for service providers (OECD, 1996f, p. 6). Moreover, in many cases, the benefits are the receiver's, not the sender's. (A similar problem exists for telephony and has been solved through billing services that charge the receiver, such as green numbers in France and 800 and 900 number in the United States.) It is possible that the distributed computing power of the Internet would reduce the severity of accounting problems. Usage-based pricing arrangements are already operating in New Zealand, Chile and the US Department of Defense and are in place for Australia and MCI (<http://www.sims.berkeley.edu/resources/ifocon/pricing.html>, 20 February 1996; Lang, 1996).

Another argument advanced against usage-based pricing is that it would eliminate the egalitarian, democratic nature of the Internet, work against the promotion of research and education, reduce widespread use and penetration, and stifle the present creative innovation. It is difficult to analyse these claims, but an experiment with usage-based pricing in Chile is attributed with slowing Internet development (Baeza-Yates *et al.*, 1993). Also, many major Internet developments (*e.g.* the Mosaic browser, GateD) have emanated from universities, where Internet use has been prolific. Likewise, in countries that lack the relatively high penetration of the United States, usage-based pricing might very well limit the development of the Internet.

In conclusion, the most likely pricing scheme of the future will probably be not be any one single model but some combination of the four schemes listed above. Users will pay a flat fee for "best-effort" service, and when QoS must be ensured, the new RSVP protocol will be used to reflect a user's priority, with a corresponding usage charge.

5. POLICY IMPLICATIONS AND OPTIONS

The Internet is not likely to "melt down" in the near future, nor is there likely to be a bandwidth glut that will make Internet use "too cheap to meter". The question is how to accommodate the anticipated

explosion in demand for bandwidth-consuming services and to ensure that the system has the reliability and quality of service needed to support an information economy and society.

While government intervention to solve the congestion problem is undoubtedly not necessary, governments do have a role to play. Government played an important role in establishing the Internet, and government has an interest in maintaining infrastructures that are important to economic development. In fact, several broad policy areas deserve consideration.

Promotion of research

The inability of any one firm to appropriate the returns from basic research implies that such research should be performed or subsidised to some degree by the government. A number of research areas are worthy of consideration, such as funding the development of new hardware and software, especially the routers and router software which have been identified as central to easing congestion (NSF, 1996b, p. 15). In addition, governments should include research on the behaviour and management of the network, such as developing methods for improving the collection, analysis and use of measures of Internet traffic and QoS, and using this information to develop traffic models (*egress and ingress matrices*)³ that better account for self-similarity traffic patterns.

Demonstration projects

The government has traditionally played a role of test bed for new technologies, establishing the feasibility (or the lack thereof) of especially risky technologies that exceed the tolerance of the marketplace. DARPA played this role for the initial Internet 30 years ago. While there is little rationale for government to continue to play a core role in the development of the Internet today, it can continue to make useful contributions of a more marginal nature (*e.g.* the development of the RSVP protocol).

Promote infrastructure competition

Empirical studies indicate that the pricing schemes in markets where PTOs retain monopoly control slow development of the Internet. By maintaining high underlying charges for capacity, PTOs restrict the growth of "dial-up" and leased-line Internet access services. This suggests that the causes of Internet congestion are not merely technical and

that increasing capacity is not the whole solution to the problem. Issues such as the full integration of different networks and regulatory reform are also potentially central elements of a solution.

The technology involved in these networks is changing very fast, and it is impossible to foresee which technologies will provide the basis of the future architecture. In such an environment, liberal market access has proved to be the most efficient market structure for promoting innovation and ensuring a structural adjustment consistent with supply and demand. In the absence of an open and free market, it is likely that the economic and social benefits governments foresee from the development of an information economy and society will be delayed.

Promote regulatory safeguards

Many have argued recently that, to reduce congestion, governments need to become more directly involved in the planning and operation of the Internet (Welch, 1996). This concern is due to the fact that the industry is currently very fragmented, so that there is insufficient co-ordination and planning. In particular, ISPs sometimes refuse to share information with others owing to the sensitive competitive nature of the data. Experts complain that issues crucial to the Internet – routing table growth, unfriendly or broken TCP implementations, and address size and structure – have not been resolved because of lack of co-ordination and co-operation. While few want direct government regulation, some suggest using the threat of government regulation to motivate the industry to organise itself (NSF, 1996b).

A non-regulatory alternative would be to have a trusted third party (possibly government) acting as a co-ordinator, as has been done in sectors such as semiconductors (SEMATECH in the United States) and more recently multimedia (the Multimedia Services Affiliate Forum – MSAF). The government could provide a forum for interindustry discussion, planning and research. Government or another third party could collect, analyse and package the sensitive data so as to protect competitive information but still provide a basis for mutually beneficial planning. Given the global nature of the Internet, this would have to be undertaken in an international context. A proposal to establish such a forum, the Co-operative Association for Internet Data Analysis (CAIDA), has been made to the NSF. But the usefulness of such an organisation is tempered by the fact that few ISP engineers now have the time to participate in existing Internet forums such as the North American Network

Operators Group (NANOG) or the Internet Engineering and Planning Group (IEPG) (NSF, 1996b, p. 4).

Reducing market imperfections by providing better QoS information

A more economically efficient alternative to regulation is to reduce the market imperfections that currently lead to an imbalance between supply and demand and thus generate congestion. One step towards this goal would be to provide consumers with better indicators of services. Currently, the only measures by which consumers can judge a service are cost and other customers' opinions. Service indicators are needed so as to develop a market where consumers can differentiate demand on the basis of service characteristics. To date, ISPs have been reluctant to develop such indicators because the current technology of the Internet is "not amenable to that [level of] control" (Sean Doran, NSF, 1996b, p. 6). Moreover, compiling some of these QoS indicators could breach the privacy of individual users. Nonetheless, if ISPs do not provide such information, large users will either collect it themselves (e.g. the Automotive Network Exchange, some educational institutions) or hire third parties to do it for them. With many evaluators using different methodologies, unreliable and misleading indicators are the likely result, causing even more confusion and doing little to solve the imperfections of the market.

An alternative would be to engage in research on which data can be most feasibly collected to provide sufficient information on the quality of service. As both a huge user of Internet services and a neutral third party, government could play a key role in arbitrating the development of standard measures and their use. This has been done for many other industries: the government, sometimes through regulation and other times through coercion or agreement, has overseen the development of indicators that provide consumers with information that is useful in the marketplace; examples include nutritional data on packaged foods, automobile fuel efficiency estimates, and common performance reporting standards for financial investments. Government could play a similar role to help consumers identify different levels of service on the Internet.

6. CONCLUSION

The huge growth and rapid evolution of the Internet has revealed weaknesses in the system, most visibly in terms of congestion. While this is unfortu-

nate, the system has shown impressive resiliency to date. Solutions to the problem of Internet congestion are likely to reflect the nature of the Internet itself: a loose conglomeration of different hardware and software that has been networked together by borrowing ideas and technology from a wide variety of sources and then allowed to evolve. In this vein, no

one solution will solve the problem of congestion. Rather, it will be a variety of techniques – more capacity from a variety of sources, an evolving system of protocols (ATM, IPv6, RSVP), and a variety of pricing schemes – that are likely to support the Internet as its role evolves.

NOTES

1. Internet congestion has become a very popular topic in the non-technical press; the following is only a small sample: William Gurley (1996), "It's the End of the Net as We Know It", *Fortune*, 26 April; Peter H. Lewis (1996), "Traffic Jam on the Internet", *International Herald Tribune*, 25 June; "The World Wide Wait", *Infoworld*, 26 August 1996; Lester Welch (1996), "Government Leadership Needed to Rescue Overworked Internet", Commentary, *New Technology Week*, 15 July; Margot Williams (1996), "Plan Ahead to Survive Network Traffic Backups and Crashes", *The Washington Post*, 1 September 1996.
2. One of the most outspoken critics of congestion on the Internet is Bob Metcalf, inventor of the ethernet and founder of 3Com Corp. See for example, "Predicting the Internet's Collapse", *InfoWorld*, 4 December 1995.
3. These are standard practice in telephony, where different carriers can see incoming and outgoing calls between carriers on a per call basis. However, ISPs do not now have this possibility, and the means to do so would be somewhat more complicated owing to the use of packet switching and the lack of the virtual circuits that exist for telephony.

COMPONENT SOFTWARE

1. INTRODUCTION

The software industry changes constantly: new types of software, new versions of existing software, new approaches to creating, managing, and communicating data. Software innovations are often labelled “revolutionary” or “groundbreaking” although existing software technologies remain relatively untouched. However, one new group of technologies, collectively referred to as component software, may bring about very great changes. Component software is likely to affect how software is changed, how easily innovations reach consumers, how consumers select software applications, and the environment within which applications compete. It also redefines some basic concepts in computer software, such as “document” and “application”.

Component software technologies provide a range of capabilities. Some, such as Sun Microsystems’ Java, deliver components over networks. Others, such as Apple Computer’s OpenDoc, focus on tight integration of small software components. Still others, such as Microsoft’s OLE and ActiveX, offer some capabilities in both of these areas. All have the potential to rewrite many of the rules that previously governed the software marketplace. This potential has not gone unnoticed. In less than a year, Java went from an obscure development project to industry-wide acceptance. The US National Institute for Standards and Technology is currently spending US\$150 million annually on projects to study better ways to create component-based software (Joch, 1996; also, <http://www.atp.nist.gov/atp/focus/cbs.htm>). Component Integration Laboratories (CI Labs), an industry association of computer companies developing component software, was chosen to receive the InfoWorld Magazine’s 1995 Landmark Technology Award for its OpenDoc technology (*InfoWorld*, 1996c). Major computing companies such as Microsoft, IBM, Apple, and Sun have recently released major products that incorporate or enable component software.

This section of the Outlook describes component software, discusses how it differs from conventional software, provides an overview of some of the major technologies, and considers its implications for consumers, developers, and the marketplace.

2. WHAT IS COMPONENT SOFTWARE?

The major technologies

Component software involves a range of technologies with different basic capabilities. Three of the most important commercial architectures for component software are Java, OpenDoc, and OLE/ActiveX.¹ All three have already been deployed, although the effects are just beginning to be felt. They differ substantially in their focus.

Java is a set of technologies for writing, transmitting, and executing platform-independent programmes. The two core technologies are the Java language itself (an object-oriented high-level programming language) and the Java Virtual Machine (a virtual computer that executes Java code using the computational resources available on a specific platform). Java makes it possible to transfer small applications (often called applets) across networks for execution on any computer with a Java Virtual Machine. For example, a piece of Java code could be written on an IBM mainframe, transferred over the Internet, and executed on a computer using an Intel chip and the Microsoft Windows operating system. In fact, Java applets can run on almost any computing device, provided it is equipped with the Java Virtual Machine.

Java was developed by Sun Microsystems, and was released in 1995. Since then, scores of hardware and software vendors have announced their support, including Microsoft, Apple, IBM, Oracle, and Netscape. Java is available for all major computing platforms, including Windows, Macintosh, and Unix. It has a number of security features that allow users to download and run applets without having to worry about malicious acts. The Java language itself and Java compilers are designed to prevent malicious

code from being generated; all code is screened before execution to ensure that an altered compiler was not used to produce unsafe code, and additional platform-specific security features can be implemented to help ensure, for example, that a downloaded application will not erase a hard disk or cause a machine to crash.

OpenDoc is a component software architecture that focuses on integrating the functions of many small components. It is a set of technologies that extends an operating system and allows components to work together, creation and storage of compound documents, scripting and automation, and interoperability with other component software architectures such as OLE and Java. It can be used in several ways. An editor component can create and edit part of a document, such as text, table, or graphic. A viewer component allows part of a document to be viewed but not edited. Finally, a conventional application can be slightly altered to be a container for parts created by OpenDoc editors.

OpenDoc was originally developed by Apple Computer, but it is now managed by CI Labs, a non-profit industry association that licenses, validates, and registers OpenDoc software. CI Labs was founded in September 1993, and OpenDoc was first released in late 1994. The association's five major sponsors are Adobe, Apple, IBM, Novell, and Justsystem, the world's largest Japanese software vendor. Other members include: Oracle, Lotus, the Object Management Group, the X Consortium, the Interactive Multimedia Association, and the Intelligent Pad Consortium. As of autumn 1996, CI Labs had over 2 000 members in 50 countries, with three-quarters in the United States and one-quarter in Europe and Japan.

There are versions of OpenDoc for nearly every major computing platform, including Windows, Macintosh, OS/2, and Unix. A large number of software development firms announced their support of OpenDoc in 1996, including Adobe, Claris, Digital, Novell, and Oracle. Several major development environments support the creation of OpenDoc components.

OLE (object linking and embedding) and *ActiveX* are two related technologies that provide application integration and network delivery, respectively. OLE allows conventional applications to share functions. It can be used, for example, to embed a portion of a Microsoft Excel spreadsheet into a Microsoft Word document. With both Excel and Word loaded, a user can edit the spreadsheet directly (using Excel commands) within the Word document. ActiveX enables

interactive content for the World Wide Web. Like Java, ActiveX can be used to create simple multimedia effects, interactive objects, and sophisticated applications.

Both OLE and ActiveX were developed by Microsoft Corporation, and are based on a common core of technologies. OLE is an integral part of Windows 95 and other Microsoft operating systems and is incorporated into many software applications by Microsoft and other vendors. As of mid-1996, Microsoft supported ActiveX on its Windows operating systems, and it was working towards support for Macintosh and Unix operating systems (Microsoft, 1996a). As of late 1996, 14 companies that create Web design and development tools had built ActiveX support into their products, allowing users to create and make use of ActiveX controls in their programmes. In July 1996, Microsoft announced plans to pass specifications and appropriate technology for ActiveX to an independent standards group. Microsoft's likely contribution will be specifications and source-code reference implementations on multiple platforms, including Unix and Macintosh (Microsoft, 1996b). No similar move has been announced for OLE.

Competition, unity, and synergy

In many ways, component software technologies are in competition. Two of the principal ones, OLE and OpenDoc, largely overlap. Some consider that OpenDoc is technically more sophisticated than OLE,² and OpenDoc has been designed so that OpenDoc-compatible components will also be compatible with OLE; therefore, software designers can achieve two goals while adhering to a single software standard (Apple Computer, 1994). However, OLE has been on the market for several years as part of Microsoft's Windows operating environment, while OpenDoc is a more recent introduction. In addition, OLE is incorporated into many existing applications and is the preferred technology of Microsoft, the market leader in many software categories.

Competition also exists between Java and ActiveX. Both provide a way to deploy applets over networks. However, Java appears to be gaining an early lead because of its wide availability and its focus on platform independence. In addition, ActiveX's approach to security is very different from Java's: it relies on a registration process that verifies the origin of certified applets, rather than severely limiting the damage an applet can inflict with this approach, however, ActiveX applets can, for example, be specifically designed to shut down a machine that

runs them (Andrews, 1996). Ultimately, Java's approach may better satisfy users' security concerns, although ActiveX's may suffice for many purposes.

In many essential aspects, however, these technologies are oriented toward common goals. First, they all attempt to break conventional applications into smaller chunks (components or applets), or at least to allow large applications to share functions. Second, all have been strongly influenced by the growth of computer networks and collaborative work. Java and ActiveX focus on delivering code over networks and OpenDoc presumes that users can download viewers freely from networks. Third, all three attempt to facilitate the use of heterogeneous computing platforms. Java applets can run on any platform with a Java Virtual Machine; OpenDoc relies on strong data standards to allow components to access files, regardless of what hardware and software were used to create them. Finally, all have similar effects on the software industry, albeit for different reasons.

Interestingly, the remaining differences in the technologies may offer the potential for synergy between them. For example, several OpenDoc components already provide a way to deploy Java-based applets within any OpenDoc document. A Sun initiative called JavaBeans facilitates the interaction of Java applets with components from other frameworks such as OpenDoc. OpenDoc itself contains a technology called "component glue" that allows OpenDoc components to interoperate with components based on OLE technology. Component glue allows programmers to create OLE components using OpenDoc's framework, and it also allows OLE components to look like OpenDoc components within OpenDoc.

Collectively, the technologies contained in Java, OpenDoc, and OLE/ActiveX offer a range of important capabilities. Some subset of these technologies is nearly certain to succeed in the software marketplace, with profound effects on how software is created, distributed, and used. In order to show the capabilities of these technologies, it is useful to consider the two poles of the spectrum: integration and networked delivery.

Integration

Conventional software applications are organised around tasks. Today's word-processing applications, for example, contain the functions necessary to write documents, including text editing, spell checking, page layout, to create graphics, tables,

and equations, and even to access and create documents on the Internet. In contrast, component software which focuses on integration is organised around functions. Instead of using a single application to write a document, one uses a set of software components, each of which fulfils a single function. The same components are also used for other purposes, such as composing e-mail or editing a database. Each component is smaller than a conventional application, but interacts closely with other components to produce greater quality and quantity of functions.

An advantage of this approach is that software components can be combined in different ways, depending on the user's needs. A biologist can use a specialised speller component to check reports and e-mail messages; a mathematician can use an equation-editing component to add equations to technical papers and Web pages; any user can add network capabilities to a document by using a Web-browsing component.

Software components have been likened to the hardware components of computer systems or stereos (e.g. system unit, keyboard, and monitor; tuner, amplifier, tape deck, and speakers). Users can "mix and match" components as they wish because the components share a set of standard interfaces. For example, a document with text, a graphic, a table and a live data link to the Internet, all arranged in a particular layout, also has available a set of ancillary functions, such as spell checking and grammar checking. Where a conventional application handles all these functions together, component software separates them. Thus, a user who is editing text and wishes to edit a graphic merely clicks on the graphic, deactivating the text editing component and activating a graphics editing component. The menus change to provide access to relevant commands, as do any associated palettes or toolbars. If the size of the graphic changes, the other components are informed and change their size or shape appropriately. Similarly, the spell checking component can access and change text in the text part.

Networked delivery

Conventional software is organised around long-term use. A user purchases a software application (e.g. a word processor), installs it, and continues to use it for a period of months or years. The version installed must be compatible with the particular hardware and operating system of the user's computer. When a new version is released, the user must

update the application, a process that can be tedious and time-consuming.

In contrast, component software approaches that focus on networked delivery provide for small applications, often called applets, to be downloaded over a network and run immediately. These applets can be run within a software environment that interprets between the applet and the particular hardware and software configuration of the user's machine. This allows a single applet to run on nearly any machine.

Consider, for example, an application for placing an order from an on-line catalogue. Under a conventional software model, users would have to download, install, and run a custom-built application specifically written for their hardware and software configuration. Unless a customer placed regular orders with a given vendor, it would be difficult to justify the time and potential expense of downloading such applications from vendors and subsequently updating them. With component software, however, vendors can write an order application that will run on any machine with the component software architecture. Users can download and run the applet each time, because applets are generally far smaller than conventional applications.

3. EVOLUTIONARY AND REVOLUTIONARY CHANGES

Stanford University economist Brian Arthur notes three important features of the software industry. The first concerns the software product: users incur relatively high costs when switching among different hardware and software products. The second concerns the software development process: software is expensive to develop but cheap to produce. The third concerns the environment in which software operates: networks of users want compatible software. These three features lead to what Arthur calls increasing returns to scale: the products of large firms are favoured over those of small firms. Increasing returns create market imperfections, as large firms can achieve near monopoly power and certain technologies, sometimes inferior ones, can become "locked in" (Arthur, 1989; also, Arthur, 1996; *The Economist*, 1996b).

Component software, however, can affect all three features. It lowers switching costs by breaking software products into smaller, interoperable components and by delivering components that can run on nearly any computing platform. It can lower development costs by allowing software to be written in more

manageable units. Finally, it can change software compatibility by allowing a single component to run on multiple platforms and by enforcing strong data standards.

The product: software applications

For most computer users, size constitutes a principal change in recent computer software. The number of features contained in applications has increased dramatically, as has the amount of disk space consumed and the amount of memory required (Figure 10.1), owing to the variety of sophisticated functions that are now built in, as noted above. Users, even those whose needs are relatively modest, purchase, store, and load complete applications, some of which they will use only in part and infrequently.

When users decide to switch between conventional software applications, high costs are incurred because they must change not only how they edit text, but also how they carry out other functions. While switching costs have been lowered somewhat by the consistency of modern graphic user interfaces, substantial retraining may still be necessary because so many functions change at once.

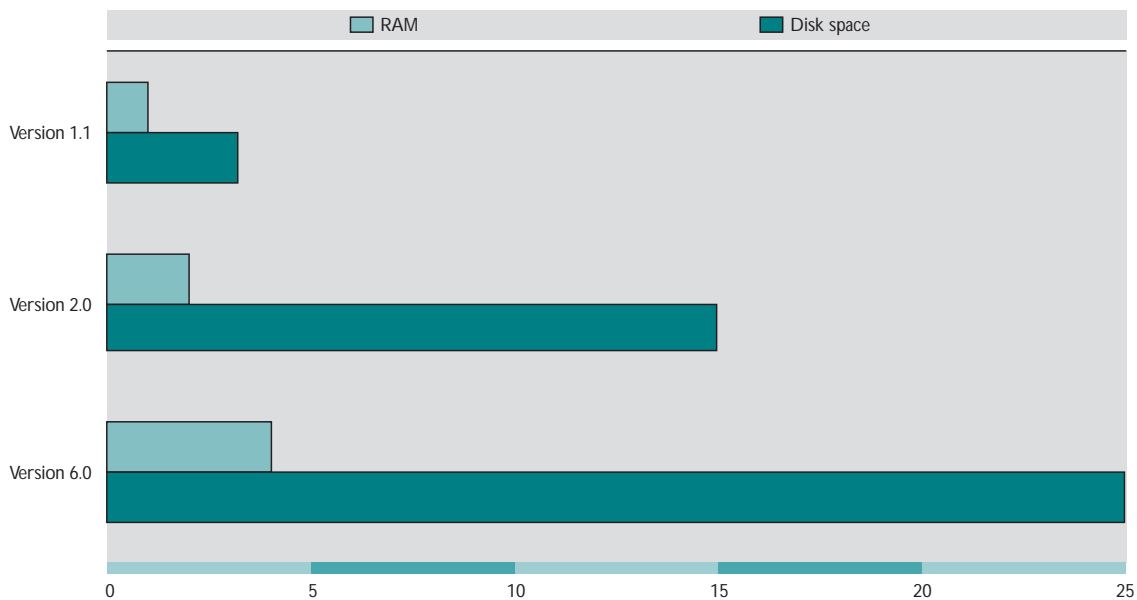
Component software that focuses on integration addresses these concerns by allowing users to select software by function, rather than accepting a collection of functions bundled together. The functions can be combined to meet the user's needs, rather than those determined by the vendor. In this way, users do not have to learn the conventions of several different applications, all of which fulfil the same basic functions.

Component software that focuses on networked delivery can also decrease switching costs. First, as noted above, components written using technologies such as Java work on any hardware and software that supports the Java Virtual Machine. Second, because applets are downloaded and opened automatically, users are not faced with the installation and maintenance problems posed by conventional software.

The process: software development

The problems users encounter with large applications have also been reflected in the software development process. Marketable applications have become much more difficult to design and implement because, to be competitive, they must contain many functions. For example, if a software designer develops a radical innovation for text editing, it will have

◆ Figure 10.1. *Requirements for Microsoft for Windows*
Megabytes



Note: Requirements for full installation and use of Microsoft Word for Windows.
Source: *PC World* (June 1991, p. 158; April 1992, p. 162; March 1994, p. 160).

little chance of reaching the market unless it is embedded in a word processor able to edit graphics, tables, and equations and check spelling and grammar.³ Because the economics of marketing and distribution favour large, expensive applications, it can be very difficult for a developer to market a small, focused application successfully. Small software developers find it increasingly difficult to compete in established software categories, and the innovations they can offer are delayed or lost. As a result, the production of many classes of computer software, once havens for small innovative firms, has become increasingly concentrated in large firms such as Microsoft, Apple, and Corel. Microsoft alone earns nearly half of the world's total PC software revenue (Gleick, 1996). These firms are the only ones with the resources to produce, market, and support large applications.

