TABLE 8.16. Unemployment in various countries, 1933–1993 (% of labour force)

Country	1933	1959–67 avg.	1982–92 avg.	1993
Belgium	10.6	2.4	11.3	12.1
Denmark	14.5	1.4	9.1	12.1
France	4.5[a]	0.7	9.5	11.7
Germany	14.8	1.2[b]	7.4	8.9
Ireland	n.a.	4.6	15.5	17.6
Italy	5.9	6.2	10.9	10.2
Netherlands	9.7	0.9	9.8	8.3
Spain	n.a.	2.3	19.0	22.7
UK	13.9	1.8	9.7	10.3
Austria	16.3	1.7	3.5	4.2
Finland	6.2	1.7	4.8	18.2
Norway	9.7	2.1	3.2	6.0
Sweden	7.3	1.3	2.3	8.2
Switzerland	3.5	0.2	0.7	4.5
USA	24.7	5.3	7.1	6.9
Canada	19.3	4.9	9.6	11.2
Japan	n.a.	1.5	2.5	2.5
Australia	17.4	2.2	7.8	10.9

[a] 1936.
[b] The Federal Republic for the period 1959–81.
Source: Maddison (1991); OECD, *Employment Outlook* (1993).

promising results in bio-technology, in information technology, in materials technology, and in other areas were being achieved. In the view of the scientists and technologists, there were almost unlimited horizons. The OECD group came to the conclusion, therefore, that the slow-down in industrial productivity that was now everywhere apparent must be due to a failure to utilize these new results of scientific and technological activities, not to the limits of science itself. The limits to growth were the limits of a particular set of technologies and of a particular technological and managerial regime, not limits to technology in general and certainly not to the new technologies that were forging ahead everywhere.

Obviously, these conclusions are very close to our own exposition of the need to change the institutional and social framework when a specific technological regime (in this case the mass production regime) was reaching its limits. The debate in the 1980s and 1990s increasingly turned to these problems of institutional change in relation to the extraordinarily rapid growth of the most prominent new technology—the information and communication technology (ICT)—and its potential applications everywhere in the economy.

9

The Emergence of a New Techno-economic Paradigm: The Age of Information and Communication Technology (ICT)

9.1 Introduction

In this chapter, we shall argue that we are now witnessing yet another industrial revolution in the sequence analysed in Chapters 5–8. This time the pervasive and radical nature of the wave of technical change is less controversial. The chairman of the United States Federal Reserve, Alan Greenspan, has spoken frequently of the 'new paradigm', referring specifically to computers, telecommunications, and the Internet as the source of the remarkable spurt of growth in the US economy in the 1990s. He has also warned of the 'irrational exuberance' on the New York Stock Exchange in response to the immense potential of the Internet and other new technologies. Even those who have disputed the revolutionary character of earlier waves of technical change often have little difficulty in accepting that a vast technological revolution is now taking place, based on the electronic computer, software, microelectronics, the Internet, and mobile telephones. These industries were growing in the United States in the 1990s at a very high rate and accounted for the greater part of growth in the entire economy. The dramatic nature of the technological revolution has been underlined by some of the gigantic mergers that took place in 1999 and 2000. From a very much smaller base and on a much smaller scale, bio-technology was also growing very rapidly in the closing decades of the twentieth century. In one sense, it too is a very special form of information technology and it is interacting increasingly with computer technology.

Such disagreement as remains centres on the question of whether there will be a hard or a soft landing for the United States before a longer period of widespread economic growth is unleashed in the world economy. Some leading American economists have had reservations about the 'new paradigm', believing that this expression exaggerates both the changes in the technology and even more the changes in the behaviour and management of the economy. We ourselves incline to the belief that the stock market inflation in the United States in the late 1990s was indeed based in part on irrational exuberance about the future rate of return on Internet stocks and other so-called 'high tech' stocks, as well as a more general overvaluation of financial assets. It thus had some of the features of the 1929 boom and some characteristics of the manias for canals and railways, which accompanied earlier waves of technical change already discussed (Shiller 2000).

One of the most dynamic fields of organizational and institutional innovation is certainly the financial market. The competition is ferocious: it is necessary to capture savings in all their forms by multiplying new bank products, rearranging the systems of alliances, and redefining the shape of the service. The capital market inflation is at the very centre of this drive for innovation, as it is both its cause and its consequence. Innovation requires more innovation, and the inflationary process requires more funds, and consequently further changes. The decisive change in this regard has been of course the growing privatization of national systems of social security and the reconstitution of pension, insurance, and mutual funds. These funds today own the majority of stocks in most developed countries, and this is a radical change. Furthermore, as larger and larger inflows are required in order to maintain the liquidity of this market, the process of privatization extends over borders and challenges all resistance.

The consequences of this storm are immense. Capital market inflation accelerates the process of disintermediation and weakens regulations and the effectiveness of monetary policies at the national levels, given the extreme volatility of the foreign exchange markets. Moreover, the pension funds are not strictly dependent on credit policies influencing the short-term interest rate, as they are financed from wages and salaries, not from borrowing. Consequently, their expansion diminishes the capacity of central banks to control the liquidity of the banking system (Toporowski 2000: 132). As long as this inflation is sustained through the positive prospect of gains, the failure of the scheme is not foreseeable, but its fragility is obvious in the longer term. *The Economist* magazine, which is of course very well aware of this fragility, repeatedly exhorted Greenspan to tighten credit policy throughout 1999 and 2000, and grew increasingly frustrated by his failure to respond adequately.

However, in his semi-annual report to Congress in July 2000, Greenspan explicitly disavowed any intention of targeting the stock market to counteract inflation: 'We do not and have not been targeting the stock market to stabilize the economy' (Martin 2000: 13).

It was this policy of benign neglect that caused the critics of the Fed to argue that monetary policy actually encouraged the huge inflationary distortion of asset prices. On 22 January, *The Economist* wrote in exasperation: 'if, like this newspaper, your sums tell you that shares are over-valued even on the most bullish interpretation of America's remarkable economic performance, and its future productivity prospects, then you should be worried—seriously so' ('A Tale of Two Debtors', 22 January 2000: 17).

No one can predict the future course of events in a very unstable system, as so much depends on the rate and direction of social and political change, both in the United States and in other countries, and also in the international financial institutions. Therefore, since the institutional and social changes associated with this technological revolution are still unfolding and are at a relatively early stage, this chapter is confined to an account of the emergence and formation of the new constellation of innovations, starting with the new core input of microelectronics (Section 9.2), continuing with the carrier branch, which is obviously the computer and software industry (Section 9.3) and with the new infrastructure, i.e. telecommunications and the Internet (Section 9.4), and concluding with some of the organizational innovations (Section 9.5), the cultural changes (Section 9.6), and some future problems of social change that are already apparent (Section 9.7). With such a fast-changing technology and such a rapid rate of structural change, readers should not expect to find here an up-to-date account of the latest developments in ICT. There are many other sources for such accounts. This chapter is necessarily *historical* in nature, in keeping with the main objective of the book.

9.2 The New Core Input: Chips with Everything

Integrated circuits provide the most spectacular example of price reductions of all the core inputs we have considered. The story has often been told and has become part of standard industrial history and of mythology. Although certainly not completely accurate, 'Moore's Law', first enunciated in 1965, is widely believed to have held roughly true down to the end of the century. Indeed, Bill Gates (1995/6) maintained that the law would probably hold for another twenty years. According to his account, Gordon Moore, who was the co-founder of Intel with Bob Noyce, predicted in 1965 that the capacity of a computer chip would double every year, but he revised this prediction in 1975, then suggesting that the capacity would double every two years. Gates estimates that the actual rate of doubling was about eighteen months down to 1995 (Figure 9.1).

Although not so spectacular as the integrated circuits (IC) revolution of the 1960s, the discovery and improvement of electronic components had been going on since early in the twentieth century, and had made possible

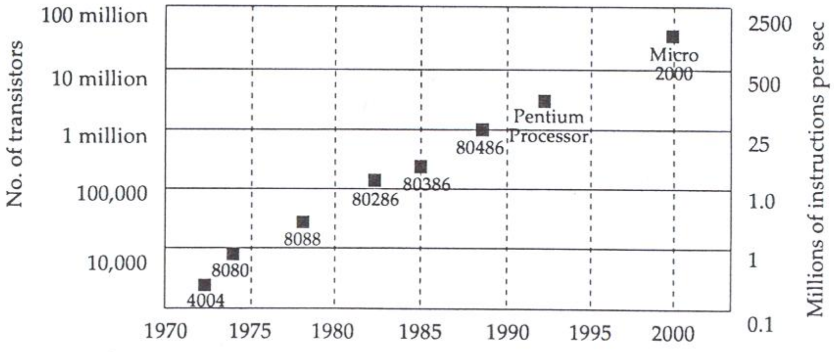

FIG 9.1. Intel microprocessor evolution, 1970–2000

Source: Gates (1996: 37).

numerous innovations in radio, radar, and television. This was especially true of the so-called *active* components—valves and transistors. It was the innovation of combining these components, at first in small but later in enormously large numbers, on one 'integrated' circuit chip that made possible the spectacular reductions in cost and improvements in performance of both electronic consumer goods and capital goods, such as computers. A few earlier innovations—in cotton spinning and weaving, in the manufacture of steel and automobiles and in the refining of oil—had reduced costs by an order of magnitude, but the microelectronic innovations reduced the cost of storing, processing, and transmitting information by several orders of magnitude. The effects of the falling cost of integrated circuits on the costs of computing are illustrated in Figure 9.2.

The earlier experimental development and manufacture of *discrete* components for electronic circuits stretched back for many decades before American firms achieved dominance in the manufacture of *integrated* circuits and electronic computers in the second half of the twentieth century. As was also the case in the electrical industry, it was mainly the research of European scientists, such as Hertz and Maxwell, that made possible the growth of the electronics industry. The interaction between scientists and engineers has remained a feature of information and communication technology (ICT) so that countries with strong scientific institutions, as well as innovative engineers and entrepreneurs, have been the leaders.

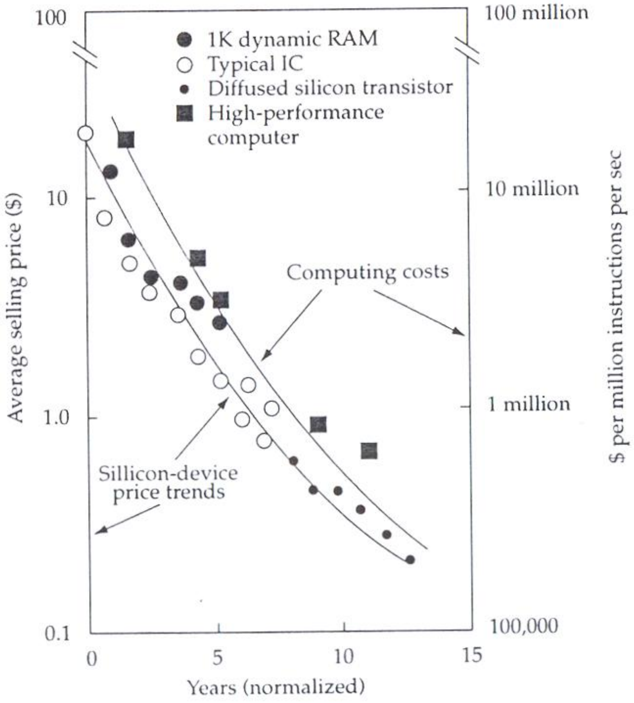

FIG 9.2. Parallel decreases illustrate how costs of computers depend on costs of semiconductors

Source: Mackintosh (1978: 53).

The first thermionic valve was invented and patented in 1904 by Sir John Ambrose Fleming, a professor at London University, and down to the First World War the radio industry was dominated by British and German firms. The Italian inventor G. Marconi established his Wireless Telegraph Company in Britain in 1897 and first demonstrated the feasibility of ship-to-shore radio communications, as well as shore-to-shore and ship-to-ship. His firm in Britain was however closely followed by the German electrical giants, AEG and Siemens. Fleming was a consultant to the Marconi company, and outstanding German and American scientists and engineers also acted as industrial consultants. It was the American Telephone and Telegraph company (AT&T) that pioneered the use of valves as relays in the telecommunications system, having purchased the rights to the use of de Forest's triode valve, invented in 1906. However, despite the outstanding contribution of de Forest, Fessenden, Langmuir and other American inventors, it was the European radio firms that dominated the global industry down to the early 1920s. Fessenden and de Forest themselves were much less successful as entrepreneurs than as inventors (Maclaurin 1949; Freeman *et al.* 1965).

From quite early on, governments recognized the potential strategic importance of radio communications in both peace and war. The naval arms race between Britain and Germany, which has been described in Chapter 7, was one of the factors that led the Kaiser to persuade Siemens and AEG to establish a joint subsidiary for radio communications—Telefunken—in 1903. This company conducted R&D, employed consultants, and designed and installed radio stations world-wide. It disputed the priority of Marconi's patents until finally in 1912 it reached a world-wide agreement with the Marconi Company on cross-licensing and know-how. This was renewed in 1919, by which time the US government felt impelled to facilitate the buy-out of Marconi's American subsidiary and to establish a powerful unified American-owned radio company—the Radio Corporation of America (RCA). With strong encouragement from the US Navy, Owen Young of General Electric negotiated the buy-out because the US government felt, after the experience of the First World War, that it could not leave such a vital strategic and commercially important industry as radio in the hands of a foreign (though Allied) power. The new RCA negotiated cross-licensing and patent arrangements with Telefunken, British Marconi, and the French CSF, as well as with the key American companies such as AT&T and Westinghouse.

Thus, from quite early on, the nascent electronic industry was at the heart of those world-wide developments in communications technology that were even then the subject of intense government interest and regulation. This government involvement was to become even closer in the interwar period, and above all during the Second World War, when the development of oscilloscopes, radar, and gun control systems became one of the central concerns of all the combatants, especially Britain and Germany. Government-financed R&D was concentrated in Germany in a private company, Telefunken, and in Britain in the state-owned Telecommunications Research Establishment (TRE, now RRE) and employed many thousands of scientists and engineers. Although government-financed research and design activities had also been important in the First World War for tanks, naval armaments, chemical warfare, and aircraft, this was the first technology to enjoy such massive support—which, moreover, continued in a variety of forms down to the present day. This was, of course, mainly for military equipment, culminating in the 'Star Wars' programme, but it continued in many areas also for civil products and systems.

Although the American, British, and other governments certainly supported much R&D for electronic components and circuits, it was in the Bell Laboratories of AT&T that civil R&D in transistor technology[1] led to the key developments in semi-conductors and to the establishment of the US semi-conductor industry, mainly by spinoff firms from Bell Laboratories and licensees of Bell technology. The role of government continued to be important, but more in the procurement of new devices and especially of integrated circuits in large quantities, rather than in R&D itself (Golding 1972; Tilton 1971).

A report in 1963 by the consultants A. D. Little stated that:

> Due to its considerable interest in semi-conductors and particularly in transistors, the government throughout the 1950s tried to stimulate the development of improved types. Around the middle of 1950 they were convinced transistors were needed for future military equipment so they accelerated the production investment. . . . The contracts for a total of thirty different types of germanium and silicon transistors were placed with about a dozen of the major semi-conductor companies . . . In many cases, this investment was matched by similar amounts of capital equipment or plant space supplied by the contracting companies. . . . Thus, a potential total capacity of over a million transistors a year was created. (Little 1963)

These numbers appear tiny today, when the integration of millions of transistors on one chip has become the norm and there is a language problem in creating the terminology to classify the increases in scale (Table 9.1).

There has seldom, if ever, been such a strong example of the cost and performance improvements that could be achieved by the scaling up of design and production, even though it was achieved in this case by miniaturization. As in the earlier examples of steel production, oil refineries, and automobiles, the combination of technical and organizational innovations with the scaling up of production proved an extraordinarily powerful method of cost reduction and gave a big advantage to large firms. The conclusions of the A. D. Little Report in 1963 and the foresight of the US Department of Defense were justified by the further research on the semi-conductor industry and most notably by the work of Tilton (1971) in the USA and Golding (1972) in the UK on scale economies. Together with a series of innovations in the design and manufacture of chips, they largely explain the prolonged domination of the industry by American firms and the relative weakness of the European industry. It was only when Japanese firms were able to exploit similar economies in the large-scale production of civil electronic products that this dominance was challenged. By the late 1980s, four of the five largest producers of semi-conductors were Japanese (Table 9.2) and the American industry was

TABLE 9.1. Integration of components per chip, 1950s–1990s

Date	Degree of integration	No. of components
1950s	Small-scale integration (SSI)	2–50
1960s	Medium-scale integration (MSI)	50–5,000
1970s	Large-scale integration (LSI)	5,000–100,000
1980s	Very large-scale integration (VLSI)	100,000–1,000,000
1990s	Ultra large-scale integration (ULSI)	>1 million

Source: Duysters (1995: 56).