This concentration has occurred despite the growing acceptance of the validity of object-oriented programming (OOP). Proponents have long touted OOP as a way to bring the software industry "into the 20th century" by enabling software to be constructed from small pre-built units, just as standard mechani-

cal and electrical parts are used in physical products. In theory, at least, OOP should allow small firms to specialise in producing objects for specific jobs (e.g. objects for displaying scrolling lists of items or handling menus), while other firms purchase and use those objects to produce applications.

OOP may yet lead to a more sophisticated market for computer software. However, the market for objects is still relatively small, and most developers work with objects provided by their development environment or objects they construct themselves. OOP techniques have helped improve the management of large development projects, but mostly because they facilitate a well-defined division of labour within a company, not because they facilitate more sophisticated relationships among firms.

Component software may be able to fulfil many of the promises of OOP, although at a somewhat different level. Objects carry out low-level functions and are sold to software developers; components carry out high-level functions and are sold to consumers. An object might handle as small a task as managing the display and actions of a menu, while a

component will handle as large a task as page layout or checking spelling.

Despite these differences, however, component software has the potential to simplify greatly the development and sale of innovative software. A software developer who finds a way to improve text editing dramatically can produce a text-editing component. Freed from having to reproduce other functions, developers can concentrate on what they do best. Users can substitute that component for their existing text editor and expect it to function smoothly with their components for other functions.

Put another way, component software takes concepts from object-oriented programming and uses them at the level of software applications. Component software duplicates some of the advantages of OOP,⁴ but at a level accessible to users as well as programmers. Component software does not replace OOP,⁴ but it allows individual developers to use different languages and programming environments to develop components that can communicate and interact because the component software architecture serves as the communication medium.

Component software that focuses on networked delivery will affect software development as well. First, developers can create a component that will function on nearly any platform. This frees them from the tedious process of producing versions for different platforms. Second, rather than distributing software through software resellers and catalogues, companies can sell applets directly over electronic networks. While major questions remain about security of payments made over computer networks, several schemes have recently been created, and their use is growing.

The environment: increased collaboration and networking

Increasing collaboration is also a key motivating factor for developing component software. Users want to share complex documents and applications over electronic networks, but face problems because of disparate hardware, operating systems, and applications. In general, each application has its own standards for storing data, and many applications are only available for certain hardware and operating system platforms. While translation software has enabled some collaboration, translation is constantly trying to keep up with increasingly complex data standards. In particular, documents that include items of many

types (e.g. text, graphics, video, audio, and numeric data) pose particular problems.

The Internet offers some of the best solutions to this problem. On each hardware platform, there are applications for carrying out standard functions (e-mail, web browsing, telnet, etc.). Relatively standard data types, such as hypertext mark-up language (HTML), Graphics Interchange Format (GIF), and Joint Photographic Experts Group (JPEG), have been defined independently of the software used to access them. Documents containing these data types can be communicated across electronic networks and used without concern for the combination of hardware and software used to create them. While the programmes that create documents using some formats are relatively expensive, the programmes to view content are relatively inexpensive (and sometimes free).

These solutions were born of necessity: nearly all aspects of the Internet were designed for collaborations using a variety of hardware and software. While this consideration was not the sole basis of component software architectures such as Java, OpenDoc, and OLE/ActiveX, it has paved the way for acceptance of components. Many users' initial experiences with the potential advantages of component software will occur while they are using the Internet, and most component software architectures allow the platform independence that facilitates collaboration.

However, component software architectures that emphasise integration, particularly OpenDoc, take data standards to a new level. They provide support for storing parts of documents in several formats, at least one of which is standard, so that a variety of components can access and alter the document. This provides a high degree of platform independence if documents are network-accessible. Different components (e.g. different text editors) could edit the same document, even if those components were run on entirely different platforms.

Indeed, component software for integration radically alters the traditional notion of a document. Today, documents are files created with a single software application. Documents "belong" to applications. With component software, instead, documents are related to a common focus rather than to the programme used to create them. Thus, a single document about a user's personal investment portfolio could contain a spreadsheet that lists investments and quantities held, a customised table of per-share prices that is automatically updated via the Internet, working notes about future investments, and links to

Web sites and e-mail addresses of companies and brokers.

The Internet encourages component software in another way. A large number of organisations wish to make custom applications available to users with various combinations of hardware and software. Now that network connections are becoming ubiquitous, the audience for an organisation's custom applications is growing tremendously. Custom applications such as electronic ordering forms and expense reports are difficult to deploy if separate versions must be created for each hardware and software platform.

Component software for network delivery can provide an easy way for such applications to be accessible to any user, almost regardless of their platform. In addition, there is no need to install and retain the custom software, because the necessary code can be delivered and interpreted each time it is needed. Finally, because new code can be downloaded each time, there is no risk of using old versions. Software updates are automatic and continual.

With network delivery of components, the nature of documents also changes, as they can contain content of nearly any degree of complexity without concern for the applications available to the user. With conventional applications, a user who downloads a document from a remote location must also have the applications needed to view it. With component software schemes such as Java and ActiveX, viewing capability can be packaged with the document itself.

4. FUTURE IMPLICATIONS

The impact of component software technologies largely depends on the degree to which the technologies are accepted into mainstream computing, and which technologies achieve market dominance. Not all component software technologies are in competition, but there are substantial overlaps, and developers can only focus on a limited number of new technologies at a time.

To a large extent, the forces affecting the conventional software market noted above also affect component software architectures: they are expensive to develop (but cheap to produce), the costs of switching between architectures is high for both users and developers, and networks of compatible architectures are advantageous for both users and developers. These forces are likely to produce one or two dominant technologies, and they will not necessarily be the optimal ones.

One of the most crucial factors in technological "lock-in" is early market momentum. Microsoft's dominant position in operating systems and applications certainly is contributing to the success of OLE/ActiveX. However, the tremendous growth of the Internet and the Internet's focus on platform independence have put Microsoft's technologies at something of a disadvantage. Sun's Java achieved nearly universal acceptance in less than a year – a remarkable achievement given that it was a relatively late entrant into the area of component software. OpenDoc has also gained substantial support from software vendors, although substantially less than Java. The next year will be crucial to achieving the initial market advantages that may lead to long-term dominance.

This issue of early market success is complicated by the way these technologies are entering the marketplace. Component software technologies that focus on integration are primarily being used by developers of commercial software products who expect to sell components directly to consumers. In contrast, component software technologies for network delivery are primarily used by in-house developers to create customised applications⁵ (Schlender and Brown in *Fortune*, November 1996). These separate markets may prolong the period before technologies are in direct competition.

As already noted, these technologies are both complementary and competitive. Java and OpenDoc have little overlap and substantial synergy; ActiveX and Java are largely competitors, as are OpenDoc and OLE. Thus, it is unlikely that a single component software technology will gain dominance.

Regardless of which technologies achieve dominance in the long run, widespread adoption of any one of them will lead to substantial changes for consumers, the software marketplace, and the environment for computing hardware and software. The changes may be subtle, but they will be pervasive. Early experience with OpenDoc, Java, and OLE/ActiveX suggests that users do not see a major difference in how they work, they merely perceive that their computers "work better" (Curbow and Dykstra-Erickson, 1995). However, the long-term effects on users and the software industry could be substantial.

Consumers

Component software will affect users in several ways. First, it will almost certainly affect ease of use, although it is not easy to predict the direction of

change. Components may improve ease of use by reducing the number of conventions a user must learn and increasing the range of application of those conventions. Desired functions such as text editing and spell checking will be available everywhere with a consistent interface. However, components may also make it difficult to know whether a co-worker will be able to view and/or edit all portions of a document. In addition, components may accelerate the proliferation of data types, particularly if vendors such as Microsoft lose market dominance and standard-setting bodies are not active in defining data standards.

Despite component software's promise to increase the seamlessness and functionality of computing, it seems certain to increase complexity. Rather than a single vendor per application, some users may be faced with dozens of vendors, each responsible for only a few of the components on the user's desktop. Each boundary between pieces of software carries the potential for error, and component software has many more boundaries than traditional applications. This point has not been lost on advocates of component software. For example, one of the primary purposes of CI Labs, the organisation responsible for OpenDoc, is to provide validation services and serve as a forum for developing data standards. In addition, it seems likely that some vendors will offer entire suites of parts, much as large vendors now provide software suites and "works" programmes that contain word processors, spreadsheets, and database applications. Such suites of components are more likely to work together.

Still, the advantages of component software could also be its downfall: it may require several, or even dozens, of components to view and/or edit each document. Users will probably not be aware of all the components needed to accomplish particular functions and may be confused by the sheer complexity of managing components. Accessing documents that are several years old, already a problem with conventional software, may become more difficult because of the number of components and translations required.

However, there are reasons for optimism. The increase of data types on the Internet (with multiple standards for text, images, sound, video) has been handled with relative ease because of the ideas that also underlie component software: free viewers and relatively consistent data standards. In addition, many approaches to network delivery of components are designed to be nearly invisible to users.

Second, component software is likely to put better, more customised software into the hands of a larger number of users. Component software for integration makes it possible to assemble special-purpose applications from quality components. Component software can also profitably address extremely small market segments. Because components can be combined at will, third parties, organisations, and even individual users can assemble applications to meet specific needs.

Component software for network delivery will also speed the distribution of quality components and ensure that a single component can run on nearly any platform. With technologies such as Java, developers can spend more time on developing a single, high-quality application, secure in the knowledge that it will run on many platforms.

Third, component software will almost certainly accelerate the trend toward increased use of computer networks. Some component software schemes, such as Java and ActiveX, are predicated on the presence of highly networked machines to which applications are delivered when needed rather than stored locally. OpenDoc, instead, assumes that users will access networks to download freely available viewers for particular types of data. In this regard, the growth of the Internet complements the trend towards component software.

The more extreme implications of Java could, in fact, radically alter the relative importance of networks and the computers linked to them. Sun, Microsoft, Apple, and other companies are already marketing inexpensive computers with little or no local storage. These machines, commonly known as network computers, are designed to function as access ports for large networks and rely on technologies such as Java to download and run applications. Network computers can greatly reduce hardware and support costs for companies, although such machines also reduce opportunities for customising a work environment and retaining private data.

Market and vendors

Component software will have important effects on markets and vendors. First, component software will affect the market itself. It diversifies market opportunities for software vendors. It allows individual components to address narrower market niches but still allows larger applications to be sold as collections of components.

Component software lowers barriers to innovation. Innovative components can be sold individually (or as part of a larger collection) without having to support other functions. This effect of component software is based on the simple economic premise of specialisation: products are produced more efficiently if individuals and groups can concentrate on what they do best.

While such software innovation is usually regarded as beneficial, merely increasing the pace of change may not be greeted with universal enthusiasm. Users and technical support groups within companies must already handle frequent software updates and other changes. However, component software should make changes less disruptive. Changing components, as opposed to entire applications, should produce relatively small changes, compared to what can occur when users are confronted with a major upgrade for an entire application. Network delivery could even make software updates entirely invisible to most users.

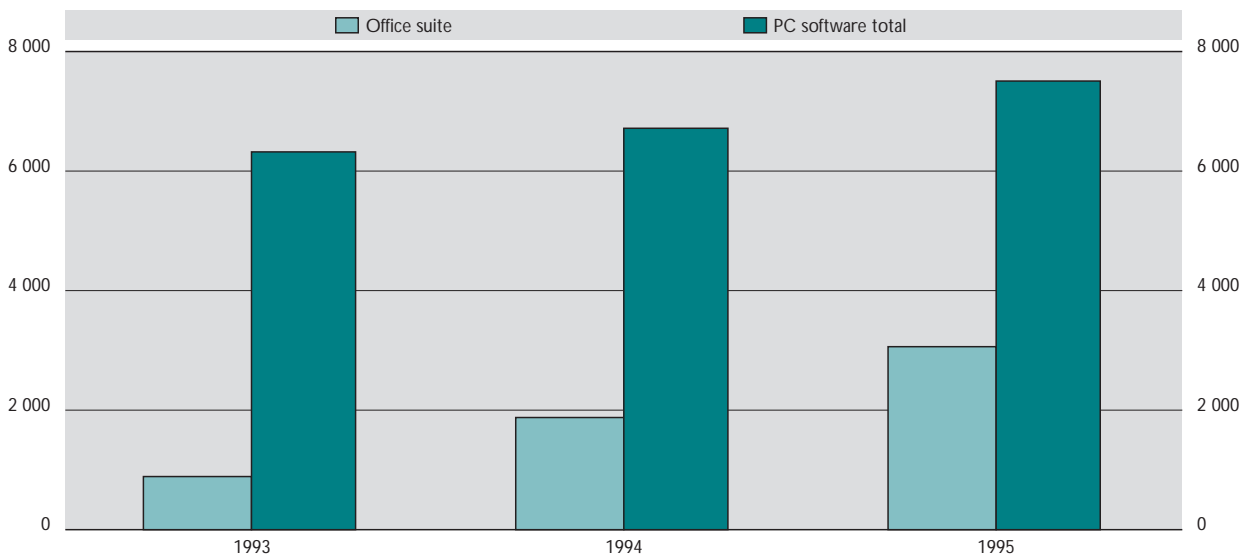
The most important effect of component software might be to reduce the importance of hardware and operating systems. Currently, much of the desktop computer market is controlled by Microsoft

and Intel, owing to the dominance of their operating system and processor standards. However, component software technologies reduce the importance of operating systems and hardware, particularly if technologies such as Java make platform-independence a reality for substantial amounts of software. In fact, Sun is relying on Java to change substantially the importance of hardware standards. It is marketing both Java-specific chips and network computers based almost entirely on Java-based applications.

Second, current practices of software bundling may be affected by component software, or they may affect the success of component software itself. Component software can lower switching costs for consumers, who can change one component but retain others. At present, however, vendors encourage users to purchase multi-application bundles, such as office suites, often with the argument that the bundled products are more tightly integrated than separately purchased products.

The question thus arises of whether software firms and consumers will move to component-based applications. Consumers' inclination to purchase applications suites (Figure 10.2) may be due to the integration that such suites offer, an advantage that

◆ Figure 10.2. *Growth of software "suites" revenue*
Million US\$



Note: Office suites include products of Microsoft, IBM/Lotus and Novell (Wordperfect, Borland). PC software data are for North America while office suites are world-wide figures. Office suites are estimated to account for one-third of world-wide PC software.
Source: Dataquest (1996b), Software Publishers Association (1996b).

might be better gained from components. However, consumers may also appreciate obtaining all their software with a single purchase and having only one place to call if problems develop. This advantage works against component software, and might lead consumers to reject software based heavily on OpenDoc and OLE as too complex for their purposes. However, if individual components are attractive enough, consumers might be willing to purchase them. If component software encourages innovation in the ways that appear likely, then components produced by highly specialised firms may entice users away from the security of dealing with large firms.

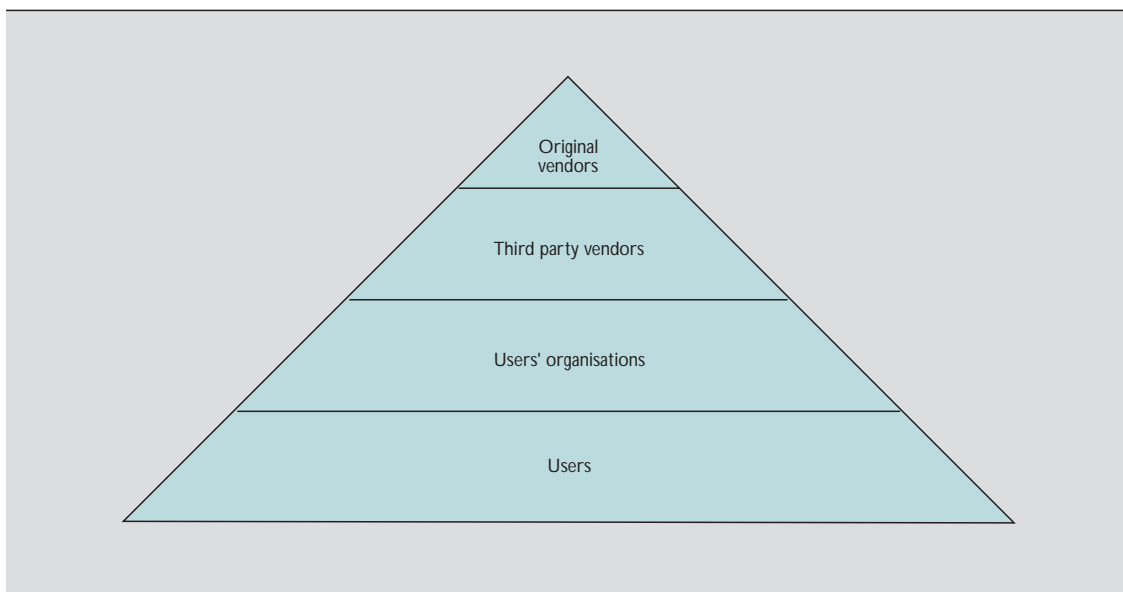
In the end, both effects will probably occur, with different users opting for different integration scenarios. Figure 10.3 shows the different possibilities. The bottom of the pyramid represents the most radical departure from current practice, with users assembling their own applications from components. At the next level are organisations, with their technical support offices assembling applications. Next come third-party vendors, addressing specific market segments with suites of components. Finally, at the top of the pyramid and representing the least change, are

traditional software vendors who create their products as suites of components.

The third likely effect on the market and vendors is an increase in the importance of standards. The success or failure of component software will depend largely on the success of data and software standards. For parts of a document to be accessible to multiple components, they must conform to strong and consistent data standards. Experience with data standards on the Internet has been mixed. While standards such as HTML and GIF are common, others have recently become a battleground for competing companies. For instance, non-standard extensions to HTML have been incorporated into several Internet browsers, and some have charged the relevant vendors (e.g. Netscape and Microsoft) with trying to define the standard so as to promote sales of their own products (Wingfield, 1995; Leinfuss, 1996).

Networked delivery of components effectively redefines the concepts of "application" and "document". Access to applications becomes a function of the network, not of a particular machine on that network. Thus, an organisation that deploys a Java application makes it available to anyone who can access

◆ Figure 10.3. *Integration scenarios*



Note: Users are the largest and most diverse group that might choose to integrate components. Users' organisations and third-party vendors represent smaller but still diverse groups. Original vendors represent the smallest change from today's software market.

the network. In addition, schemes for network delivery make it possible to deploy extremely narrow applications, which blur the traditional distinction between applications and documents. For example, there is little reason to create a traditional word processor that only edits a single document (e.g. an expense report), but Java makes it quite reasonable to deploy such an applet and to embed data (e.g. standard expense categories and organisation-specific spending limits) within it.

Standard setting for component software is already well under way. OpenDoc, originally developed by Apple Computer, was transferred in 1995 to CI Labs, which was founded by Apple, IBM, and several other firms, and was specifically chartered as a standard-setting group. In addition, CI Labs has worked with other standard-setting organisations, such as the Object Management Group (OMG) to coordinate OpenDoc with relevant external standards. As previously noted, Microsoft announced it would turn ActiveX specifications and technologies over to an independent standards body, with Microsoft as one of many members involved in decision making. More recently, Sun has been encouraged to submit the specifications for Java to an independent standards body to make it a truly open system (Berst, 1996).

Governments and private standard-setting bodies have a strong role to play in ensuring that standards processes are truly open and that individual vendors cannot unduly manipulate standards and markets to their own advantage. While there has been much concern over the market dominance of Microsoft's Windows, future concern could focus on component software standards such as Java, OpenDoc, and OLE/ActiveX. However, many component software trends could reduce such concerns, particularly the trend toward platform independence.

Environment

Finally, component software will strongly affect the software operating environment. First, vendors of component software will face a more complex environment. Rather than controlling an entire application, they will produce components that interact with other components, sometimes in unforeseen ways.

This may increase the burden of user support, already a major challenge to the software industry.

Second, component software will continue to increase the importance of large networks. As noted above, collaboration via networks is one of the forces driving component software. Networks will also advance component software by facilitating the delivery of components. If the pace of software updates increases substantially, distribution may become a bottleneck. Exchanging physical media (e.g. floppy disks, CD-ROMs), a tedious way to update software, will become increasingly outdated. Already, Java and ActiveX presume that applications are delivered via networks when needed. OpenDoc presumes that networks are available to distribute more long-lived components. Component software makes networked delivery more feasible, because components are smaller than traditional applications.

Finally, component software is likely to accelerate the trend towards a diversity of network access devices. Currently, most users access large networks through desktop or laptop computers. Component software, however, particularly technologies like Java and ActiveX, allow for providing important functions on smaller computing devices such as network computers and personal digital assistants. Java was in fact originally designed to link many small electronic devices together. This, in turn, will broaden the penetration and utility of computing into everyday life.

5. CONCLUSION

The next two years will be crucial for determining which component software technologies come to dominate and which recede into the footnotes of computing history. Regardless of the specific technologies, however, important concepts of component software integration and network delivery will produce evolutionary and revolutionary changes in the creation, sales, and use of computer software. In many senses, component software is the next logical step in an environment increasingly centred around electronic work and collaboration, yet it will also alter nearly every aspect of conventional software, as well as the very definitions of software, data, and networks.

NOTES

1. Throughout this chapter, component software frameworks are referred to by their commonly used name, which sometimes differs from their formal designation and from other designations for parts of the technology. For example, OpenDoc is officially the Distributed Component Software Architecture (DCSA), and components that have passed testing by CI Labs are referred to as Live Objects. All products mentioned are trademarks or registered trademarks of their respective companies.
2. "OpenDoc has become the more flexible, powerful, extensible and forward-looking object model, when compared with its closest business competitor, Microsoft Corporation's OLE'', writes Nicholas Petreley, executive editor of InfoWorld (*InfoWorld*, 29 January 1996, Vol. 18(5), electronic edition).
3. In the words of Alan Joch, Senior Editor of *Byte*, "The days when one programmer could bang out a commercial-grade application are over. The size and complexity of most applications are just too great for one mind." (*Byte*, January, 1996, electronic edition).
4. Indeed, nearly all component software will be created using OOP techniques. For example, Java is object-oriented, as are essentially all approaches to developing components under OpenDoc.
5. However, some vendors, such as Corel and Lotus, have committed to creating Java-based versions of their suites of office applications. Corel's Office for Java is slated to be shipped preinstalled on Corel's own network computer and, for a limited time, on Sun's line of Java servers (Corel Corporation press releases).

DATA MINING

1. INTRODUCTION

Until recently, business computing technologies were primarily oriented towards the storage and retrieval of data such as customer names, product prices, and inventory levels. Owing to the enormous progress in storage hardware and database software, firms can now easily retain vast amounts of information on customer purchases, product reliability statistics, and internal performance reports, yet the basic nature of data processing has not fundamentally changed.

Now, however, increasing attention is being devoted to interpreting that information. Data mining – the finding and representing of useful patterns in large amounts of data – is the focus of a new class of technologies, which are designed to help decision makers draw inferences from their stores of data and improve their understanding of customers, products, and markets.