TABLE 9.2. Leading semiconductor (SC) manufacturers world-wide, 1988–1989

Rank		Company	1989 SC revenues ($m)	1989 Market share (%)
1989	1988			
1	1	NEC	4,964	8.9
2	2	Toshiba	4,889	8.8
3	3	Hitachi	3,930	7.0
4	4	Motorola	3,322	5.9
5	6	Fujitsu	2,941	5.3
6	5	Texas Instruments	2,787	5.0
7	8	Mitsubishi	2,629	4.7
8	7	Intel	2,440	4.4
9	9	Matsushita	1,871	3.4
10	10	Philips	1,690	3.0
11	11	National	1,618	2.9
12	12	SGS–Thomson	1,301	2.3
13	18	Samsung	1,284	2.3
14	15	Sharp	1,230	2.2
15	20	Siemens	1,194	2.1
16	14	Sanyo	1,132	2.0
17	17	Oki	1,125	2.0
18	13	AMD	1,082	1.9
19	16	Sony	1,077	1.9
20	19	AT&T	873	1.6

Source: Dataquest; cited in *Electronic Business*, 16 April 1990; Hobday (1991).

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[1] According to some accounts, Bell hastened the announcement of its transistor discoveries in order to avoid the technology being classified and appropriated exclusively or mainly for military use.

obliged to seek an agreement with Japan, limiting the amount of Japanese imports to the United States.

However, the US industry, US universities, and the US government still had enormous R&D capability as well as determination to wrest back their lead from Japanese competition. The development of the microprocessor by Intel in 1971–2 was one of the decisive events that transformed both the semi-conductor industry and the computer industry, since it meant that a 'computer on a chip' could be manufactured very cheaply and on a vast scale. Intel became the leading firm in the semi-conductor industry and by 1994 there were once more three US firms among the top six in world-wide sales (Table 9.3). Aided by cooperative R&D and by government support through the 'Sematech' project, the US industry had successfully fought back. Furthermore, Korean firms also successfully broke into the leading group in the 1980s and 1990s.

Thus, by the 1960s linkages between the electronics industry, the telecommunications industry and the young computer industry had already become quite strong and an interdependent constellation was emerging in ICT. In fact, the intimate relationship with the computer industry had begun as early as the 1940s and had become steadily closer in the following decades, as will be described in the Section 9.3. The computer industry and the telecommunications industry became enormous markets for the products of the microelectronic industry, and, as the interdependencies between firms in this new constellation increased, so too did both cooperation and competition. Many of the large Japanese and European multi-product firms attempted to integrate their semi-conductor operations with their other activities and to gain advantages by joint R&D. IBM has been one of the largest, if not the largest, American producers of integrated circuits.

TABLE 9.3. World-wide top ten merchant semiconductor suppliers, 1991–1994

Rank			Company	1994 total SC sales ($m)	1994 IC sales ($m)	1994 Discrete sales ($m)
1994	1993	1991				
1	1	5	Intel	9,850	9,850	—
2	2	1	NEC	8,830	7,855	975
3	3	2	Toshiba	8,250	6,614	1,636
4	4	4	Motorola	7,011	5,870	1,141
5	5	3	Hitachi	6,100	5,300	800
6	6	8	TI	5,550	5,500	50
7	7	12	Samsung	5,005	4,365	640
8	8	7	Mitsubishi	3,959	3,286	673
9	9	6	Fujitsu	3,335	2,975	360
10	10	9	Matsushita	2,925	2,145	780
			Total	60,815	53,760	7,055

Source: *Worldwide IC Industry Economic Update and Forecast*, Integrated Circuit Engineering Corporation, 1995.

The rate of change in semi-conductors, computers, and even more in telecommunications has sometimes made integration hazardous. The manufacture of semi-conductors is still an extremely complicated and difficult process, requiring more than a hundred different steps of coating, baking, etching, etc. Appleyard *et al.*, after studying a number of firms, concluded that many of these steps

> are not well-understood and easily replicated on different equipment or in different facilities, and they impose demanding requirements for a particle-free manufacturing environment. Product innovation depends on process innovation to a much greater extent than is true of automobiles. . . . New equipment, with operating characteristics that are not well understood, often must be introduced along with a new 'recipe', also not well understood, in order to manufacture a new product. The complexity of the manufacturing process also means that isolating and identifying the causes of yield failures requires considerable time and effort. (Appleyard *et al.* 1996: 5)

This high degree of uncertainty, together with the huge costs of investment in new plant and new R&D for each generation of chips, creates formidable entry barriers. Similar considerations, although of course on a much smaller scale, apply to the costs of experimentation for the 'Application Specific Integrated Circuits' (ASICs). For this reason, microelectronics has remained a very R&D-intensive industry, with R&D often accounting for about 10 per cent of sales. The large multi-product firms, such as Siemens, Philips, Hitachi, and Matsushita, devote quite a high proportion of their total R&D budgets to microelectronics, and patents in that area can account for as much as 20 per cent of their total patents. Turbulence and uncertainty continue to rule in this still very fast-growing and changing industry.

9.3 Computers

Blaise Pascal had developed a calculating machine as early as 1642, and Charles Babbage had developed far more complex machines between the 1820s and the 1860s—an 'Analytical Engine' and a 'Difference Engine', which could be regarded as the ancestors of modern computers. However, despite the fact that Babbage received £17,000 in government grants to support his research (a large sum for those times), he never completed his machines. This was largely because the components available to him were inadequate for the task. It was only when electronic components, and above all microelectronics devices, became available that fast, cheap, and efficient machines could be produced. Before that time a variety of electro-mechanical machines were designed and used, such as the Z1 and Z2, made by Zuse, a graduate of Charlottenburg Technological High School in Berlin in the 1930s, and the Harvard–IBM Automatic Sequence Controlled Calculator (1937–44). Zuse's Z4 machine was actually used by the Henschel aircraft company for the design of aircraft wings. Zuse's research was disrupted by his own call-up, and by the call-up of his colleague, Schreyer (also a graduate of Charlottenburg THS), after they had started development work on an electronic computer. Valves had already been ordered from Telefunken when the project was cancelled and official support withdrawn. This was one more instance of the failure of the military–political leadership of Nazi Germany to understand the importance of science, even for their own narrow military–political objectives, as already noted in Chapter 8.

The British and American governments showed rather more understanding of the crucial importance of physics and mathematics, both for nuclear weapons and for computer science. The British government enlisted Alan Türing, a mathematician from Manchester University, to work at Bletchley Park on a machine called the 'Colossus', designed successfully to crack the German 'Enigma' military codes. The Colossus could fairly claim to be the first operational electronic computer outside academia. It used 1,500 valves and was one of the major British technological triumphs in the Second World War (R. V. Jones 1978). However, it was shrouded in secrecy for a long time and had rather a limited purpose, even though Türing himself as early as 1936 had written a theoretical paper entitled 'Can a Machine Think?' in which he envisaged universal computing machines able to undertake an almost infinite range of tasks. 'Colossus' itself could actually perform some tasks that were only surpassed by the much later development of parallel processing machines in the 1970s.

It was the University of Pennsylvania's 'Electronic Numerator Integrator and Computer' (ENIAC), built between 1942 and 1946, and its successors, the EDVAC and the UNIVAC in the late 1940s, that were the antecedents of what was to become the world's most successful computer industry in the United States. In this early period, IBM, the largest office equipment firm, which was already dominating tabulators and punch-cards, did not recognize the huge potential of the electronic computer. As Katz and Phillips (1982) have shown, the early enthusiasts for computers, who realized their immense potential, were from universities and the military, people who had had some experience with the early wartime design and development and had only later moved out into industry.

Von Neumann's work on computer architecture began when he first heard of the ENIAC in 1944 (McNeil 1990) and he joined the University of Pennsylvania EDSAC team, which followed ENIAC with a superior design. It was von Neumann who developed the basic concept of a computer as containing a central processor, memory devices, and input–output devices, making use of sequential programming, which has remained the paradigm or 'technological guidepost' for the computer industry for the rest of the century. It was used in the first computer introduced by Remington Rand in 1951. This was the UNIVAC 1, Eckert and Mauchly's 'Universal Automatic Computer', based on their University of Pennsylvania projects (Duysters 1995). Von Neumann and other leading mathematicians in the United States, such as Norbert Wiener, certainly envisioned very early on the huge range of potential applications for computer technology, but their enthusiasm was not at that time shared in American industry. As Katz and Phillips put it,

> The general view prior to 1950 was that there was no commercial demand for computers. Thomas J. Watson Senior, with business experience dating from at least 1928, was perhaps as acquainted with both business needs and the capabilities of advanced computation devices as any business leader. He felt that the one SSEC machine which was on display at IBM's New York offices 'could solve all the scientific problems in the world, involving scientific calculations.' He saw no commercial possibilities. This view moreover persisted even though some private firms that were potential users of computers—the major life insurance companies, telecommunications providers, aircraft manufacturers and others—were reasonably informed about the emerging technology. A broad business need was not apparent. (Katz and Phillips 1982: 425)

Even though they had many shortcomings, such as the need to replace valves frequently, the large space required, and the overheating caused by numerous valves, the first electronic computers were more than a thousand times faster than the earlier electro-mechanical machines, and the later developments in microelectronics increased this speed by further orders of magnitude (Table 9.4). T. J. Watson's son, recalling these days later, said that during this period, 'IBM slept soundly' (Belden and Belden 1962: 100).

Even after producing the 650 model under the pressures of the Korean War in the early 1950s, IBM was still greatly underestimating the potential future market. Its Product Planning and Sales Department forecast that there would be no normal commercial sales of the 650, while the Applied Science Group forecast a sale of 200 machines. In the eventual outcome, over 1,800 machines were sold. However, once IBM realized that it had fallen behind UNIVAC and other firms, it did move fairly fast. This change was also associated with a change in management and with the settlement of an anti-trust suit brought by the Department of Justice against IBM over its dominant position in the punch-card market. Again, as Watson Jr put it,

> Finally, we awoke and began to act. We took one of our most competent operating executives with a reputation for fearlessness and competence and put him in charge of all phases of the development of an IBM large-scale electronic computer. He and we were successful. (Belden and Belden 1962: 100).

Although IBM was successful in the 1950s and 1960s with its catch-up strategy, it remained generally a fast follower rather than a first innovator (W. D. Hoffmann 1976), and was caught 'asleep' once again when the small personal computer erupted into the market in the 1970s and 1980s. IBM had become one of the most profitable firms in the world with the success of its large mainframe business computers, the 1401 and the 360 series. Its huge success stimulated many attempts at imitation both in the USA and in Europe. Most of these efforts failed. Both RCA and General Electric had to withdraw from the market in the early 1970s after the failure of heavy investment to secure an adequate market share. IBM was successfully challenged in the market only in specialist sectors, such as process control, minicomputers, and the very largest machines. Efforts

TABLE 9.4.(*a*) Technical progress in computers, from valves to microelectronics

Measures of various characteristics	Vacuum-tube computers (valves early 1950s)	Hybrid integrated circuits IBM 360 system late 1960s
Components per cubic foot	2,000	30,000
Multiplications per second[a]	2,500	375,000
Cost ($) per 100,000 computations	$1.30	$0.02

[a] A single multiplication on mechanical or electromechanical computers took more than one second.

Source: *Fortune*, September 1966.

TABLE 9.4.(*b*) Increase in computing power over time, 1944–1981

	Model	Computational speed (arithmetic operations per second)
1944	Harvard Mark I (electromechanical)	0.4
1946	ENIAC	45
1951	UNIVAC I	270
1953	IBM 701	615
1961	IBM 7074	33,700
1963	CDC 3600	156,000
1965	IBM 360/75	1,440,000
1972	CDC Cyber 176	9,100,000
1976	Cray 1	80,000,000
1981	CDC Cyber 205	800,000,000

Source: OTA (1983).

by various European firms in France, Germany, the UK, Italy, and Sweden to compete in their national markets with some government support had only limited success.

TABLE 9.4.(*c*) Comparison of IBM 650 (1955) and Fairchild F-8 microcomputer (1970s)

	IBM 650	F-8	Remarks
Physical volume (ft^3)	270	0.01	F-8 about 30,000 times smaller
Weight (lb)	5,650	1.0	
Power consumption (W)	17,700	2.5	F-8 consumes 7,000 times less power
Memory (bits)	3K main, 100K secondary	16K ROM, 8K RAM	
CPU	2,000 vacuum tubes	20,000 transistors	650 also needed many discrete resistors and capacitors
Time for adding two numbers (μsec)	750	150	
Reliability (mean time between failures)	hours	years (3 m–10 m hours is a typical mean time between failures for a current micro-processor—more than 300 years—but the subsystems with which the microprocessor communicates—e.g. terminals, printers—may be much less reliable)	F-8 at least 10,000 times more reliable
Cost	$200,000 (1955 $)	under $1,000 with terminal	

Source: OTA (1983).

In 1948 John Parsons had shown that all the movements and speed changes of a universal precision milling machine could be controlled by a mathematical computer, and in the early 1950s numerically controlled machine tools had been developed under a government contract at MIT Servo-mechanisms Laboratory. In the 1950s and 1960s the range of applications of computers was greatly extended. Although most computers in the 1960s were installed for office-type applications, an increasing number were installed for industrial process control systems. Many improvements in design, control, and programming followed, culminating in the MOLINS System 24 in 1969, which could be regarded as the first 'flexible manufacturing system' (FMS), combining several machine tools, together with guided vehicles and computer-aided design (CAD). The FMS, together with robotics, following Engelberger's 'Unimation' robot in the mid-1950s, made possible the diffusion of a wide variety of computer-controlled manufacturing processes over the next three decades. John Diebold (1952), in his book on the 'Automatic Factory', had envisaged many of these applications of computers but had pointed out that they could be successfully developed and used only after a prolonged period of training people with new skills, reorganizing management systems, and redesigning production processes. The development first of minicomputers by the Digital Equipment Corporation (DEC) in 1963, and later of microcomputers in the 1970s, greatly facilitated the progress of manufacturing automation together with computer graphics and work-stations incorporating specialized software and peripheral equipment.

However, it was in the service industries, in office applications, and in the home that the advent of the personal (micro)computer was to have the greatest impact. During the period of mainframe dominance, large computers were typically operated by a special department of user firms, an 'EDP' (electronic data processing department) and the major activities were fairly standard programs, such as payroll calculation, invoicing, sales records, etc. The Fordist paradigm still prevailed in the organization of large firms and EDP was fitted into it, even if sometimes rather uncomfortably. Smaller machines were used for process control in manufacturing and in medicine, as well as in design and scientific work, but computers were certainly not yet the ubiquitous feature of the industrial and office landscape that they are today. It was only the advent of the microcomputer, based on Intel's microprocessor in the 1970s, that made cheap computing universally available to every firm, large or small, to schools and colleges everywhere, and to millions of personal users (Table 9.5).

As we have already described in Section 8.6, the Fordist mass production paradigm based on oil, automobiles, and consumer durables encountered increasing social problems in the 1970s and 1980s, such as the OPEC crises of 1973 and 1979, the environmental pollution associated with fossil fuel consumption, and the increasing dissatisfaction with Fordist work-styles. The slow-down in productivity growth (Table 9.6 and Figure 8.4), the much higher levels of unemployment in this period of structural crisis, and the problems of managing inflationary pressures stimulated the acceptance of ideas such as a 'change of techno-economic paradigm' and the widespread critique of the old mass production paradigm (as for example in the MIT study *Made in America*: Dertouzos *et al.* 1989). However, it was only when computers, microelectronics, and telecommunications offered a new, technically reliable, and economically efficient mode of growth on a large scale that the new constellation could take over as the chief engine of growth. The most influential of these new developments was the advent of the personal computer and of the Internet. The stock of personal computers (PCs) reached over 100 million in 1997 in the United States, well over 50 million in the European Union, and 25 million in Japan (Table 9.5), and this scale of diffusion was possible only because of huge price reductions, and improvements in design, performance, and user-friendliness in the 1980s and 1990s.