Data mining is not a single technology or approach but a loose amalgam of techniques. Some, including statistical techniques such as linear regression, have existed for decades. Others have been developed much more recently. They have various names: data mining, data analysis, classification, knowledge discovery, machine learning, and on-line analytical processing. However, all are partly or entirely devoted to finding and representing useful relationships in very large quantities of data.

Data-mining techniques are novel because they are oriented towards discovering new patterns, rather than merely evaluating existing ones. Traditional statistical and database systems excel at answering questions such as: “How many customers from Helsinki purchased our product in March?” However, they are not suited for questions such as: “What are the characteristics of the customer groups most likely to respond to our promotional literature?” Questions such as this require searching through many possible relationships to identify useful ones. This is the task of data mining.

While some organisations have systematically analysed their databases for years, large-scale hardware and software support has been lacking. In the past five years, however, interest in data-mining applications has ballooned, and it has spurred the development of specialised software packages, hardware support, and consulting services to analyse data in the gigabyte (Gbyte) range. As a result, many more firms are undertaking data mining projects, particularly when their activities generate data in the normal course of business (e.g. shipping, mail order, and airlines).

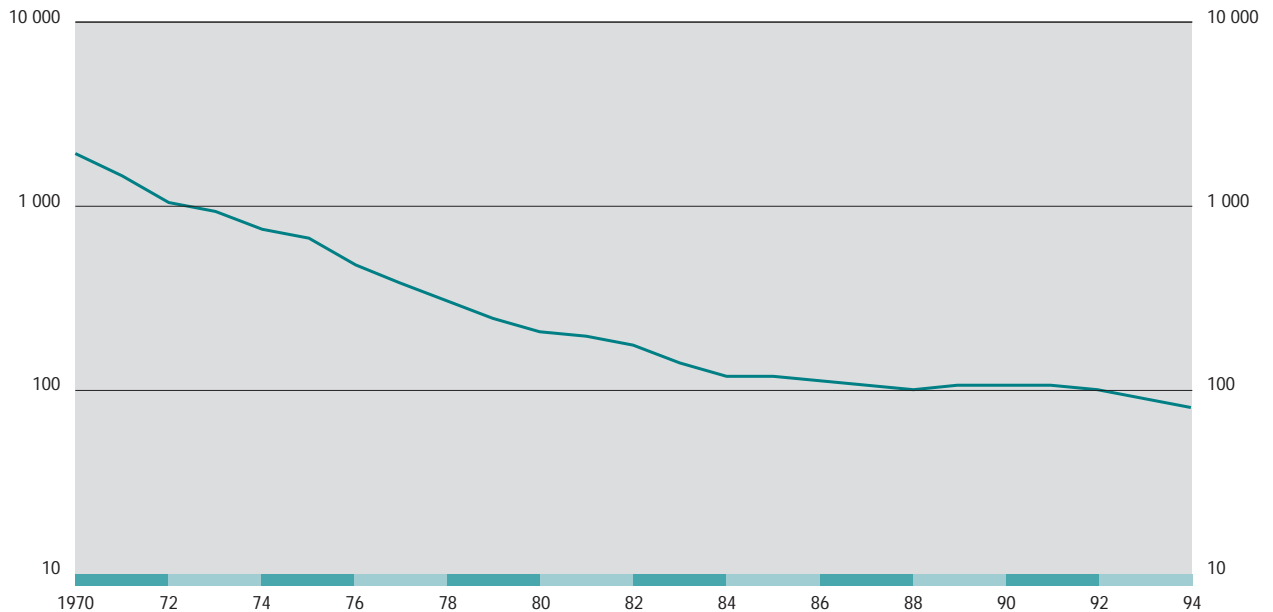
This section of the outlook introduces data mining, discusses how it relates to several other important trends in markets and information technology, provides examples of applications, and surveys the implications for consumers, firms, and markets.

2. BUSINESS TRENDS

Data mining is the inevitable result of several business trends.¹ First, businesses are collecting and storing larger amounts of data than ever before. The development and application of database software, along with advances in mass storage such as the storage density of magnetic media and development of sophisticated compression technologies, enable companies to retain information and make it available for internal and external use. With the sharp drop in the cost of storing large amounts of data (Figure 11.1), the use of database software has grown tremendously. One industry analysis found that 30 per cent of companies surveyed with databases larger than 100 Gbytes expected their databases to grow beyond a terabyte within the next year and estimated that in 1997 large databases would probably be at least twice the size of large databases in 1996 (Winter Corp., 1996).

Many of these databases are generated during normal business operations. For example, retailers regularly record the identity of each item sold and can often identify individual customers, on the basis of

◆ Figure 11.1. **US Price Index for Direct Access Storage Devices**
 Index, logarithmic scale, 1992 = 100



Note: Beginning with 1987, tape drives are included.
 Source: Triplet, 1996b.

credit or discount cards. These records can be used to study purchasing patterns.

For example, the US-based ShopKo Stores, a large retail chain, uses data mining in its advertising and merchandising departments (Datamation, 1996). It has discovered many “linked” purchases, *i.e.* items that are often purchased together. Moreover, many such purchases have links in one direction only. For example, a camera purchase is often linked to a film purchase, but not vice versa. Identifying these linkages allowed ShopKo to organise store layouts and promotional literature more effectively. According to Jim Tucker, Chief Information Officer of ShopKo, implementing data mining has been “worth millions” to the company.

The development of truly large databases (in the gigabyte and terabyte range) has spurred interest in what is now called “data warehousing”: organising large amounts of data and making it available company-wide. Data warehousing is an integral part of many data-mining efforts, because the quality of the relationships that can be discovered in data is related in part to the quality and quantity of data available. While it is possible to analyse data from

existing databases, such analyses frequently reveal problems of availability and quantity of data.

Another related trend, targeted marketing, has spurred interest in data-mining techniques. As communication technologies shift from broadcast media (*e.g.* television, radio, newspapers, magazines) to more personalised forms (*e.g.* e-mail, Web browsing, phone, direct mail), interest in how to customise the information provided to potential customers has increased. Data mining offers the potential to identify the preferences of specific customer groups and to indicate what sorts of promotional material most affect their purchasing habits. Similarly, identifying preferences can be used to target products for that group, particularly if the product allows efficient customisation (*e.g.* personalised electronic newspapers).

For example, Kraft Foods used data-mining software from IBM to analyse purchasing behaviour on the basis of point-of-sale data, among others, to help target its mailing of coupons to specific households (IBM, 1996a). Their project identified the groups of customers most likely to be interested in the coupons; they then used the profiles for coupon mailings, sending the most appropriate coupons to

each household. Although Kraft has not released specific results, they have expressed “delight” with the results, according to IBM.

The growing importance of the Internet has only encouraged this interest, because direct interactive links with consumers allow firms more opportunities to customise their advertising and products. In addition, the Internet may radically alter how advertising is conducted (Schrage, 1994). If consumers no longer obtain information primarily from broadcast media, they may choose to limit their exposure to traditional broadcast advertisements. Consumers may only visit a company’s Web site if enticed by customised messages or services provided at the site. “Narrow-casting” affects not only information but also the potential for advertising.

As reports and purchases are increasingly made electronically and handled automatically, the potential for some kinds of fraud increases. One of the most common uses of data mining is to detect fraud. For example, The Travellers Insurance Company uses an electronic fraud detection (EFD) system for detecting and undertaking pre-investigative analysis of healthcare fraud (Major and Riedinger, 1992). The system assembles detailed statistical profiles of each healthcare provider from records submitted for claims and compares them to profiles of other providers of the same type. Using the statistical profiles and built-in “rules of thumb” about the types of deviations that indicate fraud, the system can flag cases for further analysis. Fraud-detection systems based on similar principles are in use in the credit card and cellular phone industries.

A final trend in computing, increased processing power, has enabled widespread use of many data-mining techniques. Until relatively recently, it was not feasible to use some of the intensive search algorithms (see the section on technology below), except on some very small problems. Parallel and distributed hardware, along with appropriate software, have made it possible to apply a broader array of data-mining techniques.

These three trends have converged to encourage research, development, and application of data mining techniques. New research efforts on data mining have increased, and existing research efforts in fields such as statistics have coalesced around data-mining applications. Among the indicators of research interest are several technical workshops and a new annual conference, the International Conference on Knowledge Discovery and Data Mining, two new academic

journals,² and a number of recent books (e.g. Fayyad *et al.*, 1996).

This research proceeds hand in hand with commercial activity. The number of providers of commercial data-mining software and consulting services has increased dramatically in the past two years. The META Group estimates that the market for data mining software and services will be US\$300 million by 1997 and will increase to US\$800 million by the year 2000 (META Group, 1996). Box 11.1 provides three examples of large data mining projects.

While there is strong demand for the type of analysis that data-mining techniques provide, this does not necessarily indicate that data-mining techniques are mature and well-understood. While many techniques have been honed over decades of use, many others are still under active development and will be for years. As a result, some data-mining packages are collections of techniques that can only be used effectively by an experienced analyst. Data mining is still far more art than science.

This being said, data mining is also fast becoming an essential business tool. The understanding gained from data mining can improve a firm’s internal operations and marketing in a variety of ways. Examples include:

- *Strategic decisions.* Managers may want to know where to locate a new retail store. By evaluating the factors that influence the relative success of current locations, data mining can provide a way to evaluate potential locations.
- *Day-to-day decisions.* Managers often face repeated small decisions which collectively determine a business’s success or failure (e.g. credit approval). Data mining can provide rules of thumb to assist managers in making such decisions.
- *Targeted marketing.* With a limited advertising budget or sales staff, it may be important to target resources where they will be most effective. Data mining can indicate factors that help determine whether marketing efforts will succeed.
- *Fraud detection.* Credit-card companies, cellular communications providers, and others must guard against fraudulent use of their services. By constructing profiles of individual customers, unusual account activity can be automatically detected and reported.

Box 11.1. **Examples of data mining****Leeds Building Society**

The Leeds Building Society was established in 1848 and was Britain's fifth largest building society prior to its recent merger with the Halifax. Traditionally, such organisations use credit scoring to provide guidance on whether to grant a mortgage application. Credit scoring uses information on the applicant to produce an overall numeric score that indicates the level of risk involved in granting the mortgage. The Leeds, however, also wanted to predict potential arrears problems among their existing 500 000 mortgage accounts. It used data-mining software from Attar Software (in partnership with Price Waterhouse) to find rules for predicting arrears problems (*Mortgage Finance Gazette*, June 1994; http://www.attar.com/pages/case_1bs.htm).

The project produced a number of models that predicted potential arrears problems. In many, the risk factors were classic, but in others, they were surprising. One, the case of a loan involving a business introduced to the Society by a third party, was usually considered a factor that reduced risk. One pattern identified risks among customers with high incomes, risks that human analysts might tend to discount.

Financial Crimes Enforcement Network

The Financial Crimes Enforcement Network (FinCEN), an agency of the United States Department of the Treasury, was established in 1990 to support and assist federal, state, and local law enforcement agencies. FinCEN uses data-mining techniques to identify targets for investigations of money laundering and other financial crimes. The data-mining techniques are part of the FinCEN Artificial Intelligence System (FAIS).

FAIS processes approximately 200 000 reports a week on large currency transactions (bank deposits and purchases involving over \$10 000 in currency reported by financial institutions). Those reports are analysed using link analysis to establish whether there are related transactions that may indicate suspicious activity. These linked reports are combined with additional information from law enforcement and Treasury records (e.g. criminal referrals, customs service border crossing information), and analysts apply additional analytical tools to eliminate legitimate activities. As of May 1995, the system had generated over 400 investigative support reports corresponding to over US\$1 billion in potentially laundered funds (OTA, 1995c).

3. THE PROCESS OF DATA MINING

Data mining is difficult to describe. While many data-mining techniques have strong theoretical foundations and can be formally specified, the entire process is often experimental and iterative. However, one way to describe data mining involves five phases (Fayyad *et al.*, 1996):

- *Data selection.* A subset of all possible records is selected for analysis. They might be selected because prior analysis suggests they are potentially useful, and some sets might be excluded because they contain errors or are not representative.
- *Data pre-processing.* Known anomalies are removed and missing data dealt with. For example, missing data may be filled in on the basis of similar records, or may be assigned a special code to indicate its absence.
- *Data transformation.* The records are transformed in some way. For example, the values of new fields might be calculated on the basis

of old ones, the values in one field might be re-coded to facilitate analysis, or the selected data might be combined with another database.

- *Analysis.* One or more analysis techniques are applied. For example, a clustering algorithm might be used to indicate potential groupings of customers, or a modelling algorithm might be used to find the optimal linear combination of several variables that predict spending habits in groceries.
- *Interpretation.* The results of analysis are examined to suggest conclusions (e.g. urban dwellers spend nearly twice as much as rural dwellers on cosmetic products). These conclusions often suggest the need for new analyses and additional data.

Because interpretation of data mining results often produces additional questions, the process is almost inevitably an iterative one.

It is easy to overlook the steps prior to data analysis, but experience has shown that, while time-

consuming, such steps are among the most important. Mellon Bank has applied data-mining techniques to some ten projects over the past several years (SAS Institute Inc., 1996). The projects included credit card management, fraud detection, targeted marketing, and help-desk response. Often, the phases prior to analysis (data selection, pre-processing, and transformation) took longer than the other components of the process, accounting for 50 to 80 per cent of total time spent. Mellon's experience confirms that data mining is more than merely applying algorithms.

The goals of the analysis phase may differ from project to project. Many analyses attempt to produce predictive models. For example, a direct-mail advertiser might model the response rate to particular kinds of mail solicitations, whereas an automobile manufacturer might model situations in which inventory shortages occur. Some analyses might aim to discover groups or clusters within a database. For example, a telecommunications firm might look for groups of customers with similar calling patterns and discover that some customers living in residential areas behave more like business customers because they maintain offices in their homes. A third type of analysis might look for anomalous cases in a large database. For example, analysing insurance claims might yield cases with charges far exceeding the average charge. These anomalies might represent billing errors, misclassified records, or fraudulent claims.

Such analyses may sound fairly conventional. Indeed, good managers analysed their internal databases long before the recent surge of interest in data mining. However, this interest has done more than just rename an old activity. Two things distinguish recent efforts at data mining from conventional analyses. As noted above, data mining focuses on searching for useful relationships, rather than merely evaluating the factors in a particular relationship. Conventional statistical tools excel at the latter task, allowing users to formally test hypotheses conceived independently of the data. In contrast, data mining seeks to assist with the former task, the search for relationships. Second, the scale of data-mining efforts dwarfs most conventional analyses. Many statistical procedures were designed for relatively small data sets, where records number in the tens or hundreds. Data mining techniques typically are used for thousands or millions of records.

IBM's Advanced Scout data-mining software, for example, is helping professional basketball coaches better understand the strengths and weaknesses of their teams (IBM Corp., 1996*b*). With the software and

data from past games, a coach can explore the best strategies to use against particular teams and the best times to use certain players. The software can even bring up video footage of specific instances of a detected pattern. The raw data and video footage have been available for years, but data mining allows coaches to make effective use of them.

4. TECHNOLOGIES

As already noted, data mining employs many different analysis techniques. No single technique can possibly fulfil all analytical needs, and techniques are constantly developed and refined. Data mining ranges widely, incorporating advances in statistics, databases, artificial intelligence, and scientific visualisation, among other fields. The technologies for data mining can be characterised in at least three ways: by the task they are intended to address, by the representation used for the discovered patterns, and by the algorithm used to search for possible patterns.

Tasks seek to address the analytical challenges that are posed. One common task is to build a predictive model, for example, to predict likely response to direct mail solicitation or the likelihood of an inventory shortage. Another common task is to detect deviations from expected behaviour, often a way to detect fraud. Other tasks include finding and describing clusters of records (*e.g.* customers who represent a market segment) or discovering network-linked records (*e.g.* customers who call each other frequently).

Data-mining techniques can also be characterised by the form of language they use to represent patterns. Predictive models, for example, can be represented as linear equations, logical rules, decision trees, or interconnected networks. The choice of representation affects what sorts of relationships a data-mining technique can find, because some representational forms cannot handle adequately some sorts of relationships. It also affects how easily relationships can be interpreted, the important final step of data mining.

Finally, data mining techniques can be characterised by the algorithm used to search for relationships. Implicit in a particular representation (*e.g.* an equation) is a space of possible relationships that can be expressed in that form. Usually, it is impractical to search the entire space. Therefore, an algorithm must be chosen to search a portion of the space and select among the alternatives within the space searched. For example, linear regressions can produce optimal

equations under rather restrictive assumptions, but produce nearly optimal equations under a much larger set of assumptions. Similarly, several recursive partitioning algorithms³ construct accurate decision trees while searching only a small subset of all possible trees.

5. CHALLENGES

Nearly all data-mining techniques implicitly or explicitly search for a large number of possible relationships. As already noted, this distinguishes data mining from many conventional approaches concerned with estimating parameters and testing statistical hypotheses. Data mining techniques often create and test thousands of potential relationships.

The search process creates several technical challenges. First, searching for many relationships can be expensive in computation time. Even a relatively small number of variables can be combined in many ways, thereby quickly making even simple procedures rather intractable. Thus, researchers in artificial intelligence and statistics have created ways to limit searches, while still discovering nearly optimal relationships. In a few cases, researchers have identified techniques for finding the optimal solution while avoiding an exhaustive search.

A second technical challenge is to determine the validity of the relationships discovered. Is a relationship true in general, or is it merely a quirk of the particular database being analysed? This sort of question is addressed by many statistical tests, but because they search through many possible relationships, data-mining techniques violate the assumptions of many statistical tests. Instead of relying on traditional tests, researchers in data mining and statistics have had to devise more sophisticated methods for determining the validity of relationships.

In addition to these technical challenges, users of data mining also face operational challenges. First, initial data-mining efforts often reveal that some of the strongest relationships in the data are the result of errors and inconsistencies in data collection and recording. Data quality is a major factor in the successful application of data mining techniques.⁴ Second, gaining access to data is often a major challenge. The easiest data to collect are often not the most useful data, and institutional barriers can make it difficult to change what data are collected. In addition, large corporate databases often run on older systems that are optimised for relatively simple

database queries, rather than the more complex operations required for some data mining techniques.

6. IMPLICATIONS

The speed with which data mining technologies are moving from research laboratories to commercial implementations makes it particularly important to examine their implications. They are likely to change substantially the way in which some markets function, the internal organisation and practices of many firms, and the relationships those firms have with their customers.

Market

Probably the most obvious effect that data-mining technologies will have on markets is to increase their segmentation. Data mining will almost certainly increase targeted marketing, because it allows identification and characterisation of market segments with specific characteristics. This may lead to greater efficiency because information can be targeted at those for whom it is best suited. While some broadcast media offer a relatively inexpensive way to communicate with potential customers, the move from broadcast media to more targeted media is attractive to consumers and effective, and, in the long run, this will probably force firms to use data mining techniques to customise their advertising (and potentially their products) to small market segments.

Companies

For companies, data mining reveals the importance of collecting and maintaining data on internal and external operations. Data mining turns large databases into a major competitive asset, and the management and market information derived from those databases can represent a key competitive advantage, particularly for service-oriented companies. For this reason, in some companies, the position of Chief Knowledge Officer replaces that of Chief Information Officer.

Increasing emphasis on targeted marketing has implications for firms as well. Customers' long-term relationships with a company from which they receive customised information and products may lead them to expect higher levels of customer service. This in turn can give a company additional information about a customer, allowing even more targeted marketing and sales in the future.

Such relationships can lead to entirely new forms of business. For example, many new firms are providing customised information over the Internet, and they are building profiles of their customers' preferences and interests. Over time, these profiles may become quite accurate and detailed and represent a substantial asset to the company. This asset can be used to retain the customer (through superior service) and can also be sold to provide information to other retailers (much as some periodicals currently market their mailing lists).

Consumers

Such customer profiling raises serious issues of privacy of a new sort. Most privacy issues concern information obtained directly from records or correspondence that reveal personal details. However, data mining has the potential to infer important details on a person's life indirectly. For example, purchasing records for food, medicine, and entertainment could be used to infer illnesses and participation in risky behaviour and on that basis to deny insurance or credit, even though direct questions on such issues might be prohibited by law.

Thus, the privacy issue may come to cover not only the facts about an individual, corporation, or government but also what can be inferred from those facts. In many cases, the ability to infer additional information is enhanced when large numbers of records are combined. This can happen in two ways. First, when organisations share data, large numbers of fragmentary records on a specific individual can be combined, thus raising the potential for invasion of privacy. Individuals may give different information to various firms or government agencies, yet still feel that their privacy is protected; however, when such bodies share information, these isolated pieces may form a mosaic that may constitute an invasion of privacy. Second, large numbers of records about different individuals can be combined if an organisation is large enough, and while one individual's record may not indicate much, the capacity to look at thousands or millions of records can reveal patterns

that can then be applied to draw inferences about the individual record.

Another concern relates to the mechanism of direct marketing. Consumers are likely to be the target of increasingly sophisticated marketing campaigns which seek to address their individual needs. As discussed above, this has advantages for both the consumer and the market. However, mass marketing has a democratic character that targeted marketing lacks. For example, some US consumers expressed outrage recently when they discovered that a popular catalogue that sells women's clothing was distributing catalogues with different prices to different market segments. If the price differences were intentional, the firm's economic logic was solid, but consumers' notions of fairness were violated. Targeted marketing campaigns can produce unintended effects for unwary companies.

Given consumers' potential concerns about privacy and fairness, companies may need to offer incentives to consumers to compensate them for perceived losses. Widespread use of data mining will increase firms' efforts to collect data on their customers, but firms may have to "bargain" with consumers to overcome their reticence. For example, some US supermarkets offer small discounts to customers who use a "shopper's card" which is scanned during each visit. This allows the stores to identify individual customers' purchases and track buying habits in detail, rather than in the aggregate. Consumers, in turn, can obtain a small discount if they allow such data collection or they can forego the discount and shop anonymously.

7. CONCLUSION

Data mining represents a fundamental shift in what information technology can provide to businesses. Rather than just providing a way to store and retrieve records, it can assist in drawing inferences from those records. This shift, from facts to inferences, will affect the operation of individual firms, the organisation and dynamics of markets, and the opportunities and threats faced by consumers.

NOTES

1. Data mining techniques apply to other areas besides business. Scientific, technical and government uses are at least as numerous. However, this paper focuses on business uses.
2. *Data Mining and Knowledge Discovery*, from Kluwer Academic Publishers; and *Intelligent Data Analysis*, from Elsevier Science, Inc.
3. Including ID3, C4.5 and CART.
4. Thus the need for techniques for "data cleaning."

INFORMATION TECHNOLOGIES AND THE PACKAGED CONSUMER GOODS INDUSTRY

The packaged consumer goods industry consists mainly of the processed food, over-the-counter drugs and toiletries, and apparel industries and their distribution channels – mainly supermarkets, department stores and speciality retail outlets. While it is difficult to determine precisely their contribution to the economy as a whole, the food, beverages and tobacco industry (ISIC 31), the textile, apparel and footwear industry (ISIC 32), and the retail and wholesale sectors (ISIC 71), taken together, represented over 25 per cent of OECD area jobs in 1993. This section of the Outlook looks at the effect of information technologies (IT) on this industry, both because of its innate importance and as an example of broader changes occurring throughout the economy.

In most OECD countries, the population and the economy have grown little over the last three years, and markets for consumer goods have matured. Industry emphasis has therefore shifted from creating demand to fulfilling it. As buying power has diminished, brand loyalty is eroding rapidly and store brands and economy labels are exploiting consumers' greater price sensitivity. Even where manufacturers, notably those with a global presence, retain some market control, retailers are demanding that their suppliers adhere to new information-intensive practices that allow for product variety and frequent, small-lot deliveries, thereby reducing retailers' exposure to the market and increasing that of manufacturers (Abernathy *et al.*, 1995). As a result, the packaged consumer goods industry is radically changing the way it does business, and much of this change is tied to information technologies.

In 1995, the consumer packaged goods industry as a whole spent an average 2.2 per cent of revenues for information systems in North America and 1.5 per cent in Europe. This was an increase of 8.5 per cent from the previous year in North America, but a decrease of 0.1 per cent in Europe (CSC Index, 1996). As Table 12.1 shows, the industry's priority areas for IT expenditures common to both North America and

Table 12.1. **Priority areas for spending on IT systems by large consumer products firms**

North America	Europe
1. Order processing/handling	Delivery/logistics
2. Customer service	Order processing/handling
3. Delivery/logistics	Sales
4. Manufacturing/operations	Manufacturing/operations
5. Sales	Production planning/scheduling

Source: CSC Index, 1995.

Europe, are order processing/handling, delivery/logistics, manufacturing operations, and sales.

1. THE USES OF IT

Information technologies allow the packaged consumer goods industry to offer a greater variety of products while keeping inventories low at all stages. This requires a high degree of co-ordination along the entire supply chain, from manufacturers to distributors to final consumers, and IT has been instrumental in making this possible. While some of what has been done is industry-specific, most is relevant to the economy as a whole as it seeks to integrate IT. In particular, a better understanding of both consumers and the market and faster reaction time are now generally required. To meet these needs, low-cost, high-power computing is being implemented, in order to increase the information intensity of logistics, marketing, production and distribution (see Part I, Networked Computing and servers). As these systems are deployed and linked, firms are led to re-evaluate their procedures and their role and position in the entire chain of supply and demand.

The following discussion examines first how information technologies are being implemented to improve the inbound logistics of the supply chain that extends from suppliers to manufacturers. It moves on to look at the manufacturing process itself

and then outbound logistics and the distribution of products. It turns then to the impacts on sales and marketing and issues related to interaction with consumers. A final section draws attention to a number of potential problem areas, some of which are, or could become, policy issues.

Inbound logistics and the supply chain

Problems commonly encountered in the supply chain include insufficient inventory information on delivery and tracking of suppliers and ineffective replenishment schemes, resulting in stock-outs or overstocks and thus in reduced cash flow, wasted products, and capital tie-ups. Research carried out in the late 1980s showed that stock-outs and overstocks led to a 25 per cent decline in profits in the US apparel industry (Table 12.2). Retailers, who bore a large portion of the reduction, were strong advocates of change.

In an effort to correct these problems, firms are trying to match consumer demand much more closely to retail supply while minimising inventories. They do so by increasing the variability of deliveries and the variety of products stocked. For example, at the "stock-keeping-unit" (SKU) level, the average number of apparel products offered by US manufacturing units increased by 63 per cent between 1988 and 1992 to over 6 000 items. Moreover, over the same period, the average number of new products introduced per business unit increased from by over 1 000 to 3 688, while the average number discontinued increased by the same amount to 3 050 (Abernathy *et al.*, 1995). Supermarkets have also seen a vast increase in the variety of products they carry (Figure 12.1).

To place orders on a timely basis so as to optimise inventory level yet not exhaust stocks, retailers must link sales data with order processing. Using information technologies such as bar-code systems, they can automate identification of products, confirm

products received against those ordered, etc. To take again the example of US apparel manufacturers, less than 5 per cent of firms surveyed put filled orders via EDI in 1988; just four years later, in 1992, the percentage had risen to over 30 per cent (Abernathy *et al.*, 1995) (Table 12.3). The return on this investment is estimated to be high; bar-code scanning in the US retail sector is reported to have saved the industry \$2.7 billion in 1992 (CSMG, 1996).

Information technologies make it possible to create inter-firm networks so that information flows quickly and accurately between companies in the supply chain: orders are processed immediately, deliveries co-ordinated, and a smooth flow is ensured. To date, many of these networks have been forged by large firms such as Wal-Mart (see Box 12.1), but as the cost of computing continues to drop and as scheduling algorithms based on artificial intelligence and discrete event simulation become more available, smaller firms are likely to adopt, or be obliged to use, these techniques as well.

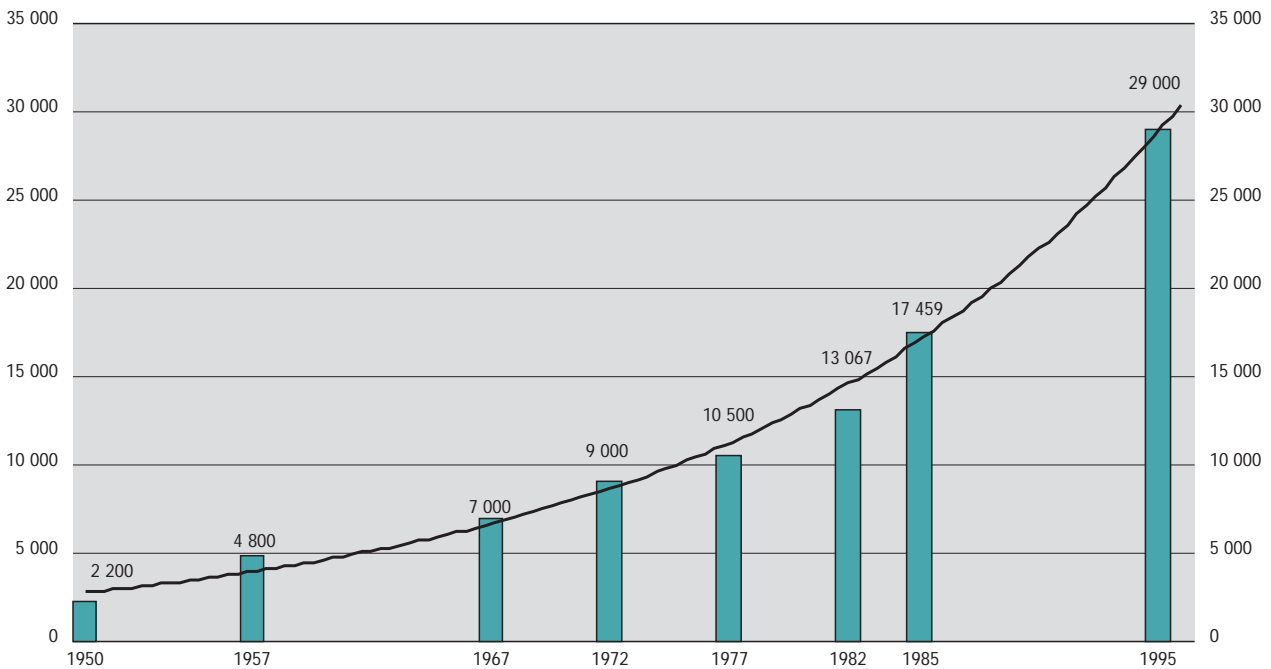
Manufacturing

For manufacturing, the key issues are, first, process flow manufacturing – better yield and closer quality monitoring (see Box 12.2) – and, second, integrating manufacturing into the logistics chain (inbound and outbound) to optimise scheduling of production and resources. Improving the quality of the workforce through training and creating more user-friendly manufacturing equipment are crucial to using IT to improve manufacturing. Managing the logistics of production is further complicated by recent changes in the competitive environment. These include pressures to: produce more varieties (a shift from continuous to batch manufacturing) at lower cost; turn out more natural products, which may be more perishable, but maintain shelf life; bring more new products to market faster, which increases

Table 12.2. **US apparel stocking costs/losses**
Billion US\$

	Textile mills	Apparel manufacturer	Retailer	Total costs/losses
Forced mark-downs	0.3	2.0	5.0	7.3
Stock-outs	–	0.2	1.7	1.9
Inventory	0.5	1.3	1.5	3.3
Total	0.8	3.5	8.2	12.5

Source: Office of Technology Assessment, 1987.

◆ Figure 12.1. *Items per store in US supermarkets*

Source: Baily and Gordon (1988), The Food Institute (1996).

the burden of paperwork for regulatory approval of new products; comply with mounting consumer demands by providing a complete audit trail whereby individual products can be traced back through every step of production.

A variety of IT applications have been implemented on the shop floor in response to these pressures, but the more fundamental transformation that is occurring within the packaged goods industry is the repositioning of the manufacturing process in the value-added chain. The implications for manufacturing have five different dimensions.

Inter-firm co-ordination. Manufacturing can no longer concentrate solely on producing the product; instead, it must be an active participant in a co-ordinated value-added chain. Manufacturers are forced to optimise production and delivery on the basis not of their own criteria but those of the system as a whole. Toyota, a pioneer in the use of IT, has synchronised its production so closely with its ball-bearing supplier, Minebea, that ball bearings are delivered five times a day. Also, using electronic data interchange (EDI), textile suppliers can inform apparel manufacturers of the timing, size, colour and

location of their fabric on an incoming truck. To achieve this level of co-ordination, teams from manufacturing, logistics, and marketing (and different companies) must be brought together to design and operate the production process. They will demand “groupware” for concurrent engineering – team-work tools for information workers based on high-power, low-cost servers.

Forecasting for better planning. The nature of orders is shifting from pre-specified batch orders with a long lead time to real-time incremental orders that must be satisfied very quickly. This shift forces manufacturers to forecast demand and plan production accordingly. Consequently, “the ability of a supplier to gather and analyse available data on demand patterns and to incorporate the results into internal forecasting, planning and decision-making processes becomes critical to competitive performance” (Abernathy *et al.*, 1995). This requires two sorts of computing resources: an information system that provides real-time and historical data on costs, demand, and capacities and decision-support tools that make it possible to foresee the effects of a change in manufacturing on costs and profits.

Table 12.3. **Apparel manufacturing practices in the United States, 1988 and 1992**

	1988 ¹	1992 ¹	% change
Minimum standard practices			
Products marked with UPC bar-codes at SKU level	21.9	60.4	176
Product code listed in UPC catalogue	13.6	46.6	243
Purchase orders received via EDI	4.5	31.6	602
Model stock programme governed by retailer	7.0	15.8	126
Model stock governed by manufacturer	4.8	7.5	56
Advanced information practices			
Electronic funds transfer with retailer	1.6	5.3	231
Point-of-sale (POS) data received from retailer on an individual store basis	5.7	15.0	163
Point-of-sale (POS) data received from retailer on an aggregate (across stores in chain) basis	7.4	16.7	126
Distribution practices			
Capital equipment investment in distribution centre (DC) per US\$1 000 shipped, 1988US\$	5.0	9.7	94
Information system expenditures for DC (per US\$1 000 shipped, 1988US\$)	4.2	9.1	117
Training for DC employees (US\$000s, 1988US\$)	0.9	1.0	11
Deliver floor ready merchandise to retailer (% of volume shipped)	40.6	50.3	24
Shipping containers marked with bar-coded shipping container marker (SCM)	7.0	32.1	359
Advance shipping notice (ASN) sent to retailer prior to shipment	2.7	15.9	489
Ship products to individual stores rather than retail DC (% of volume shipped)	33.6	31.1	-7
Other services to retailers			
In-store fixtures provided by manufacturer	2.4	6.2	158
Product labelled with manufacturer's label with retail price	15.0	18.0	20
Product labelled with retailer's label with retail price	20.3	28.4	40

1. Means represent unweighted averages of percentage of 1992 sales volume sold using stated practices.

2. UPC: Universal Product Code.

3. SKU: Stock Keeping Unit.

Source: Abernathy *et al.*, 1995.

Fine tuning of production. In the past, there was a trade-off between producing a standard world product (low cost, high volume) and flexibility (customised product at high cost). Advances in IT reduce the severity of the trade-off and make it possible to

better tailor products to specific regions and to specific social, economic and demographic groups. To accommodate increased variety and lower production runs, standard component processes are required which can be reassembled easily, with local distrib-

Box 12.1. **Wal-Mart**

Wal-Mart has used computing and communications intensively to create an automatic replenishment system that is widely recognised as the most sophisticated in retailing. This system supported a revenue stream of \$94 billion in 1995, up by a factor of four from 1990 to become the world's largest retailer. Earlier versions of this system powered the huge growth Wal-Mart experienced during the 1980s: it grew from 276 stores in 1980 to 1 528 in 1990, while revenue grew from \$1.2 billion to \$26 billion. By the beginning of the 1990s, Wal-Mart had passed Sears, Roebuck and its discount competitor, K-mart, to become the largest US retailer. The distribution system played an essential role in its move into food, and from 1987, it had direct links to manufacturers such as Proctor and Gamble. When food was added to discount merchandise, revenue per store doubled, and the number of products carried rose to around 100 000.

The computerised distribution system has now advanced from automatic replenishment on sales to predictive modelling. Overall IT investment, from hand-held computers to POS (point-of-sale) terminals to VSAT (very small aperture terminals) communication networks, amounted to \$600 million between 1987 and 1992 and has increased since. This investment has been credited with saving roughly \$1 billion per year over rivals whose distribution costs are roughly 4.5-5 per cent of sales, as opposed to Wal-Mart's 3 per cent. Between 1983 and 1993, Wal-Mart achieved a compound annual growth rate of 30.6 per cent, more than three times the average for retailers.

Source: Sellers, 1996; Reid, 1995; *Fortune*, 1992; The Food Institute, private communication, 1996; Abernathy *et al.*, 1995; *Business Week*, 1992.

Box 12.2. **Some new IT applications used in manufacturing**

Enhancing *programmable logic control systems* so that they can be controlled continuously in real-time and provide closer monitoring and regulation and improved quality and reproducibility.

More sophisticated *non-linear control algorithms* to preserve quality – neural networks, which “learn” the process from a large number of cases.

On-line optimisation using *real-time simulations* that run in parallel with the process.

Integration of databases for laboratory batch checks with production for continuous quality assurance.

Smart instruments containing their own embedded processors – e.g. “sniffing noses” for the brewing and food industries.

“*Sensor fusion*” for a more complete picture of the process, built up from many low-grade sensors using high-power computational algorithms.

Clean rooms and whole “clean buildings” with intelligent controls to enhance quality.

uted controls for each component module, as the overall scheduling of the complete new process is being orchestrated. This is a significant change from traditional monolithic and inflexible processes, as it is possible to provide variety at low cost.

Quality control. Improving product quality and consistency has been made easier by analytical techniques based on “data mining” which analyse large databases of past production settings and parameter values to predict future problems and process trends (see Part III, Data Mining). Data-mining techniques were used, for example, to analyse old data in order to identify a pattern that linked high variations in quality to a single operative with inadequate training (Forge, 1994).

Concurrent engineering. It has become essential to reduce the time required to bring a new product to market. Concurrent engineering, using groupware, allows different units in a firm (design, production, marketing, sales) to work in parallel instead of sequentially. In one example (not however from the packaged consumer goods industry), Boeing used concurrent engineering to tie together more than 230 cross-functional design teams, thereby allowing nearly 4 000 engineers to work simultaneously on the design of its 777 aircraft. It is estimated that this new system saved Boeing over a million labour hours, cut defects by 50 per cent, reduced development time by 25 per cent, and allowed Boeing to gain regulatory approval in record time (Council on Competitiveness, 1996).

IT-supported R&D. The use of sophisticated simulation systems reduces the time spent on R&D. Instead of building mechanical models or engaging in laboratory experiments, computer simulations can test theories and explore alternatives in a fraction of

the time. For example, the research director of Pilkington, a UK glass manufacturer, estimates that without IT, his R&D budget would have to be two to three times its size to achieve the same results (Wagstyl, 1996). For its part, Du Pont cut the time needed to create a new polymer fibre catalyst from years to weeks at a cost of \$25 000 rather than \$5 million (Wimmer and Katz, 1988).

Impact. The “informatisation” of manufacturing will result in the deployment of more computing power at every step and the employment of more highly skilled workers. This will ultimately lead to higher productivity. Recent work by the US Department of Labor shows that increasing the average education level of manufacturing employees by one year leads to an increase in labour productivity of 8 per cent and that increasing the proportion of non-managerial workers using computers from one-third to two-thirds increases labour productivity by 5.4 per cent (Black and Lynch, 1996).

The end result is a set of performance measures for manufacturers that go beyond price to include speed, accuracy and flexibility (Abernathy *et al.*, 1995). UK leaders in the brewing industry, for instance, have accelerated the consumption cycle by 85 per cent; by using much closer control of brewing parameters and high-speed canning, they have been able to move from 22 days to under three days for brewing and delivery (Irvine, 1996). Moreover, the product cycle is becoming more effective, producing what is wanted, when it is wanted.

Overall, the effects of IT on performance and profits are significant. In the US clothing industry, inventories have been reduced by 60 per cent since 1985. Retail mark-downs have been reduced by up to 40 per cent, as the right goods are being ordered and

excess merchandise does not have to be marked down. In-stock positions have been improved by up to 95 per cent, leading to an increase in sales of up to 30 per cent (CSMG, 1996). While the new systems put some domestic suppliers at a disadvantage because of the significant investments in IT required, they are much more likely to disadvantage foreign manufacturers whose lack of proximity puts them at a competitive disadvantage.

Impacts on outbound logistics and distribution

As strategies shift towards just-in-time systems, finer and finer niche marketing and less-than-truckload deliveries, logistics and distribution are taking on greater importance, becoming essential elements of competition. At the heart of this shift is intensified use of IT in distribution centres and warehouses or distribution centres:

- shift from hand-picking based on printed lists to paperless order picking systems;
- radio links for warehouse route maps and scanners for checking items against remote lists;
- optimised scheduling of robot forklift trucks and guided vehicles;
- automation of pallet and carton stacking, rotation and delivery by robot shelving and sophisticated conveyer belt systems.

For distribution, computer-based tracking and predictive scheduling aids are coming to the fore. For replenishment, the use of electronic data interchange (EDI) linked directly to electronic point-of-sales (EPOS) equipment, with real-time processing, can smooth relations between suppliers and retailers by reducing late orders and errors. At McKesson, a producer of pharmaceuticals, warehouse personnel wear on-arm radio-linked scanners which check the item picked against the order; such systems can reduce errors by 72 per cent and handling time by 10 per cent (*Logistics Today*, 1993). A study of the US apparel industry found that this shift towards information-intensive "quick response" inventory management caused annual investments in information systems to more than double, from \$4.20 per \$1 000 shipped in 1988 to \$9.10 in 1992 (Abernathy *et al.*, 1995) (Table 14.3). In turn, there is some evidence that IT expenditures for distribution are paying off; aggressive use of EDI and EPOS by the UK supermarket chain Smithfield and its suppliers led to a 25 per cent reduction in inventories, a staff cut of 10 per cent in the ordering and inventory management depart-

ments, and a reduction in the order-delivery cycle from five days to two (Kavanagh, 1996).

The transportation industry is also seizing upon IT systems to meet the challenges it faces. As stricter requirements decrease efficiency in distribution, distributors are making use of IT to achieve finer scheduling to meet just-in-time delivery demands, while minimising the number of small, daily deliveries and buffer stocks. IT is also used to scan bar codes into mobile data systems which are used to track goods in transit by using vehicle positions obtained from satellite-based global positioning systems (GPS). Tracking systems also identify problems in operations, alert operations staff to delays or ruptures in supply, direct emergency help and trace hijacked vehicles.

At the extreme, informatisation of outbound logistics and direct contact with customers might reduce the need for warehouses and even retailers in some cases. Over 90 per cent of Wal-Mart goods never go through a warehouse but are shipped directly from the manufacturer to the store (Tapscott, 1996). EDI allows some shippers to clear cargo through customs while they are still at sea, eliminating the need for warehouses where goods are stored as they await clearance. Furthermore, women can now buy perfectly fitting jeans from Levi's Home page on the Internet: they learn how to measure themselves and can place an order using a credit card. A few weeks later, they receive jeans guaranteed to fit perfectly fit for \$10 extra; in this way both the traditional retailer and wholesaler have been eliminated, as have overstocks (Tapscott, 1996). Sales on this basis jumped by 300 per cent in the first year, and plans are being made to extend the programme to men's jeans and pants (<http://www.pcca.com>, 10/09/96).

Impacts on sales and marketing

Sales and marketing are struggling with changing tastes and a greater variety of tastes. The trend is away from the global brand and towards micro-marketing, ultimately to a single consumer. These changes have heightened competition and have led to more sophisticated pricing and promotion strategies, which are shaped by information obtained from a wide variety of information technologies such as EPOS checkouts, credit card information, scanning in warehouses and supermarkets, and from the field. In Japan, this information is used to vary prices during the day to encourage a smooth flow of shoppers. In the United States, mail-order firms send catalogues with prices that vary depending on the wealth of the postal code. Some US supermarkets now have three

different prices for the same item, depending on the customer's loyalty and level of spending (Ody, 1996b). By analysing EPOS data, retailers can calculate the price elasticities of products exactly; this gives them access to crucial data for plotting pricing strategies and is valuable to manufacturers, who can see how much lower their price must be to compete with competitors.

In general over the last 15 years, increased competition has led to a decline of 10 per cent in US retailers' gross profit margins (Brennan, 1995). Average wholesaling margins in the drug industry have dropped from 7 to 3 per cent (Quinn and Baily, 1994). For some segments, however, there is evidence that firms adopting information-intensive, "lean-retailing" practices have operating profits approximately double those that do not (Abernathy *et al.*, 1995). Likewise, research shows that 75 per cent of retail sales volume comes from the top 30 per cent of shoppers. Thus, the identification and targeting of this group is a key to profitability and further fuels the shift from mass to individual marketing (Ody, 1996b).

Information on the position and tactics of rival brands is often as crucial as knowledge about customer buying patterns. For example, in the United States, Frito-Lay has a sales force of 10 000 who use hand-held computers to check shelf inventory and competitors' positions and prices. The data is processed nightly for next-day reports for pricing and inventory decisions. Larger amounts of low-cost computer power are increasingly needed to handle the raw flow of data to:

- recognise sales patterns and trends quickly and to "micro-market" as new segments emerge;
- use data mining to recycle old sales data using new algorithms to find long-term trends and hidden sales patterns;
- link data on socio-economic class to geographical locations using a geographical information systems (GIS), infer lifestyle and probable purchasing patterns from postal codes, and predict social class and age from Christian names;
- use EPOS returns to optimise store and shelf layout, in-store promotions, and price changes;
- employ search engines and software to extract consumer concerns and trends from large data bases;

- make use of software tools (based on a new software technology called components, see Part III, Component Software) that allow marketers to develop their own custom applications easily and instantly.

Interacting with the customer

As the price of IT drops and processing power increases, the focus of IT systems has begun to shift from concentrating on things to concentrating on people – a strategy called efficient consumer response (ECR) (Ody, 1996c). This technique uses IT to add convenience, speed and information to shopping. For example, some supermarkets are allowing consumers to self-scan purchases so that they can keep better track of purchases and avoid check-out lines. Interactive information kiosks have been installed to provide customers with information about products and in some cases even sell them. Loyalty cards give consumers discounts or special privileges and provide retailers with important information about shopping frequency and selection. In-store technology such as video cameras, sensors and infrared counters track customer traffic to identify "cold spots" and areas in need of more staffing (Ody, 1996c). A new generation of affordable high-power computing will provide video servers and many other forms of multimedia support in supermarkets or department stores as multimedia promotions become common.