According to most accounts, IBM was too fixated on mainframe large computers to recognize the change in the world computer market arising from the PC. By the time IBM got round (in 1980) to launching a crash development programme for its own PC, there were already several firms well established in the new market, including Atari, Apple, Commodore, and Radio Shack, and sales had already reached $1 billion. A special team was assembled outside the main IBM inhouse R&D establishment, first under Jim Lowe and later under Don Estridge, and was given one year to develop a saleable product. They succeeded, but only by (for IBM) the unusual procedure of buying in most of the parts, both hardware and software. In his iconoclastic

TABLE 9.5. National telecommunications and other indicators, various countries, 1997

Countries	GDP (US$ bn)	Population (millions)	Main lines ('000)	Lines/100 ('000)	Cellular users ('000)	PCs ('000)	Internet users ('000)
Argentina	323.2	35.7	6,750	18.9	2,013	1,400	170.0
Australia	346.3	18.4	9,350	50.7	4,893	6,700	1,600.0
Belgium	242.4	10.2	4,769	46.9	974	2,400	300.0
Brazil	688.1	164.5	15,106	10.0	4,400	4,200	1,310.0
Canada	617.6	30.3	18,460	60.8	3,420	8,200	4,500.0
Chile	77.1	14.5	2,600	17.9	410	790	2,000.0
China	917.7	1,221.6	70,310	5.8	13,233	7,500	400.0
Colombia	76.1	37.4	5,334	14.3	1,265	1,214	130.0
Denmark	169.7	5.3	3,339	62.9	1,450	1,900	300.0
Finland	119.8	5.1	2,866	55.8	2,147	1,600	1,000.0
France	1,392.9	58.6	33,700	57.5	5,817	10,200	500.0
Germany	2,102.7	82.1	45,200	55.1	8,170	21,000	2,500.0
Greece	120.9	10.6	5,328	51.0	938	470	150.0
Italy	1,145.4	56.8	25,698	45.2	11,738	6,500	585.0

TABLE 9.5. Continued.

Japan	4,192.7	125.7	60,381	48.0	38,254	25,500	8,500.0
Korea, Republic of	442.5	45.9	20,422	44.4	6,910	6,931	800.0
Malaysia	98.5	20.5	4,223	20.6	2,461	1,000	600.0
Mexico	402.8	97.6	9,264	9.5	1,745	3,600	520.0
Netherlands	360.5	15.6	8,860	56.6	1,717	4,400	900.0
Norway	153.4	4.4	2,325	52.8	1,677	950	500.0
Poland	135.6	38.6	7,510	19.4	857	1,400	800.0
Portugal	102.3	9.9	3,819	38.5	1,507	740	500.0
Russia	449.8	147.3	26,875	18.2	485	4,700	600.0
South Africa	129.1	42.3	4,646	11.0	1,600	1,800	800.0
Spain	531.3	39.1	15,854	40.5	4,338	4,800	525.0
Sweden	227.8	8.9	6,010	67.8	3,169	3,100	800.0
Taiwan	n.a.	21.7	10,862	50.1	1,492	2,570	1,500.0
UK	1,288.2	57.6	30,292	51.8	8,993	11,200	2,500.0
USA	8,079.9	268.0	170,568	64.0	55,312	109,000	40,000.0
Venezuela	87.5	22.4	2,804	12.5	1,072	850	35.0

Source: Mansell and Wehn (1998).

TABLE 9.6. Average annual growth rates of labour productivity, 1870–1980 (GDP per man-hour)

	1870–1913	1913–50	1950–60	1960–70	1970–80	1973–80
France	1.8	1.7	4.3	5.1	3.8	3.7
Germany[a]	1.9	1.2	6.6	5.2	3.6	3.2
Italy	1.2	1.8	4.3	6.3	2.5	1.7
Japan	1.8	1.4	5.7	9.6	4.3	2.6
UK	1.1	1.5	2.3	3.2	2.4	1.6
USA	2.1	2.5	2.4	2.4	1.5	0.8

[a] Federal Republic 1950–80.

Sources: Maddison (1980).

but very entertaining account, 'All IBM Stories Are True', Robert Cringely (1996) suggests that IBM made some serious strategic errors by bringing in Microsoft for the operating system, which led ultimately to that firm's dominance in the PC software market. Other accounts, however, argue that IBM could not have foreseen the fateful long-term consequences of its deal with Bill Gates,[2] head of what was then a very small software company (fifty employees). Microsoft became for a while one of the most powerful firms in the world through its near-monopoly of PC operating systems. By 2000, however, its own dominance was increasingly at risk because of anti-monopoly proceedings in the USA and the EU and the rise of new competition, notably from LINUX, an interesting non-commercial cooperative software development organization which had received some backing from IBM.

Although it succeeded in keeping a position in the world market for personal computers, IBM encountered far more serious competition in the 1980s and 1990s than ever before. It was obliged to reduce its labour force worldwide by more than 50 per cent, from 400,000 to 200,000, and suffered a drastic decline in profitability. An increasingly high proportion of IBM sales came from software and systems rather than hardware. The relative decline of large mainframe computers compared with the proliferation of PCs and workstations led to a large number of new entrants taking advantage of the drastic change in scale economies. Competition came from many sides, including Japanese firms such as NEC, Fujitsu (large machines), and Toshiba (portables), and from numerous small firms 'cloning' the main features of the PCs. It also came from software firms as the relative importance of software grew in relation to hardware. The story is somewhat cynically but amusingly told in Cringely's (1996) aptly entitled book, *Accidental Empires*. Although classified as a 'gossip columnist' for *Infoword*, Cringely was a former Stanford professor and rather well-informed. No recent book has shown more vividly the degree

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[2] Gates himself thought that IBM had got a 'fabulous deal—a one-time fee of about $80,000 that granted the company the royalty-free right to use Microsoft's operating system forever. In other words, we practically gave the software to IBM' (Gates 1996: 54).

of turbulence and uncertainty in both software and hardware innovations in the United States, or the role of very young computer enthusiasts ('The Triumph of the Nerds'). These young enthusiasts could be compared in some respects to the creative dissenters of the Industrial Revolution. Not surprisingly, Bill Gates himself believed that IBM made a big strategic error in not accepting his proposal that IBM should buy up to 30 per cent of Microsoft stock—'so that it would share in our fortune, good or bad. We thought this might help the companies work together more amicably and productively' (Gates 1996: 63).

New developments in the 1980s for the most powerful computer systems were based on the 'transputer' and parallel processing, enabling a number of computers to combine together. The interaction between industrial R&D and university groups was again important in developing new architecture, as well as the interaction between semi-conductor firms and computer firms (Molina 1989). IBM's capability in semi-conductor technology continued to be a source of strength, although it also had to collaborate with Intel and other component firms. The rise of network computing provided new opportunities for IBM in the 1990s, and the changes in the telecommunications industry, which made this possible, are described in the following section.

9.4 Telecommunications

As with the computer industry, the forerunners of the modern telecommunication industry go back a long way, but, as with computers, the introduction first of electro-mechanical technology and then of electronics marked a decisive change in the performance of the systems. The electric telegraph of Wheatstone (UK) and Morse (USA) in the 1830s and 1840s had already provided a communications system that was of great importance for the railways, for news agencies, and for the military. Alexander Graham Bell's invention of the telephone in 1875 was not at first recognized as a revolutionary break-through in telecommunication, because the technology was at first effective only over short distances, whereas telegraphy could be used over very long distances. Western Union, the strongest telegraph company, at first thought of telephony as a small niche business and, although it was a strong competitor of Bell, using its own network of telegraph lines, it agreed to leave the telephone business to Bell in return for a percentage of Bell's rents and royalties. This followed a patent dispute in which Bell sued Western Union for infringement of the Bell patents in 1879. The Bell company agreed not to enter the telegraphy market until its basic telephony patents expired in 1894. This agreement gave Bell a near-monopoly in the telephone network in the United States which it retained for nearly a century, although at the price of accepting a fairly strict system of government regulation in order to avoid nationalization in 1913 (Duysters 1995). Most European countries had already established public ownership of their postal, telegraph and telephone services. The threat of nationalization followed Bell's aggressive acquisition of many smaller independent local telephone companies and the relocation of its stocks to the New York American Telephone and Telegraph Company in 1899 to avoid state regulation in Massachusetts.

De Forest's invention of the triode electronic valve for radio led to a drastic change in the competitive strength of telephony. As already noted, AT&T acquired the right to use the valve (tube) as a relay in the telephone system in 1907 and this enabled the telephone to replace the telegraph as the most important device for long distance as well as short distance communication. Thus began the intimate relationship between electronics and telecommunications which became ever closer during the twentieth century. The next big step was the use of the transistor in telephone exchanges. Bell and other telephone companies had attempted to use the valve in exchanges as well as in relays, because the biggest bottlenecks to productivity improvements in telephony were in transmission and in switching. As the number of subscribers grew, manual exchanges needed very large numbers of operators to make connections, but it proved impossible to use valves in the switches, because they burned out too quickly and used too much power. Consequently, the telephone networks had to rely on improvements in electro-mechanical technology between the 1920s and the 1960s.

The first electronic exchange, using transistor technology, was installed in the United States in 1960. From that time onwards computers and switching equipment were increasingly influenced by the same technological changes. The first use of *digital* technology followed in 1965 with the introduction of Pulse Code Modulation (PCM) in AT&Ts Electronic Switching System No. 1 and of Stored Programme Control (SPC), which greatly increased the speed and flexibility of the system. 'The electronics regime that drove the electronic computer market ever since it originated in the 1940s increasingly determined the rate and direction of technological progress in the telecommunications industry. This convergence of technological regimes can be seen as the start of what would be known as the overall convergence process of Information Technologies' (Duysters 1995: 83). Thus, the growing technological interdependencies of the computer and electronic industries with each other, and of both with the telecommunications industry, were already firmly established by the 1960s. The constellation of new very fast-growing industries, which had initially developed quite independently of each other in the nineteenth and early twentieth centuries, had now crystallized into a new technology system which became generally known and recognized as 'ICT'.

It is important to realize however that *technological* convergence and other close relationships between the three industries did not necessarily lead to *business* convergence. Von Tunzelmann and Soete (1987, 1988) showed that, in spite of a high degree of technological convergence, many firms in each industry in the 1980s continued to pursue their own specialized business interests and to strengthen their own core competence in that field. Analysis of patent statistics and of technology alliances by Duysters (1995) confirms this conclusion. Leading telecommunications equipment makers did take out many patents in computers and microelectronics, and leading semiconductor firms took out more than half their patents in the field of telecommunications, but there were no big changes in these proportions between 1980 and 1993, that might demonstrate a big shift in core competence and business specialization. Firms that did try to enter one of the other industries (e.g. IBM into telecommunications), whether by acquisition or by innovation, were generally not successful. However, Duysters concluded that, in spite of the barriers to entry, such as production and marketing know-how and skills, technological convergence would ultimately lead to the repositioning of firms through strategic alliances and networks. Their role in the evolution of the constellation is discussed in Section 9.5.

One other major trajectory of technical change which proceeded in parallel in the telecommunications industry was in the carrying capacity of cables. Originally dependent on thin copper wires, telephony systems needed greater and greater bandwidth to carry the huge increases in traffic. At first this need was met by the development of coaxial cables, but it was the development of optical fibres in the 1970s that provided the orders-of-magnitude improvement that liberated the system from bandwidth constraints (Figure 9.3). It now became possible to deliver the huge number of signals for digital telephony, sending vast quantities of data and images almost instantaneously over an 'ISDN' (Integrated Services Digital Network) at rapidly falling cost. An American writer, George Gilder (1993), estimated that the 4 kHz telephone lines to American homes and offices in the early 1990s would explode to 25 *trillion* Hz of fibre optics.

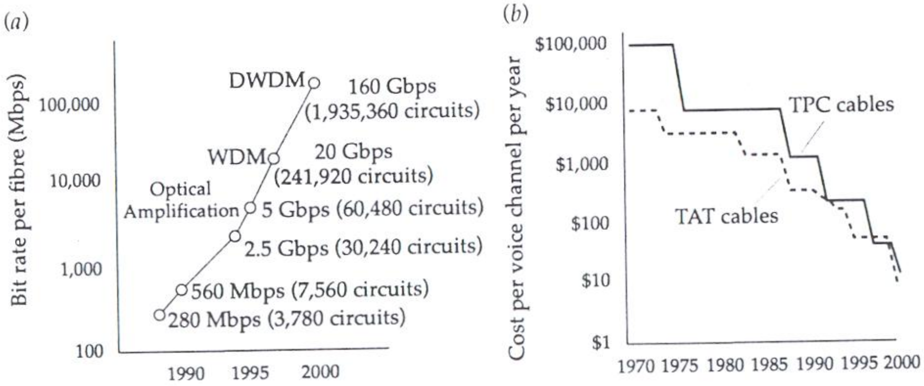

FIG 9.3. International submarine cable capacity and cost

(*a*) Capacity per fibre, 1985–2000
Note: Circuit figures indicate the number of 64 Kbps circuits plus signalling overhead.

(*b*) Submarine cable cost per voice channel per year, 1970–2001
Note: System cost is derived from total construction costs divided by the system's lifetime. Figures assume compression ratio of 5:1 on post-1988 systems.

Source: Mansell and Wehn (1998).

However, at the same time as *wired* communication was experiencing this technological revolution, *wireless* communication was undergoing an equally radical transformation as a result of satellite communication and cellular telephone networks. Gilder concluded that the digital computer networks of the future would function both over wires and in the air:

> As for the decendants of television, the dominant traffic of the future will be store and forward transmission of digital data among millions of telecomputers. These machines will be capable of summoning or sending films or files, news stories and clips, courses and catalogues anywhere in the world. Whether offering 500 channels or thousands television will be irrelevant in a world without channels, where you can always order exactly what you want, when you want it, and where every terminal commands the communication power of a broadcast station today. (Gilder 1993: 95)

The extraordinarily rapid growth of the mobile telephone network, together with the power and performance of the handsets in 1998–2000, appeared to confirm Gilder's prophecies. He also concluded that the technical changes would drive the institutional changes and in particular that centralized broadcasting stations and/or centralized telephone systems would no longer be needed, just as in his view mainframe computers would be displaced by client–server networks and networks of personal 'wallet' computers carried by most individuals.

Whether or not this vision comes about depends of course on many social, cultural, and political changes, as well as on the technical changes, which are in many cases easier to foresee. The small size of the picture on the hand-held telephone may yet prove a major barrier to its universal acceptance, and other cultural factors may exert a powerful influence on the future evolution of the system. The social changes involve the birth of new institutions as well as the death of old ones, the rise of new forms of regulation as well as the deregulation of older services and industries. They are further discussed in Section 9.6 and in the next chapter.

The trend in the 1970s and 1980s following the breakup of the Bell system in the United States was towards privatization of the old public monopoly services and a regulation regime, which would not only permit but encourage new entrants into the world of telecommunication networks and services. This policy was based on the belief that a more competitive environment would stimulate the growth of all kinds of new information services, such as those envisaged and listed in Table 9.7, and would also lead to a more rapid reduction in charges.

Most of these services did in fact become available during the 1980s and 1990s through a combination of telephony and television, especially in the United States, where cable networks were much more rapidly introduced than in Europe. However, it was by a combination of computers and telecommunications through the Internet that the world-wide diffusion of information services made the most rapid progress. The Internet was originally introduced in the 1960s as an Advanced Research Projects Agency (ARPA)

TABLE 9.7. Information services potentially available to households as envisaged in the 1970s

Passive entertainment	People—people communications	Interactive television	Still-picture interaction	Monitoring	Telephone voice answerback	Home printer	Computer terminals (including the viewdata television set)
Radio Many television channels Pay television Dial-up music/sound library	Telephone Telephone answering service Voicegram service Message sending service Telemedical services Psychiatric consultation Local ombudsman Access to elected officials	Interactive educational programmes Interactive television games Quiz shows Advertising and sales Television ratings Public opinion polls Audience-response television Public reaction to political speeches and issues Television interviewers soliciting audience opinion Debates on local issues Telemedical applications Bidding for merchandise on televised auctions Betting on horse races Gambling on other sports	Computer-assisted instruction Shopping Catalogue displays Advertising and ordering Consumer reports Entertainment guide City information Obtaining travel advice and directions Tour information Boating/fishing information Sports reports Weather forecasts Hobby information Book/literature reviews Book library service Encyclopaedia Politics Computer dating Real estate sales Games for children's entertainment Gambling games (such as bingo)	Fire alarms on-line to fire service Burglar alarms on-line to police Remote control of heating and air conditioning Remote control of cooker Water, gas, and electricity meter reading Television audience counting	Stock market information Weather reports Sports information Banking Medical diagnosis Electronic voting	Electronic delivery of newspaper/magazines Customized news service Stock market ticker Electronic mail Message delivery Text editing; report preparation Secretarial assistance Customized advertising Consumer guidance Information retrieval Obtaining transportation schedules Obtaining travel advice/maps	Income tax preparation Recording tax information Banking Domestic accounting Entertainment/sports reservations Restaurant reservations Travel planning and reservations Computer-assisted instruction Computation Investment comparison and analysis Investment monitoring Work at home Access to company files Information retrieval Library/literature/document searches Searching for goods to buy Shopping information; price lists and comparisons Real estate searching Job searching Vocational counselling Obtaining insurance Obtaining licences Medicare claims Medical diagnosis Emergency medical information Yellow pages Communications directory assistance Dictionary/glossary/thesaurus Address records Diary, appointments, reminders Message sending Dialogues with other homes Christmas card/invitation lists Housing, health, welfare and social information Games (e.g. chess) Computer dating Obtaining sports partners