On-line shopping is taking off slowly. Home shopping of all forms, including the "traditional" TV shopping networks such as the Home Shopping Network in the United States, account for only \$2 to \$3 billion today in sales worldwide and thus remains a negligible of total retail and wholesale activity. In the future, however, they may grow quickly, because for day-to-day shopping the advantages, in terms of convenience and savings, could be immense. Already, Peapod, located in Chicago and San Francisco, allows customers to purchase groceries over the Internet. Amazon Books in the United States claims to be the world's biggest bookstore, offering over a million volumes; it exists exclusively on the Internet. Anderson Consulting estimates that by the year 2005, about one-fifth of commodity groceries will be bought without going to a traditional grocery (Foremski, 1996).

2. CONCLUSION

Information technologies have significantly changed the nature of the packaged consumer goods

industry by helping to keep inventories at all stages low while offering a greater variety of the products consumers want when they want them. This requires much more co-ordination across the entire value-added chain that stretches from producers of raw materials to manufacturers to distributors to retailers to final consumers. Information technologies have been instrumental in making such co-ordination possible and in doing so have transformed the industry. While some of the changes are industry-specific, most apply to the economy as a whole as IT is integrated into production processes. These changes are likely to have a significant impact on the nature of business, individual privacy, the environment, technology and existing public policies.

Business

Electronic links create new inter-firm interdependencies. As POS information becomes a necessity for planning, forecasting and competing, access to such data is of crucial importance and gives firms that possess it considerable market power. However, establishing these electronic links is costly and requires a high degree of trust and co-operation; a situation may arise in which there are barriers to entry for new, small suppliers and diminished competition. As these barriers would be particularly difficult for importers to surmount, they might protect domestic jobs, dull a source of downward price pressure, and create further incentives to engage in foreign direct investment.

The aggressive use of these technologies to link retailers with suppliers has *profound implications for intermediaries* such as wholesalers, many of which will have either to alter radically their businesses to provide different services or face elimination. The traditional role of "market makers", brokers and logistical co-ordinators is undermined by these technologies and by competitive pressures to improve quality while maintaining or lowering prices.

As IT allows significant improvement in quality by providing more variety, timeliness, and tailoring to the individual, usually for the same or lower price, *the advantages of small businesses are reduced.* Many small businesses have complained that the "Walmarting of America" has forced small businesses to close, eliminated jobs, and caused town centres and the fabric of some communities to deteriorate. More generally, there is a fear that the economic advantage associated with these technologies will lead to a "winner-take-all" scenario that will create an anti-competitive situation in some sectors.

Individuals

New retailing strategies might pose a threat to privacy. The greater sophistication of capturing consumer information through EPOS and the ability to analyse those data in relation to other data, so that marketing can occur on a one-to-one basis, raise issues regarding personal privacy. The ability to identify which individuals might be bad credit risks or suffer from health problems or pursue "alternative life-styles" is easily derived from the data that tell marketers which consumers are likely to buy their products. The policy issue is whether an individual's privacy can be protected in some cases but exploited in others, given the ready accessibility of the technology and the information.

Environment

Although just-in-time production and delivery strategies save on inventory costs, their *impact on the environment* is less positive, as plants may receive eight to ten deliveries a day rather than one and many trucks may arrive with less than a full load. The contents of the average supermarket trolley have already covered 4 000 km by van or truck, and 70 per cent of deliveries to European shops take up less than one cubic metre (Evans *et al.*, 1993). Yet as retailers cut stock volumes, deliveries will increase.

Technology

As these networks extend across more firms, *it becomes ever more necessary for the IT industry to adhere to common open standards* that allow these systems to operate across a wide cross-section of platforms and operating systems. An obvious solution is to use the Internet, and many firms are already exploring this possibility (e.g. the Automotive Industry Action Group, <http://www.aiag.org>; GE's TradeWeb, <http://www.getradeweb.com>). These systems require a high level of reliability and quality of service (QoS), qualities which are elusive at present on the Internet (see Part III on Internet Congestion).

While current technology has made possible the development of these systems, as the number and sophistication of the systems grow, so will *data storage, processing and communications needs.* In the past, a reasonably large database was a gigabyte or larger. With 1 074 supermarkets in 17 states, one US supermarket chain (Food Lion) generates more than 100 gigabytes of raw data which are accessed by 65 merchandisers; another retailer, US American Stores, uses a third of a terabyte (333 billion bytes) to

store data on food products and expects this to increase to 2 terabytes when non-food products are added (Ody, 1996a). To access and analyse such quantities of data will require that the pace of IT innovation continue and that new software developments such as data mining become more commonplace.

Public policy

The impact of information technologies on the packaged goods industry is measurable – fewer stock-outs, lower inventories, fewer overstocks – but, in most cases, the change is a qualitative one – speed, convenience and variety – that defies measurement. Consequently, it is likely that official productivity statistics, price indexes, and growth rates underestimate the impact of these changes and in aggregate might contribute to *a less reliable picture of economic performance*. As these technologies permeate more industries, especially services, the imprecision is likely to increase and thus reduce the usefulness of traditional indicators for policy making.

The unique feature of these technologies is the system-wide gains in efficiency they achieve as they link different actors in a wide cross-section of industries, not their impact on specific firms. *Fostering such system-wide improvements requires rethinking*

technology and innovation policies, such as technology diffusion programmes, that tend to focus on one industry such as manufacturing, while in fact the largest contributors to the system-wide gains comes from services such as wholesale trade, transportation and retail trade. This suggests the need to widen the notion of “innovation” from a focus on high technology in manufacturing to include consumer goods and services.

For such networks to be effective, the units involved must be able to operate in concert. *Artificial barriers*, such as regulations that limit what firms in a particular industry can or cannot do, will reduce the system’s productivity and lead to higher prices, thereby lowering consumer satisfaction and reducing the international competitiveness of the product. Examples of such barriers are restrictions on the size of stores, rules that require certain hiring practices, and laws that do not allow firms to compete with public monopolies. Likewise, for this system to function properly, cheap and easy access is needed to information and communication technologies; conditions that increase their cost will slow their diffusion and place industries that use information technologies, whose competitiveness may depend upon them, at a disadvantage.

Part IV

DEFINITIONS AND METHODOLOGY

1. DEFINITIONS

IT markets

Spending data are provided by International Data Corporation (IDC), Framingham, Massachusetts. IDC defines information technology spending as revenue paid to vendors for systems, software, and/or services for sales into the distribution channels or to the final customer. Based on the IDC's detailed product classification, IT products are aggregated to form the following categories:

Hardware

- *Multi-user systems*: large- (general-purpose or high-speed scientific computers), medium- (traditional supermini-class computers and systems classified as small mainframes) and small-scale systems.
- *Data communication equipment*: LAN hardware, modems, multiplexers, packet switching equipment, digital switching equipment, communications processors, cluster controllers, channel extenders.
- *PCs and workstations*: general-purpose, single-user, microprocessor-based machines capable of supporting attached peripherals, and which can be programmed in a high-level language; plus PC add-ons (e.g. printers, upgrade or replacement storage devices, tape, and upgrades of CPU or memory).

Packaged software

Commercially available programmes for sale or lease from system vendors and independent software vendors (ISV). Not included are specially designed applications software solutions added by turnkey systems houses to systems acquired from a hardware manufacturer or other third party.

- *Systems software and utilities*: programmes designed to: *i*) operate hardware through basic operating systems and programming languages, increase the efficiency of systems personnel through system performance measure-

ment tools, improve the operating capabilities of the hardware system by routing the flow of data among machine units, and handle data entry and delivery; or *ii*) ensure programme integrity through maintenance and security programmes, convert programmes from one language to another, organise data resources through sort/merge products, and monitor machine usage. Major components include operating system enhancements (e.g. multiple virtual storage/enterprise system enhancements), network operating systems, and data centre management software, especially automated operations programmes.

- *Application tools*: programmes that allow users to retrieve, organise, manage, and manipulate data and databases. This group is divided into four sub-categories: data access/retrieval, data management, data manipulation, and programme design/development. It includes all database management system (DBMS) software; decision-support and executive information system (EIS) programmes; spreadsheets; front- and back-end computer-assisted software engineering (CASE) tools; and emerging areas such as co-operative processing and/or object management applications development tools.
- *Application solutions*: programmes designed to provide packaged solutions for specific problems inherent in an industry or a business function. Such software can address "cross-industry" functions (e.g. accounting, human resource management, payroll, project management, word processing and other office activities) or specific industry solutions for vertical markets (e.g. banking/finance, manufacturing, health care, oil and gas exploration, etc.).

Services

- *Professional services*: payment for contractual services for system and/or software develop-

ment; system design, integration, installation and related training/education, facilities management, and consulting services for IT purposes only (*i.e.* management consulting services are not included). This does not include, however, data processing that a vendor may resell from the client's site to a number of unrelated users at other sites, nor does it include traditional time-sharing services or so-called processing services.

- *Support services*: repair or replacement of components of computer systems hardware (including data communications equipment). Maintenance revenue may be generated by on-site maintenance, time and materials, parts for self-maintenance, and/or depot services, in each case on a services contract or non-contract basis. To avoid double-counting with the packaged software or professional services categories, the support services category excludes software support contracted as a part of long-term update and support agreements.

Semiconductors

Data are provided by two industrial sources: World Semiconductor Trade Statistics (WSTS) and Dataquest. The former is an industrial association of about 80 semiconductor manufacturers, representing about 90 per cent of the market in terms of value of production; it produces detailed sales statistics for its members. The latter is a private research and consultancy firm. Figures given by both sources concern the "commercial" ("merchant") semiconductor market only and not internal or "captive" consumption. Each source uses its own methodology based on different definitions of product categories. Dataquest uses a broader product classification, and this leads to some difference in survey results.

IT and the economy

For this section, a broader definition of the IT sector, which includes communications equipment and services is used; it is therefore referred to as the ICT sector.

Value added and employment

Value added and employment data come from the OECD STAN (Structural Analysis) database. STAN was created to fill the gap that exists between detailed data collected through industrial surveys,

which have limited international comparability, and national accounts data that are more internationally comparable but only available at fairly aggregate levels. Through the use of established estimation techniques, the OECD Secretariat has created a database that is compatible with national accounts for 22 countries. It covers 49 manufacturing industries for six variables and has annual data from 1970.

Value added data are current price, national-accounts-compatible value added and represent the contribution of each industry to national GDP. *Employment* data refer to number of persons engaged and include number of employees, as well as self-employed, owner proprietors and unpaid family workers.

For each of these variables, the ICT industry is broken down into two sectors: ICT manufacturing and ICT services:

- *ICT manufacturing* comprises the following two sub-sectors:
 - *Office, computing and accounting equipment (OCA)* (ISIC Rev.2, 3825), which includes: the manufacture, renovation and repair of office machines and equipment, such as calculating machines, adding machines, accounting machines; punched card system machines and equipment; digital and analogue computers and associated electronic data-processing equipment and accessories; cash registers; typewriters; weighing machines except when scientific apparatus for laboratories; duplicating machines except photo-copying machines; and other office machines.
 - *Radio, TV and communication equipment (RTC)* (ISIC Rev.2, 3832), which includes: the manufacture of radio and television receiving sets, sound reproducing and recording equipment, including public address systems, gramophones, dictating machines and tape recorders; gramophone records and pre-recorded magnetic tapes; wire and wireless telephone and telegraph equipment; radio and television transmitting, signalling, and detection equipment and apparatus; radar equipment and installations; parts and supplies specially used for electronic apparatus classified in this group; semiconductor and related sensitive-semiconductor devices; fixed and variable electronic capacitors and condens-

ers; radiographic, fluoroscopic and other X-ray apparatus and tubes.

- *ICT services* refers to Communication services (ISIC Rev.2, 72), which include services rendered to the public whether by post, wire or radio and whether intended to be received audibly or visually. Services for the exchange or recording of messages are also included, but not radio and television broadcasting studios and stations.

Production

Production data are provided by Elsevier Advanced Technology. Data are based on the Standard International Trade Classification (SITC), Rev.3. and aggregated by Elsevier into the following product categories:

- Electronic data processing (752 and 759.9)
- Office equipment (751.1, 751.2, 751.3, 763.3, 763.8, 759.1)
- Communications and radar (764.3, 764.8, 764.9, 874.1)
- Telecommunications (763.8, 764.1, 764.9)
- Consumer audio and video (761.1, 761.2, 762.1, 762.2, 762.8, 763.3, 763.8, 764.8)
- Components (761.1, 764.2, 764.9, 771.1, 771.2, 772.2, 772.3, 772.4, 772.5, 776.2, 776.3, 776.4, 776.8, 778.6, 898.4)

For details regarding the SITC, see: *Standard International Trade Classification*, United Nations Statistical Papers: Series M, No. 34, Rev.1, 1961; Rev.2, 1975; Rev.3, 1986.

Trade

Trade data are derived from the OECD NEXT database and are based on the Standard International Trade Classification (SITC), Rev.3. The values are expressed in current US dollars and relate to declared transaction values of the countries (imports C.I.F. and exports F.O.B.). The reporting countries are OECD Member countries. Using the SITC codes, trade data are aggregated into the following product categories:

- *Computer equipment* includes: 752.1 (analogue or hybrid automatic data-processing equipment); 752.2 (digital ADP machines); 752.3 (digital CPUs); 752.6 (input or output units); 752.7 (storage units for ADP); 752.9 (other computing machinery); and 759.97

(parts/accessories for data processing equipment).

- *Electronic components* include: 772.2 (printed circuits); 772.3 (electrical resistors); 776.1 + 776.27 (thermionic, cold cathode or photocathode, valves and tubes); 776.3 + 776.81 (diodes, transistors and similar semiconductor devices); 776.4 (electronic integrated circuits and microassemblies); 778.6 (electrical capacitors and parts thereof); and 776.29 + 776.88 + 776.89 (parts for goods in sub-classes 776.1 + 776.27 and 776.4).
- *Communication equipment* includes: 764.11 (telephone sets); 764.15 (switching equipment); 764.81 (receivers and terminals); 764.91 (line equipment); 764.3 (transmission equipment); and 764.13 + 764.17 + 764.19 (other equipment).

Trade performance indicators are derived from the OECD STAN database which adheres to an industrial classification (ISIC Rev.2).

R&D

R&D expenditure data are derived from the OECD ANBERD (Analytical Business Enterprise Research and Development) database. ANBERD was developed in order to create a consistent data set that overcomes the problem of international comparability and temporal discontinuities associated with the official R&D data submitted by Member countries in response to the OECD R&D survey. Using established estimation techniques, the OECD Secretariat has created a database for 15 of the largest OECD R&D-performing countries for the period 1973-93. It is designed to provide analysts with a comprehensive and internationally comparable time-series on industrial R&D expenditures. ANBERD covers those R&D activities carried out in the public and private business enterprise sector, independently of the source of funds, and is closely tied to the creation of new products and production techniques. In this section, ICT comprises the two manufacturing sectors OCA and RTC.

2. PRICES AND CURRENCY CONVERSION

Prices

Values of homogeneous goods and services are expressed in common units of currency and may be considered as being equal to the number of units of quantity of the product multiplied by the price per

unit of quantity. Thus, the changes in values of goods and services can be directly factored into two components: changes in their prices and changes in their volumes or quantities. Figures may be estimated at current or constant prices:

- Data in *current prices* reflect the prices at which transactions have actually taken place and are often directly measured and intuitively easier to interpret. In addition, it is practically impossible to obtain data in *constant prices* at a detailed sectoral level because of both practical and conceptual difficulties. Time-series estimates at current prices therefore reflect the evolution of prices at which transactions take place and, in interpreting them, account must be taken of such factors as the overall inflation rate, however defined, the relative inflation of one industry's products versus other industries' products, and price increases due to the actions of government (if taxes are included in the definition of the price, the tax rates may change) and/or enterprises (such as the exercise of monopoly power or as part of the marketing strategy of the transactor). More fundamentally, current price measures make no effort to account for changes in the quality of a product over time.
- In contrast, *constant price* measures use the prices of the products in a single past period multiplied by their volumes, *i.e.* the quantities of the products, adjusted for quality changes if such changes have taken place. Figures expressed at constant prices thus eliminate effects of changing product prices, including changes in relative prices between sectors. In the case of R&D expenditures, there is a growing need for R&D deflators which would measure changes in prices of inputs, as opposed to implicit GDP (output) deflators.

Figures at constant prices are particularly difficult to calculate and to interpret in the case of industries such as office, computing and accounting machinery (OCA) where technological advances lead to the rapid introduction of new products, the obsolescence of old products, and important changes in

the quality of existing products over time. One of the striking characteristics of the computer industry, for example, has been the constant innovation and the improvement in quality, specification and performance accompanies by lower prices. Rapid quality changes in this industry have been one of the major factors hampering the comparison of "like with like" and thus the compilation of price indices necessary to calculate constant price estimates (see Part I).

Currency conversion

Purchasing power parities (PPP) are the rates of currency conversion that equalise the purchasing power of different currencies (Annex Table 4). They measure the ratio of the price levels between two countries. As the consumer price index measures the differences in the price of a standard basket of goods and services in the same country at different times, PPPs measure differences in the price of a standard basket of goods and services in different countries at the same time. This means that a given sum of money in a national currency, when converted into different foreign currencies at the PPP rates, will buy the same basket of goods and services in all countries. Data converted to a common currency (the OECD uses the US dollar as the common currency of "numeraire") by means of PPPs are thus expressed in the same set of international prices and may be said to be in "real" terms (OECD, 1995). PPPs were used to convert R&D expenditure data although these only allow for differences in general price levels between countries, not differences in price levels of R&D.

Data converted to a common currency using *exchange rates*, on the other hand, reflect the differences in price levels among countries as well as differences in volumes purchased in different countries (Annex Table 5). They are thus essentially "nominal" measures. For countries other than the United States, then, time series will reflect fluctuations in the exchange rate against the US dollar and may say little about the evolution of the variable concerned. When exchange rates were used to convert data, *current* US dollar exchange rates were used to minimise distortions due to currency fluctuations.

GLOSSARY

ANSI	American National Standards Institute. ANSI is the US government body responsible for approving US standards in many areas, including computers and communications. ANSI is a member of ISO. See ISO.
ARPANet	Advanced Research Projects Agency Network. The origin of the net is to be found in the late 1960s project launched by the Advanced Research Projects Administration (ARPA) to create a link between American universities and high-tech defence contractors.
ASIC	Application-specific integrated circuit.
ATM	Asynchronous transfer mode. An advanced switching technology that can handle large data capacity requirements to transmit all type of information, data, video or voice. ATM allocates the bandwidth dynamically using a fixed-size packet (called a cell).
Backbone network	System of high-speed connections that route long-haul traffic, connecting to slower regional and local data paths. The term is relative, as a backbone in a small network will likely be much smaller than many non-backbone lines in a large network: it is the top level in a hierarchical network. Stub and transit networks connected to the same backbone are guaranteed to be interconnected.
Bandwidth	The frequency range of a transmission channel, usually expressed in kiloHertz (KHz) or megaHertz (MHz). For digital traffic, this defines its carrying capacity.
Baud	Baud is the number of times per second that the carrier signal shifts value, for example, a 1 200 bit-per-second modem actually runs at 300 baud, but it moves 4 bits per baud ($4 \times 300 = 1\ 200$ bits per second).
Bit	Binary digit. A single digit number in base-2, in other words, either a 1 or a 0. The smallest unit of computerised data.
Browser	Software that makes it possible to read hypertext, <i>i.e.</i> allows users to access and browse the WWW. It can display HTML pages in their desired format. It is designed to switch from one document to another via Hyper Text. The most popular browsers are Netscape Navigator, Microsoft Internet Explorer and Mosaic.
Byte	A set of bits that represents a single character. Usually there are 8 bits in a byte, sometimes more, depending on how the measurement is being made.
Cache	Faster-access memory used to temporarily store information to provide a faster response time.
CASE	Computer-assisted software engineering.
CERN	European Organisation for Nuclear Research.
CISC	Complex instruction set computer.
CMOS	Complementary metal oxide semiconductor.
Data mining	Software to support the identification of meaningful new correlations, patterns and trends in databases using pattern recognition technologies, together with statistical and mathematical techniques.
DECT	Digital European cordless telecommunications.

DNS	Domain name server. The system that locates the IP addresses corresponding to named computers and domains. A DNS name consists of a sequence of information separated by dots.
Domain name	The unique name that identifies an Internet site. Domain names always have two or more parts, separated by dots. The part on the left is the most specific, and the part on the right is the most general, the domain.
Domain	A part of the DNS name. The domain to the far right is called the top-level domain (e.g. “.org”, “.edu”, “.fr”).
DRAM	Dynamic random access memory.
E-mail	Electronic mail. messages, usually text, sent from one person to another via computer.
Ebone	European backbone. European network federating 23 national networks.
EDI	Electronic data interchange. Facilities and standards for the transmission of electronic versions of documents, such as orders and invoices, over telecommunications networks.
Ethernet	A very common method, invented by Xerox and approved by ISO, of networking computers in a local network (LAN). Ethernet will handle about 10 Mbit/sec and can be used with almost any kind of computer.
EIS	Executive information systems. Systems, for use by senior management, which provide information, from both internal and external sources, on the key factors required to manage an organisation, together with software to analyse and present information.
FAQ	Frequently asked questions.
Firewall	A device (or software in a router) that links an organisation’s internal TCP/IP network to the Internet and restricts the types of traffic that it will pass, to provide security.
FTP	File transfer protocol. A tool to transfer files between two Internet sites.
GIF	Graphics interchange format.
Gigabyte (GB)	One gigabyte is 1 073 741 824 bytes, <i>i.e.</i> 2^{30} bytes.
Gopher	A finding aid to text-based resources on the Internet organised as a set of menus. Menu items can be links to other documents, search utilities, or information services.
GSM	Global System for Mobile Communications.
GUI	Graphical user interface.
Host	A computer directly connected to the network.
HTML	Hypertext mark-up language. The coding mechanism used to create easily documents, or WWW pages, with text, picture, icons, hypertext links, etc. Documents use tags to indicate formatting or structural information. It allows networked hypertext, and handles graphics as references.
HTTP	HyperText Transfer Protocol. Similar to FTP, it is a protocol that HTTP servers use to “talk” to each other to transfer hypertext and hypermedia documents across a network. HTTP is used for all file types, not just for HTML.
HyperText	Text that contains links (hyperlinks) to other documents. The documents can be linked from anywhere on the Web or can be an internal link to another part of the parent document.
Internet	A co-operatively run, globally distributed collection of computer networks, national, regional and local, that exchange information via a common set of rules for exchanging data (the TCP/IP protocol suite). (When lower case <i>i</i> is used, it refers to a network connecting two or more networks together.)
Intranet	A private network designed only for the internal use of a company or organisation and using the same kinds of software as the public Internet (the TCP/IP protocol).
IP	Internet Protocol. The last version is IPv6, which is also called IPNG (IP New Generation).

IP address	A numeric address assigned to computers connected to the Internet. It is a unique number consisting of 4 parts separated by dots.
ISDN	Integrated services digital network.
ISO	International Standards Organisation. ISO is a voluntary, non-treaty organisation founded in 1946, responsible for creating international standards in many areas, including computers and communications; its members are the national standards organisations of 89 countries. See ANSI.
JAVA	Java is a new programming language invented by Sun Microsystems specifically designed for writing programmes that can be safely downloaded through the Internet and immediately run. Using small Java programmes (called “applets”), Web pages can include functions such as animations and calculators.
JPEG	Joint Photographic Experts Group. This algorithm is used to compress data such as colour images where some loss of information, and hence loss of quality in the compressed image, is acceptable.
Kbps	Kilobit per second. One Kbps is 100 bytes per second. Actually, on a network, two bits are added for control to the eight bits that represent the character.
Kilobyte (KB)	One kilobyte is 1 024 bytes, <i>i.e.</i> 2^{10} bytes.
LAN	Local area network. A computer network limited to the immediate area, usually the same building or floor of a building.
MAE	Metropolitan Access Exchange. The exchange point, a common place for people to exchange data, information etc. MAE-LA is the exchange point for the Los Angeles area.
Mbone	Internet Multicast Backbone.
Megabyte (MB)	One megabyte is 1 048 576 bytes, <i>i.e.</i> 2^{20} bytes.
Modem	Modulator-demodulator. A device to connect to a computer and to a phone line, allowing the computer to talk to other computers through the phone system.
Multimedia	Integrated video, audio, text and graphics information, usually in digital form, for easier manipulation.
MVS	Multiple virtual storage.
NAPs	Network access points. A set of network nodes connecting mid-level or regional networks and other service providers to the high-capacity NSFNet backbone.
NCSA	National Center for Supercomputer Applications (United States).
NOS	Network operating system.
NSFNet	National Scientific Foundation Network (United States).
Office suite	A set of individual software applications (<i>e.g.</i> word processor, spreadsheet) that allows linkage among these applications, while integrated packages bundle individual applications without this linkage.
OLTP	On-line transaction processing.
OOP	Object-oriented programming. Programming according to the principles of object orientation. In an object-oriented system, objects co-operate, sending messages to one another to accomplish their overall task, as opposed to conventional, procedural programming.
Packet	The basic unit of Internet data. A message sent across the net is broken into packets. Each is marked with the address and other pertinent information, such as error-checking data.
Port	On an internet server, every service listens on a particular port number on that server. Most services have standard port numbers, <i>e.g.</i> Web servers normally listen on port 80.
PPP	Point-to-point protocol.

Protocol	Set of rules that govern the manner in which data is transmitted and received.
RISC	Reduced instruction set computer.
Router	A special-purpose computer (or software package) that handles the connection between two or more networks.
RSVP	Reservation protocol.
SMP	Symmetric multi-processing.
SPP	Scaleable parallel processor.
T1 Line	A 1 544 Mbits/s communications circuit for data or voice transmission.
T3 Line	A 44 736 Mbits/s communications circuit for data or voice transmission.
TCP/IP	Transmission control protocol/Internet protocol. The protocol used by the Internet network.
Telnet	A protocol, from the TCP/IP protocol suite, that provides remote terminal service, allowing a computer to connect and interact with remote computers.
URL	Uniform resource locator. The unique address of each document on the WWW. Includes the type of site (web page, gopher, ftp site, etc.), location, directory and filename information.
vBNS	Very high-speed backbone network service. A new advanced switching and fibre transmission network that enables transmissions at 155 Mbit/s.
WWW or W3 or Web	World Wide Web. A hypertext gateway to the Internet where resources (home pages, gopher sites, ftp sites, etc.) are interconnected via hypertext links. It is the multimedia portion of the Internet which allows users to view text, graphical images, video, sound, and animation. The concept of the World Wide Web was originally developed at the CERN (see CERN).

Appendix

OECD MEMBER COUNTRY IT POLICY PROFILES

AUSTRIA

General policies

In summer of 1995, the federal government set up 12 working groups consisting of high-level experts from administration, industry, academia, and consultancy to prepare a government White Paper on the Austrian way to the information society, which was completed in December 1996. In the context of this broad initiative, a report entitled *Information and Communication* was produced for the Ministry of Science, Transport and the Arts in August 1996. It outlined basic strategies for the telecommunications sector and the science system with respect to the information society.

In line with a related EU initiative, Austria has set up an Austrian National Host (ANH). Started in January 1995, it is a government initiative to improve telecommunications and information technology infrastructures and encourages private-public partnerships between network operators, service providers, industry, research and user communities.

Government demonstration and development projects/government procurement

It is planned to integrate public administration bodies by extending the network launched in 1996 which integrates the Federal Ministry of Finance and the revenue offices in all nine federal provinces. This A(ustria)-Net should cover most of Austria's public sector, including administration, social insurance, health, etc. It will require switching from the current MAN frame relay technology to ATM technology in order to allow transmission of data, speech (telephony) and multimedia applications. Further, it will use domain technology to provide each organisation/institution with its own virtual private network. It will be accompanied by a government-wide single num-

bering plan and the introduction of flat-rate access to governmental institutions.

Austria will establish an electronic system for monitoring road traffic. Its purpose is to control "ecopoints" related to the emissions of vehicles, as Austria and the EU have agreed to set emission limits for the main transit roads. For this purpose, all lorries of more than 7.5 tonnes registered in the EU that cross Austria will be equipped with electronic devices for storing and retrieving the relevant data. This will allow a central electronic unit to administer and count ecopoints (a certain number are allocated to each EU member state). The system will be implemented in January 1997 on the road to the Brenner pass, the main traffic link between Italy and Germany, and is expected to be fully operative in the last quarter of 1998. It will be compatible with other applications, such as electronic road pricing.

Standards

As a small country, Austria focuses on the rapid adoption of standards. One example is a government initiative to promote the implementation of electronic data interchange (EDI) based on the EDIFACT standard, diffusion of which will be supported by the Innovation and Technology Funds (ITF) via the Federal Ministry of Economic Affairs.

R&D programmes/technology diffusion

In 1996 the ITF launched Technologies for the Information Society, which will become its largest programme. It will run from 1996 to 2000 with a planned budget of US\$30-40 million and will cover four specific programmes: *i*) technology transfer: diffusion of telematic applications in small and

medium-sized enterprises with a focus on EDI; *ii*) broadband communication/multimedia: advanced use of multimedia applications in the medical, education/training, research and public administration sectors; *iii*) tele-co-operation: the set-up and use of telecommunication services for concurrent work in different locations in the services and manufacturing sector; *iv*) interoperability and interconnection: providing broad access to a large number of networks and services, as well as development and implementation of interfaces and platforms.

ITF also has a software programme, which started in 1994 and should run to 1998. Its focus is on user-producer co-operation in pilot applications and best practice, particularly in software engineering (including quality and testing, documentation, design and implementation of software and information systems).

URLs

<http://www.bmwf.gv.at/7forsch/infkom/pginfkom.htm> (German version of *Information and Communication*).

<http://bit.cosy.sbg.ac.at/acts/anh/> (the Austrian National Host).

<http://www.tcs.co.at/vtoe/wien/bmwa/ix1.htm> (ITF, which is overseen by the Federal Ministry of Economic Affairs).

<http://www.ad.or.at/erp/> (Technologies for the Information Society programme).

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Ministry of Science, Transport and the Arts (1996), *Information and Communication*, August.

CANADA

In 1996, the federal government of Canada issued a comprehensive strategy paper on Canadian policies for the Information Society, called *Building the Information Society: Moving Canada into the 21st Century*. It describes lines of action in the areas of infrastructure development, R&D, new fields of applications, development of a Canadian content industry, legal issues, and electronic accessibility of government.

Government demonstration and development programmes

Several initiatives are under way to build on the government's previous efforts in the field of information infrastructure. A government-wide e-mail system now connects 200 000 federal employees across the country. Future enhancements should permit it to support electronic commerce and mail-enabled applications.

During 1996, Industry Canada launched *Strategis*, a comprehensive source of on-line business information developed in conjunction with Canadian firms and economics departments in federal and provincial governments.

The Canadian government has undertaken a comprehensive review of administrative areas such as procurement and payment, and pay and benefits processes in order to redesign them in an integrated

fashion using new technologies. This review should result in considerable savings as well as improved delivery of services. A locally shared support service programme, encompassing about 250 pilot projects, has been introduced and allows the sharing of common administrative services and facilities.

Standards

In a joint government-industry effort, a "standards road map" will be developed. It will aim at widespread diffusion of internationally accepted standards and will be accompanied by a public awareness campaign. Through its procurement and standards-setting activities, the government will play the role of model user.

The Telecommunications Standards Advisory Council of Canada (TSACC) has established a Working Group on the Information Highway to advise on appropriate national standardisation guidelines. Its work includes identifying existing standards that facilitate connectivity and agreeing on a methodology for defining the "network of networks".

R&D programmes

The CANARIE consortium (Canadian Network for the Advancement of Research, Industry and Education), which was set up in 1993 and involves govern-

ment, business and key public institutions, started a second phase of activities (1995-99) on testing advanced networks and new applications. This phase will involve federal funding of almost C\$80 million, which is expected to leverage C\$396 million from industry and the provinces. During the first phase, 50 projects involving 175 Canadian firms, universities and research organisations received C\$18.5 million to develop technology, business, educational and health applications.

The Communications Research Centre (CRC) is a government laboratory that provides the information technology industry with facilities for testing new broadband applications and technology. In addition, the centre carries out many joint research projects with SMEs across Canada and contributes to the formation of private consortia.

The Advanced Satcom Initiative aims at providing support and risk sharing for the early development and commercialisation of satellite-based multimedia services. During Phase I, the private sector submitted a business plan for a regional commercial system offering bandwidth on demand and multimedia services. The proposal involves a direct investment by the private sector of over C\$600 million, and the government contributed a further C\$141 million. The second phase of this project should culminate in late 1999 with the implementation of a commercial system.

The government of Canada announced in March 1996 that by 1998-99 its Technology Partnerships Canada (TPC) programme would make available some C\$250 million annually in investment support to encourage technological innovation at the near-market end of the R&D cycle. This programme targets leading-edge, high-growth sectors, including selected information technologies (e.g. advanced software technologies, multimedia learnware, health-sector IT).

Technology diffusion

The National Research Council's Industrial Assistance Programme (IRAP), through its 260 industrial technology advisors, provides technical know-how and guides businesses to sources of technology and financing for R&D and technology adaptation projects. The Canadian Technology Network (CTN), a joint initiative of IRAP and Industry Canada, seeks to match SMEs with sources of technological expertise and related business advice.

The HealthNet initiative is a joint project by Industry Canada, Health Information Infrastructure Consulting, and other health community actors; it aims to foster the development of a health information infrastructure and a "hands-on" networking culture in Canada's health community. Through a series of Internet-based tools, this project seeks to educate and diffuse information using accessible wide-area network technology. The Health Intelligence Network, a recent initiative, aims to strengthen Canada's national surveillance and disease-monitoring capacity.

URLs

http://info.ic.gc.ca/info-highway/society/toc_e.html (Document: Building the Information Society: Moving Canada into the 21st Century).

<http://info.ic.gc.ca/info-highway/final.report/eng/> (Final Report of the Information Highway Advisory Council).

<http://strategis.ic.gc.ca/engdoc/main.html> (Strategis).

<http://www.canarie.ca/> (CANARIE).

<http://www.crc.doc.ca/index.html> (Communications Research Centre).

<http://info.ic.gc.ca/ic-data/industry/tpc/broche.html> (Technology Partnerships Canada).

<http://ctn.nrc.ca/> (Canadian Technology Network).

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Industry Canada, Information Highway Advisory Council (1996b), *The Information Highway: An Update on Canada*, March.

Industry Canada (1994), *The Canadian Information Highway: Building Canada's Information and Communications Infrastructure*, April.

Industry Canada, Information Highway Advisory Council (1994), *Providing New Dimensions for Learning, Creativity and Entrepreneurship, Progress Report*, November.

DENMARK

In April 1996, the Danish Ministry of Research and Information Technology published "The Info-Society for All – the Danish Model", the second Danish IT policy statement and action plan, which follows up on the 1995 "From vision to action – Info-Society 2000". The Danish government wishes to implement the following broad policy measures in order to fully realise the potential of the information society in Denmark.

Government demonstration and development projects

The government is undertaking a strong public information initiative which aims at increasing the availability of public sector information on the Internet. New initiatives include electronic case processing and archiving, as well as improving public access to official records and electronic archives. Spearhead councils were designated in 1995 to outline projects designed to improve the level of public service to individuals and companies, as well as the overall efficiency of local administrations.

Several initiatives are to be launched in order to develop an efficient electronic infrastructure and improve the flow of information among private companies, individuals and public institutions. The new Central Corporations Registry (CVR) should be established after 1997 to centralise basic data on firms. Upon completion of a survey by the Ministry of Business and Industry, reporting obligations and payment procedures to the government will be reviewed and streamlined in conjunction with recommendations from the Ministry of Research and Information Technology. A project was initiated in 1996 to improve the use of public sector databases on individuals and firms, as well as geographical and property data, focusing in particular, on issues of access and usage costs.

With regard to health policy, the MedCom project was launched over a two-year period to lay the foundation for a cohesive nationwide health information network based on the EDIFACT standard. In addition, the national plan for electronic patient journals (HEP) will conduct a development project for national standards for the Danish health service.

The Department of Education and Science, along with the National Agency of Environmental Protection, is conducting a mapping project to estimate the work-related, environmental and overall economic impact of telecommuting workplaces. In order to

study the effects of new technologies on qualification requirements, job content and work organisation, the Ministry of Labour will support various demonstration projects aimed at improving the working and living conditions of employees, as well as at evaluating the significance of telecommuting and other non-standard forms of employment (e.g. free-lance or task-specific work).

Standards

An EDI action plan is being drawn up to define the necessary EDIFACT standards before the end of 1997. This collaborative effort between the Ministries of Business and Industry, Research and Information Technology, the Danish EDI Council, and central organisations of trade and industry will determine the EDIFACT standards that public sector agencies (e.g. Danish tax authorities, Danmarks Statistik, the Danish Commerce and Companies Agency) should embrace when handling incoming reporting and entering into framework agreements on procurement.

In the area of IT security, the Danish government is proposing a bill on the introduction of an electronic "Citizen's Card" which, through the use of a PIN code, would effectively act as a secure communication key for use in electronic self-service systems (tax offices, local administrations, libraries, banks). This card would be issued on a voluntary basis and according to international standards on "intelligent" cards. It would contain an array of personal information (visible as well as electronic), while guaranteeing the users a high degree of security and confidentiality, and could be used in conjunction with other electronic identification cards.

R&D programmes

Following the recommendations of the report, *Research in Perspective: White Paper on a National Research Strategy*, the Ministry of Research and Information Technology is currently outlining a national strategy for research in various IT fields. During the period 1996-99, Dkr 120 million have been allocated for establishing and operating a nationwide research network linking together approximately 90 Danish research institutes via high-speed connections for text, image and sound.

Technology diffusion

The Ministry is initiating the development of an electronic research library and encouraging the for-

mation of "virtual institutes" where public research centres and private companies may collaborate on line. In early 1996, the Danish Committee for Scientific and Technical Information and Documentation (DANDOK) established a databank (DANDOKENbasen) for the scientific community containing more than 101 000 research references. This database combines information from universities, institutes of higher education, government research institutes, research councils and other public research institutes.

In order to improve the broad availability of information technologies, the Danish government's action plan calls for the development of public sector "info-kiosks" in libraries and public offices, as well as specific steps for ensuring convenient access to and ease of use of IT for disadvantaged groups, such as the physically disabled. In addition, a survey will be conducted to determine the needs and habits of tourists and to give them access to up-to-date electronic information systems on services, facilities and events.

The Cultural Network Denmark was established to co-ordinate and broaden information efforts among various institutes by simplifying access for individuals and groups to cultural information through the use of information technologies. During 1996, eight pilot projects were launched covering

architecture, music, cinema as well as other cultural and historical fields.

URLs

<http://www.fsk.dk/fsk/publ/1996/it96-uk/> ("The Info-Society for All – The Danish Model")

<http://www.fsk.dk/fsk/publ/it23/> ("IT in figures 1996 – 23 Pictures of the Info-Society").

<http://www.fsk.dk/fsk/publ/it95-uk/> ("From Vision to Action – Info-Society 2000" and "IT Political Action Plan 1995").

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DANISH MINISTRY OF RESEARCH AND INFORMATION TECHNOLOGY (1996), *The Info-Society for All – the Danish Model* (IT Policy Statement and Action Plan 1996), April, Copenhagen.

DANISH MINISTRY OF RESEARCH AND INFORMATION TECHNOLOGY (1996), *IT in figures 1996 – 23 Pictures of the Info-Society*, Copenhagen.

EUROPEAN UNION

In 1993, the European Commission's White Paper, *Growth, Competitiveness and Employment*, emphasised the importance and urgency of developing a pan-European information infrastructure to help revive European economic growth and competitiveness and to create new markets and jobs. On this basis, the European Council asked a high-level group of experts to suggest concrete measures; these were outlined in a June 1994 report entitled *Europe and the Global Information Society – Recommendations to the European Council*, the so-called Bangemann Report. The report emphasises the need for more rapid liberalisation and the fact that financing the information infrastructure should mainly be the responsibility of the private sector. It also argues that the European Union and its member states should create a coherent statutory framework so that the circulation of information will not be impeded by different national regulations. Subsequently, in July 1994, the Commission presented *Europe's Way to the Information Society An Action Plan*, with four main

aspects: adaptation of the statutory and legal framework; encouragement of initiatives in the areas of trans-European networks, services, applications, and content; social and cultural aspects; and promotion of the information society.

The following sections summarise activities in the areas of statutory and legal framework, research and technological development (RTD), and standardisation.

Statutory and legal framework

The central element in the adaptation of the statutory and legal framework is the liberalisation of infrastructure so that European enterprises can remain competitive internationally and help speed up implementation of a European-wide information infrastructure. Liberalisation involves: *i*) full liberalisation of networks and voice services by January 1998; *ii*) harmonisation of the regulatory environment and standards for services and technologies, such as

the Global System for Mobile Communications; and *iii*) full application of the rules of competition. Other important measures to be proposed relate to the definition of universal service and its financing, interconnection and interoperability, intellectual property rights, electronic and legal protection, media control and the international dimension.

Research and technological development

In light of the need for a concerted and co-ordinated effort at European level, EU activities in the area of RTD aim to extend, complement and enhance the research activities of member states. Over the years, they have increased in importance in terms of Community policy and allocation of financial resources. There are a number of EU RTD initiatives in the framework programmes, while EUREKA places high priority on information and communications technologies.

Framework programmes

Since 1984, EU RTD activities have been planned and co-ordinated within multi-annual framework programmes which set priorities for the duration of the programme. The Fourth Framework Programme (1994-98) – largely influenced by the Maastricht Treaty and the Commission White Paper, *Growth, Competitiveness and Employment* – outlines all Community RTD activities to be funded, up to 50 per cent in most cases, by the European Commission. The programme's total budget is ECU 13.1 billion, more than double the budget of the previous framework programme (1990-94). About one-third of the total budget is allocated to RTD for information and communications technologies.

ESPRIT (European Strategic Programme for Research in Information Technology), one of the most important of the Fourth Framework's programmes, is concerned with industrial R&D projects and technology take-up. In recognition of the fact that information technologies are crucially important to industrial competitiveness, it aims to facilitate the timely take-up of IT by European industry and the provision of appropriate products and services by Europe's IT industries. ESPRIT focuses on industry requirements and covers eight areas of research, the last four of which are "focused clusters" for achieving specific research and industrial objectives. The eight areas are long-term research, software technologies, technologies for components and subsystems, multimedia systems, open microprocessor systems initiative (OMI), high-performance computing and networking, technologies for business processes, and integration in manufacturing.

As a successor to RACE (Research and Development in Advanced Communication Technologies for Europe), ACTS (Advanced Communications Technologies and Services) was launched as part of the Fourth Framework Programme. ACTS aims at bringing together telecommunications, television, and media, which are essential for developing trans-European networks and services. Major research topics include: interactive digital multimedia services, mobility and personal communications networks, photonic technologies, intelligence in networks and service engineering, high-speed networking, and quality, security and safety of communication services and systems.

Based on results from ESPRIT and ACTS, Telematics Applications aims at developing applications by involving users and at promoting the competitiveness of European industry and the efficiency

Framework programme budget breakdown

	Funding (million ECU)	Percentage
<i>Activity 1.</i> RTD and Demonstrations Programmes:	11 381	86.9
<i>of which:</i> Information and communications technologies	3 626	31.9
1. Information technologies (ESPRIT)	2 057	15.7
2. Communication technologies (ACTS)	671	5.1
3. Telematics (TELEMATICS)	898	6.9
<i>Activity 2.</i> Co-operation with third countries and organisations internationales	575	4.4
<i>Activity 3.</i> Dissemination and optimisation of results	352	2.7
<i>Activity 4.</i> Training and mobility of researchers	792	6.0
Total	13 100	100.0

Source: CORDIS (Community R&D Information Service).

of services of public interest. At the same time, it seeks to stimulate job creation through the development of new telematics systems and services in such areas as telework and teleservices. It supports RTD activities in three areas: services of public interest (administrations and transport); knowledge (research workers, libraries, and distance education and training); and improving employment and the quality of life (disadvantaged social categories, urban and rural areas, health care and environmental protection).

Through EUREKA, launched in 1985, industry and research institutes from 24 European countries (including non-EU countries) and the European Commission develop and exploit the technologies crucial to global competitiveness. Unlike framework programmes, which are top-down (programmes are generated, supervised and funded by the European Commission), EUREKA takes a bottom-up approach (projects are generated by partners and funding from other sources is induced by the EUREKA label). EUREKA promotes pan-European, market-oriented R&D; it has about 150 projects a year and, in financial terms, information technology is the largest area. Major themes include hardware (e.g. integrated circuits, processors and peripherals), software production, and a wide range of applications in linguistics, health care, navigation, manufacturing, etc.

Standardisation

European standardisation activities in the area of information and communications technologies are carried out by organisations such as the European Telecommunications Standards Institute (ETSI), EBU, CEN/CENELEC, and ITSTC. ETSI, a standards-setting

body set up in 1988 and recognised by the European Union, provides voluntary technical specifications in the areas of telecommunications, information technology, and broadcasting. Its main task is to accelerate the process of technical harmonisation to ensure full interoperability of a pan-European telecommunication infrastructure. ETSI assists the European Commission in producing standards to be referred to in EU legislation.

URLs

<http://www.ispo.cec.be/infosoc> (Europe's Way to the Information Society: An Action Plan)

<http://www.cordis.lu/cordis/> (EU Framework programme)

<http://www.cordis.lu/esprit/> (EU ESPRIT programme)

<http://www.cordis.lu/acts/> (EU ACTS programme)

<http://www.cordis.lu/telematics/> (EU telematic programme)

<http://eureka.belspo.be/> (EU EUREKA programme)

<http://www.etsi.fr/> (EU ETSI programme)

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European Commission (1994), *Europe's Way to the Information Society: An Action Plan*, 19 July.

FINLAND

General policies

In January 1995, the Finnish Ministry of Finance published a report outlining a national strategy for the development of the Information Society in Finland. A summary of this study in English, "Finland's Way to the Information Society: The National Strategy and its Implementation", includes a progress report on developments related to its implementation during 1995-96.

Other reports relating to sector-specific strategies have been published by various government bodies such as the Ministry of Education (education and skills, research and networking, information products and services), the Ministry of Transport and Commu-

nications (development of information networks and transport telematics), the Ministry of Trade and Industry (technology projects such as the TEKES multimedia programme) and the Ministry of Health and Welfare (information technology and social services). A national Information Society Forum was established in May 1996, along with the Government Committee for Information Society Issues.

Government demonstration and development projects

There are several projects aimed at reforming public services through process re-engineering incorporating advanced use of IT and networks, as well as

at providing direct customer access to public sector information and services. According to a survey commissioned by the Ministry of Finance and conducted by the Information Technology Development Centre (TIEKE), in 1995 there were about 0.8 workstations per government employee. 8.7 per cent of these were portable and practically all were connected to LANs and had e-mail capability, while 36.3 per cent had access to the World Wide Web.

In 1996, the Ministry of Finance announced a national proposal on data security infrastructure for electronic identification. The final report recommends the use of smart card technology along with a public key system which should begin to be implemented during 1998. The use of an Electronic Citizen Card should increase data security and privacy while allowing for, among other things, electronic identification, electronic signatures, encryption of documents to be transferred and electronic payments.