Source: Guy (1985: 105–7).

project, supported by the Pentagon in the United States to ensure that some decentralized communications would remain in operation even in the event of the devastation expected from nuclear warfare. As the project advanced, and as détente made this prospect less probable, the network became available to civilian users and especially to universities for electronic mail (e-mail). Its great success in this role led to its adoption by business users and to a rapid extension of the services available. Indeed, Internet service providers became the most rapidly growing and exciting sector of the economy, first in the United States but later almost everywhere. Even companies that had never yet provided any services or made any profits became the object of intense stock exchange speculation. Venture capital companies sometimes exaggerated greatly the potential of the small new companies they were promoting. This 'bubble' did however get blown up in response to a genuine proliferation of very real prospects for an immense wave of structural change. An appropriate telecommunications infrastructure for the age of ICT was at last coming into place, and this would indeed have enormous effects throughout the economy, but especially on the delivery of services of all kinds. The potential effects of the Internet on retail trade were also considerable, but its long-term future remained controversial, as the considerable costs of warehousing and delivery systems have become more apparent and consumer response less positive than often assumed.

9.5 Organizational Change: The 'Network Firm'

In the 1950s, computers were fitting in, although somewhat uncomfortably, to the old 'Fordist' organizational paradigm. They became part of the old centralized departmental, hierarchical structures of the large firms that adopted them. Few small firms could afford them. They did not yet revolutionize the *organization* of firms, for example by making information rapidly available at all levels, and it was generally assumed that large mainframe computers in specialized data processing departments would be the normal pattern. The management structure of IBM itself reflected this, although it was always a very heavy spender on R&D and on education and training.

However, the universal availability of personal computers, the introduction of local area networks (LANs), and the rapid changes in product and process design eroded this old hierarchical structure. Because of rapid, easy access to information, some layers of management became unnecessary and top-heavy. A new style of management became widespread and contrasted with the Fordist style in many respects (Table 9.8). Networking, both within the firm and in the external relations of the firm, became especially important characteristics of the new organization, although the forms of networking are extremely varied and are often exaggerated (Chesbrough and Teece 1996).

A good example of the new networking firm was Cisco Systems Inc. Founded in 1984 by a group of computer scientists from Stanford University, by 1998 it was a global leader in designing and making networking equipment and software for the Internet, with an annual income of over $8 billion and market capitalization of nearly $100 billion. According to *Business Week*, this firm has been a leader in transforming management practices and sells most of its own goods and services over the Internet. 'So successful has Cisco been in selling complex, expensive equipment over the Net that last year [1997] Cisco alone accounted for one third of all electronic commerce' (Byrne 1998). Of course, this commerce is itself growing at a prodigious rate, which enables Cisco to deliver technical support to its customers at a far lower cost in engineering hours. By the year 2000 it was catching up with Microsoft and GE as one of the largest firms in the world.

TABLE 9.8. Changes in the techno-economic paradigm

'Fordist' (Old)	ICT (New)
Energy-intensive	Information-intensive
Design and engineering in 'drawing' offices	Computer-aided designs
Sequential design and production	Concurrent engineering
Standardized	Customized
Rather stable product mix	Rapid changes in product mix
Dedicated plant and equipment	Flexible production systems
Automation	Systemation
Single firm	Networks
Hierarchical structures	Flat horizontal structures
Departmental	Integrated
Product with service	Service with products
Centralization	Distributed intelligence
Specialized skills	Multi-skilling
Government control and sometimes ownership	Government information, coordination and regulation
'Planning'	'Vision'

Source: adapted from Perez (1989).

> The network also is the glue for the internal workings of the company. It swiftly connects Cisco with its web of partners, making the constellation of suppliers, contract manufacturers, and assemblers, look like one company—Cisco—to the outside world. Via the company's intranet, outside contractors directly monitor orders from Cisco customers and ship the assembled hardware to buyers later in the day—often without Cisco even touching the box. (Byrne 1998: 57)

Again according to *Business Week*, networking has enabled Cisco to quadruple its output by outsourcing without building new plants. When an employee needs information, 'the network is also the place to go'. Most psychologists may be relieved to know that, although 'Technology aids and abets this business model ... it does not completely displace human interaction'; the CEO has quarterly meetings with all (13,000) employees 'at a nearby convention center' and has 1½-hour birthday breakfasts with some of them. Stock options for key employees play an important role, and 'wages are less important than ownership'. Acquisitions have played a key role in Cisco's rapid growth, and critics believe that this may become a source of weakness. So far, however, few of the employees in the newly acquired companies get the sack as the acquisitions are designed specifically to capture new intellectual assets and next generation products. 'At what we pay, at $500,000 to $2 million an employee, we are not acquiring current market share. We are acquiring futures.' When Boeing and Ford told the Cisco CEO that their future networking needs were not likely to be satisfied by Cisco, the firm immediately acquired LAN switchmaker Crescendo Communications in order to satisfy the needs of its leading customers. Partnership with customers, subcontractors, and employees is the name of the game in the networking firm, according to its more enthusiastic exponents. However, the hype should not disguise the fact that real and substantial changes are indeed taking place in the ways firms are managed and conduct their external business relationships. The 'business to business' use of the Internet will probably turn out to be the most important source of productivity gains in the ICT revolution. Nor has ruthlessness disappeared from business relationships or employer–employee relationships. Insecurity of employment, temporary contracts, and part-time working have all become more prevalent, especially in the United States and the United Kingdom.

The rise of the networking firm was reflected also in the business of management consultancy. Those consultants, who continued to use the traditional media and traditional methods, were outpaced by more fleet-footed competitors who made full use of the Internet to transact their business. They were appropriately renamed 'guritos' instead of the old 'gurus'.

In his remarkable three-volume study, *The Information Age: Economy, Society and Culture*, Manuel Castells (1996, 1997, 1998) argues that in the Information Society 'the basic unit of economic organization' is no longer an entrepreneur, a family, a corporation, or the state, but a *network* composed of a variety of organizations. The 'glue' that holds the networks together is the 'spirit of information' itself—a 'cultural code' of the ephemeral, informing and enforcing 'powerful economic decisions at every moment in the life of the network'. Paying homage to Weber's analysis of the spirit of accumulation and enterprise in the rise of capitalism, Castells defines the spirit of informationalism as '[t]he culture of creative discussion accelerated to the speed of the opto-electronic circuits that process its signals. Schumpeter meets Weber in the cyberspace of the network enterprise' (Castells 1996: 199).

It is notable that Weber himself had already spoken of networks in the economy, and many economists have used the concept to characterize various features of capitalist societies, based, as they always have been, on an intense interchange between suppliers and users of materials, components, products, and ideas. How far, therefore, is Castells justified in regarding the 'network enterprise' as the defining *new* feature of informationalism and as a new stage in the development of capitalism?

In the discussion of networking among economists, there has been little disagreement on at least one major new feature of contemporary networks compared with other networks, and that is the *speed* of the technologies of communication now available—and not only the speed of processing and communicating, but also the rapid *access* to new and wider sources of information open to the participants within networks. The imaging and graphics now increasingly available within computer networks may provide a dominating framework in the representation of reality and determine the very substance of information processing for decision-making in the network firm. More than ever, the medium may become the message.