Standards

The goal of several initiatives is to promote and unify electronic information exchange among administrations at all levels and to create integrated customer-oriented public service systems with appropriately defined network standards. Legislation is currently being drafted to allow for the use of electronic media for transactions among citizens, firms and government agencies. There are also plans to promote internationally compatible solutions to problems related to protected material (e.g. copyright issues).

TIEKE has introduced a computer user "driver license" which has attracted interest internationally. In 1995, 10 000 licenses of this type were issued on the basis of a comprehensive examination.

R&D programmes

Through the Technology Development Centre (TEKES), the Finnish government has launched several initiatives, such as the Finnish Multimedia Programme which seeks to build trial environments for networked multimedia through broadband networks, digital broadcasting and cellular networks, while fostering the development of a content industry. Other projects deal with a wide array of applications such as digital media, electronic publishing, adaptive and intelligent systems, and digital media in health care. The FinTelSME programme for SMEs in the telecom-

munications industry was launched in 1994 and covers a broad range of activities from basic network technology to creation of customer-focused services.

Technology diffusion

In its January 1995 position paper, the Finnish government announced plans to support information and communication industries by providing better access to risk financing, supplying high-quality public broadcasting programmes and participating in international exchanges of programmes, and initiating digital and radio broadcasts. This report also outlines measures to enhance conditions for SMEs and encourage entrepreneurship through the use of IT and improved access to networks. In addition, the government wishes to strengthen public libraries as nodal points of an open information network.

URLs

<http://www.tieke.fi/tieke/tikas/indexeng.htm> (Information Technology Development Centre, "Finland's way to the Information Society - The National Strategy and its Implementation").

http://www.minedu.fi/infostrategy/tietostr_ToC.html (Ministry of Education, "Education, Training and Research in the Information Society. A National Strategy").

<http://www.tekes.fi/english/> (TEKES - Technology Development Centre).

<http://www.stakes.fi/stmeng1.html> (National Research and Development Centre for Welfare and Health, "A National Strategy for the Utilisation of Information Technology in the Field of Social Welfare and Health Care").

<http://www-tre.research.nokia.com/> (Finnish Multimedia Programme).

<http://www.telmo.fi/tiveke/english/index.txt> (Ministry of Transport and Communications, "National Information Network Development Programme").

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GERMANY

General policy trends

In 1995, the federal government launched a broad-scale policy initiative, "Information Society Germany", the rationale and contents of which are outlined in a report issued by the Federal Chancellor's Council for Research, Technology and Innovation, *The Information Society: Opportunities, Innovations and Challenges. Assessments and Recommendations*, Bonn, December 1995, and in a report of the federal government, prepared by the Ministry for Economic Affairs, *Info 2000: Germany's Way to the Information Society*, Bonn 1996 (in German).

The federal government has also produced several specific initiatives, one of which, "Information as a Raw Material for Innovation: Programme of the Federal Government 1996-2000", seeks to facilitate access to existing private and public sources of information. Other specific initiatives are scheduled to be formulated.

Some elements of the government's effort are described below.

Government development projects

In order to improve the information technology infrastructure, the Council for Research, Technology and Innovation has recommended upgrading the existing scientific network (DFN), which currently operates at 2 Mbit/s to 155 Mbit/s. For this purpose, the BMBF will provide DM 80 million over the next three years to the net operator. The network will be opened to other scientific and research institutions, such as libraries, scientific associations, and private research laboratories. It is planned to connect schools to the DFN at a lower speed (64 Kbit/s). This should allow the use of advanced multimedia technologies (thereby affecting both the content of publicly provided information and the development of private markets for information).

Government procurement/demonstration projects

The move of government institutions from Bonn to Berlin and the need to ensure a constant and secure flow of information between these two cities (some institutions remain in Bonn) has led to the establishment of the Berlin-Bonn Information Association (IVBB). Use of advanced information

technologies in this respect will serve as a demonstration project for other parts of the administration.

Projects in the programme "Information as Raw Material for Innovation" include:

- the establishment of an electronic patent information system (PATIS/PATIS-ONLINE) and the training and education of users (especially from SMEs);
- software development for easy end-user access to the various medical databases (SUPERBASE) of the German Institute for Medical Documentation and Information (DIMDI);
- the migration of the German agriculture information network (DAINet) to the Internet;
- a BTX-based access to the databases of the Federal Statistical Office;
- co-operative projects between publishing companies, libraries and authors for electronic publishing in the sciences
- the establishment of a scientific information centre at Karlsruhe as part of the international Scientific and Technical Information Network.

The demonstration projects are generally meant to provide start-up financing, which, wherever possible, should subsequently be replaced by income generated from the provision of information and information services.

R&D

The BMBF is to outline a framework concept, "Innovations for the Information society 1997-2001", to define central lines of action for future R&D programmes. The following current programmes will be continued: Microsystem technologies (to 1999); Production 2000 (to 1999); Massive parallel computing (to 1998); Intelligent systems (to 1999); Photonik; Display technology. In all, BMBF's funding for IT is expected to grow from DM 1 010 million in 1996 to DM 1 029 million in 1997, DM 1 048 million in 1998, and DM 1 067 million in 1999.

URLs

<http://www.bmwi-info2000.de/>

<http://www.bmwi-info2000.de/gip/programme/index.html> (also in English)

<http://www.dfn.de/bmbf/foerderprogramme/rohinfo/roh-info.doc> (in German)

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Information als Rohstoff für Innovation, *Programm der Bundesregierung 1996-2000*, Bonn, 1996.

ITALY

General policy trends

In line with the basic thrust of Italian IT policy, the improvement of basic public IT infrastructures will have high priority in coming years. The three main projects are the implementation of the Public Administration Unified Network (PAUN), the upgrading of the inter-university computing centres (CINECA, CILEA and CASPUR) and of the GARR (*Gruppo Armonizzazione Reti per la Ricerca*) network.

Public development projects

Public development projects also include elements of procurement and standardisation.

The PAUN initiative dates from a ministerial directive of September 1995 and is carried out and supervised by the recently created Authority for Information Technology in the Public Administration (AIPA). Its principal targets are the unification of some 70 networks in public administrations to ensure interoperability of applications and provide new services, with the following timetable:

- January 1996: feasibility study on protocols (available from <http://193.205.136.133/aipa.htm>;
- June 1996: triennial plan (1997-99) to co-ordinate administrations' programmes;
- 1997: pilot implementation of PAUN in the Rome MAN;
- establishing WANs beyond the Rome region and linking local area networks and PABXs with the Rome area;

- migration of existing networks to PAUN.

The GARR-2 project aims to upgrade the network of the main Italian R&D institutions (universities, R&D centres, etc.), which operates at 2 Mbit/s and will be improved to 34 Mbit/s. This project, undertaken in international co-operation, is co-financed by the Ministry of the Universities, Research and Science and the EU.

International co-operation

In summer 1996, PQB 2000, a national project in massive parallel computing, was launched as a joint effort of public (CNR, ENEA, INFN, universities) and private (Alenia Spazio, Finmeccancia) institutions. This public/private partnership will be open to wider collaboration at European level. Its focus is the upgrading of the Italian technological base for massive parallel computing.

URLs

<http://193.205.136.133/rete/rete1.htm> (the PAUN initiatives, in Italian).

<http://www.cnr.it/CNR/CNR-WWW.html> (Consiglio Nazionale della Ricerca).

<http://www.murst.it/murst/minist.html#Pian> (Ministry of the Universities, Research and Science (MURST)).

<http://www.iasi.rm.cnr.it/garr.html> (Gruppo Armonizzazione Reti per la Ricerca).

JAPAN

General policy

In August 1994, the Cabinet established the Advanced Information and Telecommunications Society Promotion Headquarters, with the Prime Minister as director and ministers from the Ministry of Posts

and Telecommunications (MPT) and the Ministry of International Trade and Industry (MITI) as deputy directors, to promote a comprehensive set of policies and measures. Subsequently, the *Basic Guidelines on the Promotion of the Advanced Information and Telecommunications Society* were issued and approved

by the Cabinet in February 1995. The relevant government agencies prepared further progress reports and, in August 1995, issued *Implementation Guidelines for Increasing the Use of Information and Communications* in six public policy fields (education, scholarship, culture, and sports; research and development; health, medical treatment, and social services; roads, transportation, and rolling stock; weather forecasting, air traffic control and other public transportation areas; and disaster prevention).

Based on a policy report, *Medium-range Plan for Advancing Info-communications Infrastructure by the Year 2000*, the MPT is promoting measures for advancing the info-communications infrastructure by the year 2000, including R&D on info-communications technologies. The report describes prospects for the advanced info-communications society by the year 2000 and proposes policy measures in the following fields: *i*) development and deployment of applications; *ii*) advancement of the network infrastructure, *iii*) R&D on info-communications technologies; *iv*) promotion of new info-communications businesses; and *v*) active participation in the development of the global information society.

To enhance awareness in the private sector and to propose a comprehensive set of policies and measures, MITI presented in October 1995 a policy report, *Programme for Regaining the Dynamism of Industries by Making Use of Electronic Information Technology*. Based on the analysis of investment in information in Japan, MITI proposed a programme to revive Japan's economy and industry which covers five areas: *i*) facilitating the introduction of IT in the industrial sector; *ii*) introducing advanced IT in the public sector; *iii*) supporting software R&D; *iv*) promoting IT development; and *v*) establishing an appropriate environment for security, privacy, and intellectual property rights.

Electronic commerce

Among measures for promoting private sector computerisation, MITI places particular emphasis on electronic commerce. Related measures include pilot projects for promoting advanced inter-firm electronic commerce (e.g. standardisation of basic specifications for processing digital graphic information, ordering) and 19 pilot projects for developing common fundamental technologies for electronic commerce between companies and consumers (e.g. security technologies such as cryptography and authentication, technologies on IC cards). In fiscal 1996, a budget of ¥ 32 billion was allocated for the promotion of electronic commerce.

MPT also launched pilot projects to promote cyber-business. Under the private-sector Cyber Business Association Japan, formed in 1995 to test the encryption and verification technology used in electronic business transactions, the INGECEP (Integrated Next Generation Electronic Commerce Environment Project) was launched in April 1996; it includes two experimental projects in which the Telecom Service Association (TSA) and the Japan Electronic Messaging Association (JEMA) participate (with a budget of ¥ 1.7 billion for fiscal 1996). The electronic commerce experimental project was recognised as an APEC project in September 1995 and as a G7 project in December 1995. In order to make this pilot project more productive, MPT plans to add the "Communications Experiment to Contribute to Electronic Money" to this pilot project in April 1997.

Computerisation of the public sector

In December 1994, a five-year plan for promoting administrative computerisation throughout the government sector was approved by the Cabinet, to begin in fiscal 1995. On this basis, the government issued an Action Programme on Common Issues for Administrative Computerisation, which aims to increase the efficiency of administrative procedures and the quality of governmental services; included are measures to introduce a WAN to connect government office buildings in Tokyo (Kasumigaseki), an e-mail system, and EDI networks connecting various agencies; to develop administrative information databases; to provide reports and statistics in electronic form; to centralise information dissemination; to handle application forms and approvals electronically and on-line.

Each of 25 agencies also prepared individual five-year plans. While they vary, common features include introducing one PC per employee, developing a LAN, introducing an electronic approval system, digital storage of documents, etc. For example, MITI issued a plan which includes measures for further job informatisation (e.g. paperless patent applications, development of a new-generation statistical system), which received a budget of ¥ 34 billion for fiscal 1996.

Significant progress has been made since the programme started. All MITI and MPT (including local bureau) employees now have a PC. There is one PC for every 1.5 employees in the Economic Planning Agency (EPA), and one for every two employees in the National Land Agency (NLA) and the Ministry of Agriculture, Forestry and Fisheries (MAFF). All other agencies are following suit. A LAN was also introduced in

six agencies in 1995 for a total of 16 with a LAN. By the end of 1996, most agencies are expected to have a LAN. Furthermore, about half of the agencies were connected to the Internet in 1995 and provide information via the Internet (e.g. MPT, MITI, EPA, MAFF, Ministry of Foreign Affairs, Science and Technology Agency, Environmental Agency, Ministry of Construction).

Review of the regulatory system

In August 1995, the Advanced Information and Telecommunications Society Promotion Headquarters set up the Working Group on the Review of the Regulatory System to examine the present regulatory system which requires private sector to keep various documents on paper and prohibits electronic processing of various applications. In order to promote the digitalisation of information and transactions, the Working Group issued a report in June 1996 which states that laws should be enacted to allow digital storage of documents and electronic processing of various applications, proposes measures to deal with possible problems, and urges all agencies concerned to proceed as of July 1996.

Infrastructure development and deregulation

As one measure for developing the infrastructure for the advanced information and telecommunications society of the 21st century, MPT created in 1995 a special financing system for the development of the subscriber optical fibre network. This system is aimed at lightening the investment burden for the Type I telecommunications carriers and cable TV operators that will construct such networks. A fund (¥ 2.5 billion in fiscal 1996) of the Telecommunications Advancement Organisation of Japan, it covers up to 2 per cent of the interest on loans (15-year loans of ¥ 42 billion in fiscal 1996) provided by the Japan Development Bank and others until the year 2000 (see MPT's *Communications in Japan 1996*).

With regard to deregulation, the MPT released, in January 1996, a set of measures for the Second Info-communications Reform, in order to stimulate the info-communications market and lower costs by promoting greater competition. Concrete issues include deregulation of telecommunications businesses (e.g. revision of market entry regulations, deregulation of Type I telecommunications business rates, revision of the framework on interconnection, interconnection of private leased circuits with public switched networks at both ends, deregulation regarding foreign ownership), the future status of NTT and

KDD, and deregulation of broadcasting (e.g. introduction of digital multi-channel satellite broadcasting).

Standards

As stated in the Basic Guidelines on the Promotion of the Advanced Information and Telecommunications Society, interoperability has been a key issue for developing an advanced information infrastructure. The Interoperability Subcommittee (Information Policy Committee, under the Industrial Structure Council), established in November 1994, presented a report to MITI in June 1995 which stresses the importance of "open interface" and proposes concrete measures including: establishment of Open Interface Inventory (tentative name); R&D on CALS, electronic library, next-generation interoperable networks; electronic commerce experimental projects; revision of government procurement policies. On the basis of these proposals, MITI plans to implement appropriate measures for interoperability.

In May 1995, the Telecommunications Technology Council presented to MPT a preliminary report, "Basic Measures for Standardisation in Telecommunications for an Advanced Information Society". It presents policies and a schedule for promoting info-communications standardisation programmes, interconnectivity and interoperability.

R&D

Based on the Science and Technology Basic Law (November 1995), which promotes comprehensive and systematic science and technology policies, the Japanese government formulated the Science and Technology Basic Plan (approved by the Cabinet in July 1996). The plan covers S&T policies for the next decade and includes measures such as constructing information/communications infrastructure at R&D institutions (e.g. provision of computers and LAN, introduction of ATM), developing networks among R&D institutions (e.g. development of inter-institutional networks) (documents in English available at Science & Technology Agency).

For fiscal 1996, MITI allocated ¥ 11 billion for the promotion of leading-edge electronic technology development, one of its computerisation-related measures. This government-led R&D project, which is key to the creation of new industries and an advanced information society, aims at breakthroughs in leading-edge hardware technologies (e.g. super microscopic processing technology).

The R&D Master Plan for Info-Communications Technologies was submitted by the Telecommunica-

tions Technology Council in May 1996. Its goal is development of an advanced info-communications society and creation of intellectual property. In this context, MPT is undertaking to promote primary R&D projects and to establish R&D frameworks, one of which is the Multimedia Virtual Laboratory, a decentralised collaborative R&D framework using info-communications networks.

Recognising that Japan's software industry has been small due to lack of market incentives for advanced software development, MITI launched the Creative Software R&D Project with a budget of ¥ 28 billion for fiscal 1996. The project is meant to serve as an incubator for venture businesses that are potential sources of creative/advanced technologies and infrastructure/common technology.

International co-operation

Aside from participating in the effort to identify international IT standards and rules (e.g. ISO, IEC, ITU), Japan participates in the 11 pilot projects endorsed by G7 ministers in Brussels in February 1995. Japan chairs the Global Inventory, the Global Interoperability for Broadband Networks (GIBN), the Electronic Libraries, and the Global Marketplace for SMEs projects. In particular, it contributes actively to GIBN, the aim of which is to begin interconnecting broadband networks among the G7 nations to test global interconnectivity and interoperability (e.g. global high-speed satellite communications, VOD interconnections, advanced telemedicine).

URLs

<http://www.mpt.go.jp> (MPT).

General policy trends

In March 1995 the Norwegian government appointed a state secretary committee to assist in coordinating the government's information technology policy. In January 1996, this committee produced a report containing 30 policy proposals and 60 measures to be implemented under the responsibility of the relevant ministries.

Government development and demonstration projects

To address the issue of the information society/information infrastructure, a National Initiative for the Networked Society (NIN) was launched in 1995.

<http://www.miti.go.jp> (MITI).

<http://www.sta.go.jp/kihonhou/kihon-e.html> (based on the Science and Technology Basic Law, November 1995, English version).

[http://www.mpt.go.jp/policyreports/english/misc/Deregulation-pack age.html](http://www.mpt.go.jp/policyreports/english/misc/Deregulation-pack%20age.html) (description of the MPT "deregulation package").

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Telecommunications Council (1994), *Reforms toward the Intellectual Creative Society of the 21st Century: Programme for the Establishment of High-performance Info-communications Infrastructures*, Ministry of Posts and Telecommunications, 31 May.

Telecommunications Council (1995), "For Achieving Globalisation of an 'Intellectually Creative Society'", Interim Report, Ministry of Posts and Telecommunications, 23 January.

NORWAY

NIN co-ordinates and initiates demonstration projects and applications requiring joint efforts by main actors in the public and private sectors.

The Division of Industry and Energy of the Research Council of Norway issued a report outlining 12 areas of application of IT, including efforts to promote EDI and the establishment of a national road information network.

A programme to advance the use of EDI as a tool for electronic commerce has been set up for the period 1996-99, with public funding of approximately Nkr 22 million a year. Its target is to have 60 per cent of all reporting from the private sector to public administration carried out electronically by the end of 1998. To this end, there will be several demonstration

projects (e.g. in the SPREDI Programme in selected lines of business), implementation plans of major public agencies (e.g. Directorate of Public Roads, Norwegian State Railways, Directorate of Taxes, National Insurance administration) will be coordinated, and EDIPRO, an organisation for the promotion of EDI, will be set up on a permanent basis.

The establishment of a National Road Information Network in the period 1996-99 is envisaged. The plan is to: *i*) formulate a strategy for an Electronic Road Net; *ii*) set up a public development project for a national road informatics network; *iii*) begin implementation. Preparation and management costs amount to Nkr 2 million, and, depending on the scale of the network, investment is expected to range from Nkr 25 million to Nkr 100 million for the entire period. A co-operative body, comprising infrastructure suppliers, the IT industry, network operators, and users will be established to specify requirements, determine the scope of activities, and supervise the establishment of the network.

The NIN initiative will extend the existing HUGIN project (High-capacity network for the development of telecommunications services and equipment in Norway) to ensure the availability of broadband networks based on ATM technology by the end of 1998. This is likely to raise total funding of HUGIN from Nkr 30 million to Nkr 40 million a year, of which half should come from private sources.

Other projects under the umbrella of the NIN include Electronic Maritime Navigation, networks for geographical information in local administration, information networking for specific industrial sectors (construction, petroleum, tourism), SMEs, telemedicine, telecommuting and environmental networks.

URLs

<http://odin.dep.no/html/nofoalt/offpub/utredninger/it/it-veien/index.html> (Den Norske IT-veien).

http://odin.dep.no/html/nofoalt/depter/ad/publ/st_ipole.html (Principles of Norwegian IT-Policy).

<http://odin.dep.no/html/english/> (Public Norwegian Government Server).

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Ministry of Government Administration (1995a), *Innspill til borsk bidrag til informasjons-infrastruktur* (Proposal for a National Information Network, NIN), 25 January.

Research Council of Norway (1995), Division of Industry and Energy, *National Information Network: Twelve Areas of Application*, April.

SWEDEN

General policies

A government bill, "Measures to broaden and develop the use of information technology" (Regeringens proposition 1995/96:125) was adopted by parliament on 6 June 1996. It presents the government's proposals for a comprehensive Swedish National IT strategy and sets out the direction for Sweden's entry into the information and knowledge-based society. There are three priority activities: the legal framework, education and training (see Part II), and public provision of and accessibility to information. The government has put forward an initial action programme. A Commission to Promote the Widespread Use of Information Technology has also been set up to advise the government on overall and strategic issues in the IT area.

In addition, because young people may drive the development of the use of IT, the government has established an Young People's IT Council, with participants between 14 and 25 years of age. It will focus on IT in schools and young people's use of IT.

The legal framework

A Legal Observatory will be established to map the legal issues related to IT development comprehensively. The five priority legal areas are privacy protection, the legal framework for handling of electronic documents in public administration, copyright issues, regulation of distance work, and a new telecommunications law. The ambition is to implement the necessary statutory changes within three years.

Government procurement

STATTEL and Statskontoret (the Swedish Agency for Administrative Development) have concluded framework contracts with a number of suppliers. STATTEL has negotiated and concluded a framework contract concerning telephony services and Statskontoret a framework contract concerning computers. Government agencies using these contracts can order services and equipment according to the conditions laid down in the framework contract. An agency is not

obliged to use these framework contracts. However, if an agency chooses other suppliers, it must follow the usual procurement procedure, which may be costly and time-consuming.

Government demonstration and development projects

The government will appoint a committee to investigate the security and availability of the Swedish part of the Internet. The objective is to diminish the net's vulnerability to interruptions and to determine what is needed to increase its usefulness through technically sound rules concerning such items as a directory of names and addresses, development of a register for choice of route, administration of security keys, and development of a national search structure.

The creation of a national directory is under way. It is to contain all telecommunication addresses that subscribers wish to have accessible and will make increased use of IT possible.

Toppledarforum (Top Managers' Forum)

The Toppledarforum (Top Managers' Forum) of the Ministry of Finance is an informal, joint-action group dedicated to modernising the public administration with IT support. It is headed by Mr. Erik Åsbrink, Minister of Finance. Other members include directors of authorities that are large-scale gatherers and users of information and the directors of the Swedish Federation of County Councils and the Swedish Association of Local Authorities.

The working programme of the Top Managers' Forum has three parts. Current and completed activities are presented under each heading.

Information management in public administration sector

- PROSIT (completed). Study of urgent regulations for efficient information supply. Proposals submitted are: policy for price levels of and access to electronic information in public administration; regulations for use of basic databases; policy and objectives with emphasis on management responsibility.
- LEXIT (completed). Initiated a review of regulations (including legislation) for IT activities and use in public administration.
- Public authorities Internet pages. Common uses of information on electronic bulletin boards of government authorities, municipali-

ties and county councils on the Internet and other databases.

- Pre-study Quality. Preparatory study on the design of an action plan for quality assurance of electronic information supply in public administration.

IT platforms (standards, technology, basic services)

- E-mail and catalogue. Implement e-mail in public administration, establish name and address directories via specification profiles for e-mail systems. Currently working on measures for implementation of e-mail and on creation of directories.
- IT-platforms. Will investigate possible common interfaces and recommend standards. Currently working on proposed interfaces and standards.
- Smartcards in public sector activities.

Re-engineering public administration with the aid of IT

- Electronic commerce. Introduce electronic procurement within the public administration. Currently working on projects involving government/counties/municipalities to establish an organisational plan to introduce electronic commerce into public administration.
- Re-engineering. Will present examples of re-engineering of public administration supported by IT. A report on electronic document and case processing has been submitted. Currently working on demonstrating/initiating examples of modernisation of activities involving several authorities with IT support.
- Geographical information system. A preparatory study has been completed on how county councils should supply information to municipalities on physical planning and land use/zoning. Currently working on pilot project aimed at reduction of lead time and streamlining of geographical information supply between county councils and municipalities.

The Swedish University Computer Network (SUNET)

SUNET now primarily serves universities. The National Agency for Higher Education has administrative responsibility for SUNET and a special board for the activity. SUNET plays an important role in the

development of the Internet in Sweden. At present, the network guarantees 11 large colleges good Internet access. An additional 15 colleges are connected via universities. SUNET will be developed to include at least the main library in each municipality and state-subsidised museums.

The database system for libraries, LIBRIS, will be developed as a national and common information resource. The government will give the Royal Library the task of developing and managing a national library system based on IT.

Standards

SOTIP (the Swedish open telecommunication system interconnection profile) is used by government authorities when analysing telecommunications needs and when purchasing telephony equipment and services. The STATTEL Commission and Statskontoret have used SOTIP as the basis for specifying the procurement of telecommunications services and PABXs. SOTIP states which basis standards are to be used and how they are to be used. At the same time, SOTIP serves as guidelines for potential suppliers. The intention is to harmonise the development of SOTIP with similar projects in government bodies in other countries and within commercial user groups.

R&D

The largest comprehensive effort in the IT field in Sweden is made within the framework of the R&D programme for which the Swedish National Board for Industrial and Technical Development (NUTEK) is responsible. Four areas for special action have been pointed out: complex technological systems, supply of competence and technology to small enterprises, production of services and use of IT, and man, technology and organisation.

NUTEK's programme has put increased emphasis on services and IT use. Under ITYP (Information technology in the services sector for enhanced professional skills and productivity), which started in 1990 and ends in 1996, about 100 projects have been financed by NUTEK, which has contributed SKr 100 million, and others. Since 1993/94, it has focused on the following fields: IT support to public co-ordinated services, tele-commuting or decentralised services production, network-based handling of knowledge, interfaces between man and computer that improve efficiency and competence, IT for job

creation, systems evaluation, and improved use of software.

Technology diffusion

The Stiftelsen för Kunskaps- och Kompetensutveckling (Foundation for Knowledge and Competence Development, KKS) supports knowledge and skills development in three areas: exchange of knowledge and skills between industry and commerce, on the one hand, and universities, colleges and research institutes, on the other; financing of research at the new Swedish small and medium-sized colleges in specific areas; promotion of the use of information technology.

The KKS supports certain types of research at the new colleges, which, unlike the universities, do not have fixed resources allocated for research. The intent is to develop close collaboration between the colleges and industry. To participate, industry must contribute at least as much as the foundation to a research project. In the next few years, the KKS will invest over SKr 1.5 billion in strategic projects.

The KKS has made education its top priority and will direct more than SKr 500 million to this sector. For three years, it will spend about SKr 100 million annually on projects having to do with schools, from pre-schools to high schools, which involve new ideas on pedagogy, schoolrooms design, teaching materials, curriculum, organisation, and technology.

URLs

<http://www.sb.gov.se> (The Swedish National IT Strategy).

<http://www.ITkommissionen.se> (The Commission proposals for measures to promote the use of IT).

<http://www.statskontoret.se> (framework for computers procurement).

<http://www.stattel.se> (framework for telephony services procurement).

<http://www.nutek.se> (Swedish National Board for Industrial and Technical Development).

<http://www.kks.se> (Stiftelsen för Kunskaps- och Kompetensutveckling – Foundation for Knowledge and Competence Development).

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SWITZERLAND

R&D programmes/demonstration

In Switzerland, a four-year R&D programme with funding envisaged at SFr 28 million was launched by the Swiss National Science Foundation in 1995. The main focus of the Swiss Priority Programme for Information and Communication Structures (SSP ICS) is the design, development, implementation and demonstration of distributed applications and the associated network technologies. Within its four modules, research ranging from basic research to development and demonstration projects can be carried out. The modules are:

- engineering of distributed applications and networks (work-flow tools, interface mechanisms, new means of software distribution and maintenance etc.);
- quality and security (electronic payments, digital signatures, software integrity, etc.);
- resource management and optimisation (e.g. network management, dynamic resource allocation, performance and cost recording);
- validation and assessment of the results of the three preceding modules with a view to their utility for industry, leading to demonstration and pilot applications.

Like its predecessor, the Swiss Priority Programme for Informatics Research (SPP IF, 1992-95,

total funding SFr 30.6 million, 48 projects), its main task is to foster co-operative research in areas of great importance to Swiss business by funding joint projects and forming university-firm competence centres. Only universities or federal research centres can act as "leaders" of such networks.

The SPP covers personnel and co-ordination costs, but not investment. Industry must provide 50 per cent of costs as matching funds. Strong emphasis is given to technology transfer.

URLs

http://www.snf.unibe.ch/Server_e/Homepage_e.html
(Swiss National Science Foundation)

<http://spp-ics.snf.ch/> (Home page of SPP-ICS)

Contact: ch59sba@snf.e-mail.com

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UNITED STATES

Historically, the US government has played an active role in the development of information technologies and their application. For example, until 1964, the US government was the only customer for US-made integrated circuits (ICs). It played a similar role in the software sector where government defence expenditures on software "aimed at creating a foundation for software R&D, training, and technology development" (US Department of Commerce, 1996). US Federal government funding is credited with underwriting two-fifths of the major US software developments between 1950 and 1980.

In terms of programmatic support for information technologies, the United States' development of IT tends to fall into four broad categories: R&D which encompasses funding prototype development; initial procurement, demonstration projects or test bed activities; eliciting opinions and views about policy

formation concerning electronic commerce; and providing assistance in the standard setting process.

R&D

Government-funded R&D has been credited with a number of important IT innovations including the development of RISC chips, networking architecture, the windows interface and parallel computing (NRC, 1995). Currently, most R&D expenditures on IT fall under two general interrelated programmes: the broad umbrella of the High Performance Computing and Commerce Initiative (HPCCI) and dual-use defence-related R&D funded by the Defense Advanced Research Projects Agency (DARPA) of the US Department of Defense.

The HPCC initiative co-ordinates separate research projects under way at the National Science

Foundation, the Advanced Research Projects Agency, the National Aeronautics and Space Administration, and the Department of Energy. This list is expected to grow in 1997 to include the Environment Protection Agency, the Department of Transportation and the Department of Education. It was created to further three broad goals: to extend US leadership in high-performance computing and communications, to disseminate new technologies, and to spur gains in US productivity and competitiveness.

The HPCCI budget has grown from US\$490 million in fiscal year 1992 to \$1.02 billion in fiscal 1996. HPCCI has been credited with training and attracting researchers to the field, fostering acceptance of parallel computing, establishing the very large integrated circuit design (VSLI), stimulating development of the Berkeley UNIX and computer-aided design (CAD) tools, supporting the development of gigabit test beds, building the backbone of the Internet, and supporting the early development of World Wide Web browsers (*i.e.* Mosaic).

In anticipation of the expiration of the legislative mandate for HPCCI in December 1996, the Clinton Administration launched a successor initiative in October entitled Computing, Information and Communication (CIC). The President's budget has requested \$1.05 billion for this programme in fiscal 1997 of which \$100 million will be spent in 1998 to expand Internet access across the United States (see below). While the new CIC will continue to support the HPCC mission, it is expanding into broader areas such as mid-level computing and network technologies. Five focus areas have been selected: high-end computing and computation; large-scale networking; high-confidence systems; human-centred systems; and education, training and human resources.

Nearly a third of the HPCC funding comes from the US Department of Defense, much of it from DARPA. DARPA's overall budget is \$2.2 billion, and while its mission is to support US defence capabilities, many of its activities have direct civilian applications (*e.g.* the Internet, simulation technologies, speech recognition technology) and it has recently emphasised obtaining technology from civilian firms rather than dedicated defence contractors (NEC, 1995). Within DARPA's Information Technology Office, three different research programmes – networked systems, computing systems and software and intelligent systems and software – are supported; these in turn fund hundreds of separate projects ranging from multigigabit router development to high performance C++ to the intelligent room. NSF supports research

fundamental to computing and information processing, provides access to advanced computing facilities, develops a national computing and communications network in support of research and education, and works to improve the education and human resource base for these research areas.

Demonstration projects

While the Internet is one of the most famous "test bed" projects supported by the US government, the National Telecommunications and Information Administration within the US Department of Commerce has overseen the Telecommunications and Information Infrastructure Assistance programme (TIIAP) which provides seed money for innovative, practical technology projects. In operation since 1994, TIIAP provides matching grants to non-profit organisations such as schools, libraries and hospitals to purchase equipment, communication services and software, and train staff for connecting to networks. It awarded 92 grants in 1994, disbursing \$24.4 million in federal funds and \$40 million in matching funds; it has now grown to 117 grants totalling \$35.7 million and \$60 million, respectively.

The most recent policy initiative to provide a demonstration project or a "test bed" for further development of an information infrastructure/ information society is the recently announced Next Generation Internet Initiative, which has three goals: to connect universities and national laboratories to a very high-speed network (100 to 1 000 times the current speed); to increase the capabilities of the Internet to handle real-time applications like video-conferencing; to support new applications that further US goals and missions such as scientific research, national security, distance education, etc. It is proposed that this initiative be funded at a level of \$100 million in fiscal 1998 by reallocating R&D money away from current defence and domestic technology activities. It is thought that as a smart and demanding customer, the federal government and leading research universities can speed the commercial availability of new products, services, and technologies, thereby helping the Internet continue its rapid growth.

Electronic commerce

On 31 December 1996, the White House released a draft framework paper regarding international electronic commerce on the Internet. The paper can be downloaded from the White House home page at

<http://www.whitehouse.gov> under the site news section. Public comments can be directed to gii@a1.eop.gov. A final version should be available this spring.

The Framework for Global Electronic Commerce is an important trade and technology policy initiative as it discusses the commercial implications of the Global Information Infrastructure (GII). It lays out the principles which should support policy development, articulates several policies, and outlines a roadmap for discussions to ensure development of a free and open global electronic marketplace. The paper identifies areas such as the principle of neutrality, the concept of source-based versus residence-based taxation, the definition and classification of income based on royalties, sale of a good, and services, and the mechanics of tax administration and compliance (e.g. identification, verification, disintermediation) as issues that need to be re-examined in light of recent technological advances in communications and electronic commerce. The paper invites comments from interested parties prior to developing rules, but suggests the following as a basis for encouraging these technologies to achieve their maximum potential:

- avoid double taxation as a result of countries claiming inconsistent tax jurisdiction owing to the “blurring of national boundaries”;
- maintain neutrality where the tax system treats economically similar income equally;
- place increased reliance on residence-based taxation of income as opposed to a source-based treatment;
- ensure that electronic documents are verifiable in order to minimise the potential for tax evasion.

Standards and guidelines

The National Institute of Standards and Technology (NIST) engaged in the following standards-setting activities during 1995/96:

- Issuing two new security guidelines that set new requirements for two components of telecommunications management networks: network elements and mediation devices (Kimmins *et al.*, 1995).
- Collaborating with the Digital Audio/Video Interoperability Council (DAVIC) and with the ATM Forum to develop tests for the interoperability of different video applications and for

the interoperability of Asynchronous Transfer Mode (ATM) products and services.

- Assisting the Institute of Electrical and Electronic Engineers standards committee 802.14 to evaluate proposals for protocol standards for coaxial cable modems.
- Testing to evaluate the performance of optical character recognition (OCR) systems that process hand-printed text. These systems automate the conversion of hand-printed letters and numbers to digital form for computer processing. NIST has collected many different samples of hand printed text for use by system developers to test and develop products and has developed a method of evaluation.
- Testing to evaluate the performance of speech recognition systems. Speech recognition technology is an easy way for humans to interact with computers, but it must be improved to work for all speakers using their natural speech patterns. Major companies and universities involved in speech recognition research are using NIST tests to evaluate and improve their systems.
- Developing a kit of tools for software diagnostics and performance analysis to include tools for diagnosis of software faults and identification of deviations from specifications, for non-intrusive methods to capture data about the performance of processors, and for analysis of distributed programmes to find bottlenecks in execution.
- Carrying out research on formal methods, reference techniques for the compression of images, and related tests.
- Developing reference data sets to help software developers improve the reliability of their mathematical and statistical software products. Currently, there are very few such tools available. The algorithms and the software are difficult to test objectively and errors often occur in special circumstances related to the problem to be solved.
- The Guide to Available Mathematical Software (GAMS). Available on the World Wide Web, GAMS helps scientists and engineers locate and use nearly 10 000 reusable problem-solving modules from currently available mathematical software packages (Wakid, 1996).

URLs

<http://www.ito.darpa.mil/ResearchAreas/List.html> (DARPA's Information Technology Office).

<http://www.ntia.doc.gov/otiahome/tiiap/tiiapone.html> (NTIA's TIIAP).

<http://www.iitf.nist.gov/documents/press/internet.htm>, 5 December 1996 (Next Generation Internet Initiative).

<http://www.whitehouse.gov> (White House framework for Global Electronic Commerce paper).

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Annex

Annex Table 1. **Worldwide information technology market breakdown, 1985-95**

Percentages except for the world total, in billion US\$

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1985-95 CAGR (%)
By geographic area												
North America	59.2	52.7	47.4	44.2	43.7	41.9	42.2	43.2	45.4	45.1	43.5	9.4
Latin America	1.5	1.5	1.4	1.4	1.6	1.6	1.6	1.7	1.9	1.9	2.0	15.6
Western Europe	22.1	26.3	29.0	30.5	30.8	33.6	32.4	31.9	28.4	27.3	28.3	15.6
E.Europe, Middle East, Africa	3.1	2.8	2.7	2.5	2.6	2.5	2.7	2.6	2.6	2.6	2.6	10.6
Asia Pacific	14.0	16.7	19.6	21.3	21.2	20.4	21.2	20.7	21.8	23.0	23.7	18.9
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	
By main segment												
PC & workstations	20.9	21.2	21.8	22.9	24.2	25.0	24.4	24.8	26.7	29.0	30.5	17.2
Multi-user systems	29.5	28.7	28.1	26.8	25.3	22.9	20.7	18.8	16.3	14.3	13.0	4.0
Data communication equipment	3.0	2.9	2.9	2.9	3.0	3.1	3.3	3.6	4.1	4.3	4.3	17.0
Packaged software	13.5	13.8	13.9	14.2	14.4	15.5	16.6	17.4	17.6	17.9	18.4	16.3
Services	33.1	33.3	33.3	33.2	33.2	33.5	35.1	35.4	35.3	34.6	33.7	13.0
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	
World (billion US\$)	158.3	193.5	235.1	276.6	300.3	345.4	364.0	391.6	405.1	455.0	527.9	12.8

Source: OECD Secretariat, compiled from IDC (1995b) data.

Annex Table 2. **Evolution of IT market breakdown for selected non-member countries, 1987-95**

Percentage of total market

	1987				1995 ¹			
	Hardware		Packaged software	Services	Hardware		Packaged software	Services
	PC and workstations	Total hardware			PC and workstations	Total hardware		
Chinese Taipei	47.8	76.3	6.6	17.1	51.7	69.9	10.7	19.4
Hong Kong	37.1	79.5	10.4	10.1	49.4	70.0	10.8	19.2
Republic of Korea	39.1	71.9	4.6	23.5	64.5	79.8	5.9	14.4
Malaysia	44.1	75.9	11.6	12.4	48.7	66.1	17.1	16.9
Singapore	25.1	78.4	9.2	12.4	41.3	59.1	16.4	24.5
Thailand	40.3	84.2	2.6	13.2	57.1	69.8	12.9	17.3
DAEs	39.7	75.4	6.4	18.2	57.2	73.7	9.3	17.0
China (PRC)	56.4	91.6	6.3	2.1	74.1	88.1	4.6	7.3
India	45.1	67.1	3.1	29.8	50.0	62.2	5.7	32.1
Indonesia	50.9	83.2	5.0	11.7	66.9	81.0	7.4	11.6
Philippines	48.7	73.5	12.3	14.2	59.8	72.4	14.0	13.6
Argentina	16.9	57.2	8.4	34.3	39.2	52.1	12.3	35.5
Brazil	19.8	53.3	13.5	33.2	30.2	52.7	15.0	32.2
Chile	26.2	57.3	11.7	31.0	43.0	57.5	14.1	28.4
Colombia	46.4	69.4	6.9	23.7	53.4	72.4	12.0	15.6
South Africa	24.3	61.5	12.2	26.3	25.4	49.2	19.9	30.9
Venezuela	15.0	50.6	20.4	29.0	38.3	51.0	14.5	34.5
Total NMC	33.1	67.6	9.2	23.2	50.1	67.4	10.9	21.7
OECD 24	21.1	51.8	14.1	34.1	28.7	45.9	19.1	35.0

1. IDC estimates.

Source: OECD Secretariat compiled from IDC (1995b) data.

Annex Table 3. **Computer application software sales¹
in selected countries/regions, 1994-95**

Million US\$

Country/region	1995	Change 1995/94 (%)
North America	7 525.3	12
Western Europe	1 987.1	19
Benelux	147.4	14
France	323.6	20
Germany and Austria	537.6	22
Greece	4.2	13
Italy	121.3	23
Nordic countries	122.2	23
Spain/Portugal	68	29
Sweden	98.5	13
Switzerland	96.6	1
United Kingdom and Ireland	465.1	17
Asia/Pacific ²	1 143.4	57
Australia and New Zealand	189.4	21
China	4.6	189
Chinese Taipei	37.9	75
Hong Kong	30.7	45
India and Pakistan	10.6	124
Japan	757.8	67
Republic of Korea	34.4	40
Malaysia	13.4	60
Singapore	42.0	44
Thailand	11.6	277
Other Asia	5.5	157
Latin America ²	158.9	11
Brazil	63.0	58
Mexico	28.9	-37
Other Latin America	65.3	22

1. Total revenues of 33 US-based software firms in 1995 (30 for first quarter 1996).

2. Includes other countries not listed individually.

Source: Software Publishers Association, 1996.

Annex Table 4. **Purchasing power parities**

National currency units per US\$

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
United States	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Canada	1.28	1.28	1.30	1.31	1.32	1.30	1.29	1.27	1.26	1.24	1.24
Mexico	0.14	0.23	0.53	1.03	1.24	1.54	1.81	1.64	1.77	1.86	2.46
Japan	218	216	210	203	199	195	194	187	184	181	176
Australia	1.19	1.24	1.29	1.34	1.38	1.39	1.37	1.36	1.35	1.34	1.35
New Zealand	1.25	1.44	1.56	1.63	1.63	1.61	1.58	1.53	1.51	1.51	1.50
Austria	14.5	14.8	14.7	14.4	14.2	14.0	14.2	13.8	13.9	13.9	13.9
Belgium	40.3	40.9	40.6	39.7	39.9	39.4	39.3	37.3	37.3	37.3	37.2
Denmark	9.25	9.44	9.59	9.54	9.53	9.39	9.22	9.03	8.79	8.72	8.65
Finland	5.79	5.91	6.00	6.18	6.29	6.38	6.32	6.27	6.09	6.15	6.23
France	6.67	6.85	6.84	6.77	6.68	6.61	6.54	6.33	6.57	6.63	6.58
Germany	2.23	2.23	2.20	2.15	2.10	2.09	2.10	2.04	2.10	2.07	2.07
Greece	78	90	99	111	121	141	162	168	184	196	210
Ireland	0.699	0.727	0.721	0.717	0.725	0.690	0.670	0.630	0.655	0.639	0.633
Italy	1 217	1 281	1 317	1 352	1 375	1 421	1 470	1 440	1 534	1 535	1 571
Luxembourg	39.0	40.3	39.2	39.5	40.4	39.7	39.7	38.4	39.6	40.0	40.3
Netherlands	2.48	2.42	2.33	2.27	2.20	2.16	2.19	2.11	2.13	2.13	2.12
Norway	9.50	9.14	9.50	9.55	9.73	9.73	9.65	8.88	8.93	9.13	9.16
Portugal	66	78	84	90	96	104	110	114	117	118	122
Spain	92	99	102	104	106	110	111	113	117	121	124
Sweden	7.95	8.29	8.42	8.63	8.94	9.34	9.99	9.67	9.83	9.91	10.1
Switzerland	2.19	2.21	2.20	2.17	2.17	2.20	2.24	2.13	2.13	2.10	2.08
Turkey	208	276	358	584	982	1 491	2 288	3 640	5 990	12 116	21 481
United Kingdom	0.549	0.553	0.563	0.575	0.590	0.602	0.638	0.608	0.637	0.646	0.646

Source: OECD, Analytical Data Bank, November 1996.

Annex Table 5. **Exchange rates**

National currency units per US\$

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
United States	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Canada	1.37	1.39	1.33	1.23	1.18	1.17	1.15	1.21	1.29	1.37	1.37
Mexico	0.26	0.61	1.38	2.27	2.46	2.81	3.02	3.09	3.12	3.39	6.42
Japan	239	169	145	128	138	145	135	127	111	102	94
Australia	1.43	1.50	1.43	1.28	1.26	1.28	1.28	1.36	1.47	1.37	1.35
New Zealand	2.02	1.91	1.69	1.53	1.67	1.68	1.73	1.86	1.85	1.69	1.52
Austria	20.7	15.3	12.6	12.3	13.2	11.4	11.7	11.0	11.6	11.4	10.1
Belgium	59.4	44.7	37.3	36.8	39.4	33.4	34.1	32.1	34.6	33.5	29.5
Denmark	10.60	8.09	6.84	6.73	7.31	6.19	6.40	6.04	6.48	6.36	5.60
Finland	6.20	5.07	4.40	4.18	4.29	3.82	4.04	4.48	5.72	5.22	4.37
France	8.99	6.93	6.01	5.96	6.38	5.45	5.64	5.29	5.66	5.55	4.99
Germany	2.94	2.17	1.80	1.76	1.88	1.62	1.66	1.56	1.65	1.63	1.43
Greece	138	140	135	142	162	159	182	191	229	242	232
Ireland	0.946	0.743	0.673	0.656	0.706	0.605	0.621	0.588	0.683	0.670	0.624
Italy	1 909	1 491	1 296	1 302	1 372	1 198	1 241	1 232	1 572	1 613	1 629
Luxembourg	59.4	44.7	37.3	36.8	39.4	33.4	34.1	32.1	34.6	33.5	29.5
Netherlands	3.32	2.45	2.03	1.98	2.12	1.82	1.87	1.76	1.86	1.82	1.61
Norway	8.60	7.39	6.74	6.52	6.90	6.26	6.48	6.21	7.09	7.06	6.34
Portugal	170	150	141	144	157	143	144	135	161	166	150
Spain	170	140	123	116	118	102	104	102	127	134	125
Sweden	8.60	7.12	6.34	6.13	6.45	5.92	6.05	5.82	7.79	7.72	7.13
Switzerland	2.46	1.80	1.49	1.46	1.64	1.39	1.43	1.41	1.48	1.37	1.18
Turkey	520	669	855	1 419	2 120	2 606	4 169	6 861	10 966	29 778	45 738
United Kingdom	0.779	0.682	0.612	0.562	0.611	0.563	0.567	0.570	0.667	0.653	0.634

Source: OECD, *Economic Outlook*, June 1996.

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