Castells has less to say about another aspect of networking, which has preoccupied economists with their focus on specialization, division of labour, and scale economies. The growing complexity of technology and science had already caused Adam Smith to stress the role of specialization in science and division of labour among scientists. Still earlier, Serra in Naples had pointed to the number of specialized skills and occupations within a city or other territory as an indicator of its sophistication and prosperity (Reinert 1997). This specialization and sub-specialization has today increased by orders of magnitude and means that any degree of 'autarchy' in the organization of 'in-house' R&D has become increasingly problematic. Networking has become more essential than ever in scientific and technical activities, as can be demonstrated by the rapid growth of collaborative research, joint ventures, consultancy, various types of licensing and know-how agreements, joint data banks, and, of course, innumerable forms of tacit informal collaboration. Hagedoorn has shown that this trend has been especially strong with respect to information technology and bio-technology (Hagedoorn 1990; Hagedoorn and Schakenraad 1992).

The advance of information and communications technology has both accelerated and facilitated the growth of networking and the economic advantages of scale economies for those firms and individuals who can accumulate specialized knowledge and have access to networks. The subcontracting of many services hitherto performed in-house has moved in the same direction. Some economists have always thought that methodological individualism, whether of firms or consumers, was the wrong foundation for economic analysis, and they will welcome Castells's theory of the network firm. However, these changes all have to be seen in the wider context of society as a whole. (See the special issue of *Research Policy* on 'Complex Products and Systems', August 2000.)

9.6 The Institutional and Social Framework and Regime of Regulation

As Bill Gates (1996) points out in his vision of the future of the information society, this society is still in its infancy. As he shows, the potential is truly immense, whether with respect to the economy or the quality of life in relation to health and education. Yet, as with all great new technologies, the social problems of assimilation and application are also immense. This is even more true of socio-political and cultural changes than of the technology. Even in the early days of ICT, the problem of information overload had become apparent. Indeed, some observers realized as early as the 1930s that this was a serious problem even before the age of computers began. The scientist J. D. Bernal (1939), in his discussion of *The Social Function of Science*, pointed to the necessity of competent abstracting and reviewing services because of the impossibility of keeping up with the growing flood of publications and information. Even more perceptively, the poet, T. S. Eliot wrote in his 'Chorus' for 'The Rock':

> Where is the knowledge we have lost in information?
> Where is the wisdom we have lost in knowledge?

If he had lived to see the Information Society, he might have added: 'Where is the information we have lost in data?' The problems of transforming data into information and information into knowledge remain outstanding problems of the Information Society, which have not been resolved by simply calling it the Knowledge Society. In attempting to analyse the 'spirit of informationalism', Castells (1996) goes back to Max Weber's classical work on the spirit of capitalism:

> No-one knows . . . whether at the end of this tremendous development, entirely new prophets will arise, or there will be a great re-birth of old ideas, or if neither, mechanized petrification, embellished with a sort of convulsive self-importance. For of the last stage of this cultural development, it might well be truly said: 'specialists without spirit, sensualists without heart, this nullity imagines that it has attained a level of civilisation never before achieved. (Castells 1996: 200, quoting from Weber's *Protestant Ethic*).

This passage recalls the debates on the future of the Internet—whether it is desirable or possible to regulate or halt the diffusion of racist propaganda or pornography, or whether the content of traffic on the Internet has its own momentum, which is beyond anyone's control. What emerges as the dominant culture of the Internet will depend as much on the 'internet service providers' (ISPs) as on the individuals who surf the net or the small firms that strive to achieve a global presence.

In the 1980s, economists such as Albert Bressand (1990) were already pointing to the ways in which networks could easily evolve into future electronic cartels. During the 1990s the wave of mergers and acquisitions heightened these fears. Whereas in the early days of ICT many economists and management consultants stressed the role of small and medium-sized enterprises (SMEs) in generating innovations and new employment opportunities, now the emphasis has shifted increasingly to the supposed advantages of the very large global firms. One of the main arguments put forward to justify the largest ever merger proposed, early in 2000, by AOL (America on Line) and the Time–Warner group of companies was that in future the large media companies must be linked to a powerful ISP. By the same token, the ISP giants would need to be linked to *content* providers. Hitherto, large media companies such as Berlusconi's European conglomerate, or Murdoch's empire, concentrated on combining various media and entertainment interests—newspapers, television, football clubs, films, etc.—under one ownership in various countries. Now such companies aspire to owning and controlling Internet access and advertising too. It is not only the sheer scale of these mergers that causes some anxiety for believers in the virtues of competition, but perhaps even more the nature of the mergers. Control over the *content* of Internet services is clearly a fundamental issue for any democratic society and for the future 'spirit of informationalism'.

M. Javary and R. Mansell (2000), in their study of 'Emerging Internet Oligopolies', conclude that 'the development of the British ISP market suggests a trend toward the emergence of an oligopolistic industry that is inconsistent with the evolution of a network "commons" which will be responsive to social values'. They point to the wave of acquisitions of small new entrants by large British and American companies, which consolidate power and control in various specialized market segments. This is a far cry from the utopian dreams of the early pioneers using the Internet, who dreamt that it would provide not only a world-wide free democratic forum for the exchange of information and ideas, but also a global market-place in which the SMEs would be able to compete on level terms. The fact that networks are everywhere forming, flourishing, and sometimes disappearing does not dispose of the question of *power* within networks. A network may seldom be a partnership of equals. Some partners are usually more equal than others, to use Orwell's satirical comment on Stalinist forms of equality. A network may be the organizational means whereby a dominant firm maintains control over its suppliers, whether of materials, components, or technology.

As in the earlier case of electrification, the Internet has indeed provided and is still providing millions of new opportunities for SMEs to enter the economy, and in some cases to prosper and make a fortune. Internet millionaires have become quite commonplace, but the trend towards concentration is very widely apparent. The risk that monopolistic corporate power will wield increasing political and cultural influence in the information society is quite evident. The information revolution did indeed weaken or destroy the *old* monopolistic power of the telecommunication utilities. As we have seen, most of these, outside the United States, were state-owned and have been broken up and privatized. Even the heavily regulated Bell private monopoly in the USA was treated in the same way. This made possible the fairly rapid development of many new services and new technologies, but renewed concentration and re-regulation is now the name of the game. Even the competition between wired (cable) systems and wireless (mobile) telephony described so eloquently by George Gilder is leading to renewed concentration. The Anglo-American Vodafone Airtouch launched a bid to merge with the German Mannesmann Corporation early in 2000, a move that rivalled the AOL merger in scale and scope. The old publicly owned state monopolies have gone, only to be replaced by new giant global multinational corporations. This has undoubtedly resulted in a substantial weakening of the power of national governments. Can they any longer control the global infrastructure?

The wave of privatization in the 1980s and 1990s and the deregulation that accompanied it were only two instances of this serious weakening of national governments, which has been a major feature of this structural crisis of adjustment. Recently, the Netherlands government published a thoughtful booklet entitled *'Governments Losing Ground: An Exploration of Administrative Consequences of Information and Communication Technology'* (Netherlands Scientific Council for Government Policy 1999: 5). This started with a proposition that is very widely accepted:

> The declining ties to a particular territorial area will, it would seem, inevitably have consequences for the capacity of the national state to act, since the regulative and directive capacity of states derives to a significant extent from instruments (such as legislation and regulations) that are territorially bound. ICT can also provide impulses in more than one direction, combining both greater internationalization ('globalization') and greater emphasis on regional and local levels. In both cases, there is a declining dominance on the part of the territorial level on which national governance is based.

To some degree, this phase of deregulation is characteristic for the emergence of each new techno-economic paradigm, as we have seen in the earlier cases of electrification and motorization. The early beginnings of a new technology are necessarily confined to a few individuals and organizations, and small new firms are typically the midwives. There were hundreds of small firms making automobiles at the end of the nineteenth century, and it was by no means clear whether the future would be steam cars, electric cars, or petrol engine cars. Dominant designs, the regulation of traffic, and technical standards took decades to evolve. Even in the oil industry, as Chapter 8 has shown, small-firm competition prevailed in the early days before the speculative bubble burst and before Standard Oil ruled. It is easy to forget now that it was a long time before the giant firms grew big enough and strong enough to dominate the industry.

According to some accounts, however, the very nature of the technology determines the configuration and characteristics of the regulatory regime. The mass production technology in this view led inexorably to a centralized regulatory regime analagous to the managerial regime within the large corporations, with its hierarchical techno-structure. The ICT constellation, on the other hand, was often supposed to lend itself very easily to self-regulating networks with minimal central control. A rather utopian view of the Internet was widespread in the 1980s, even though it was first established by the Pentagon to preserve some level of communications in the event of nuclear war. This very objective of decentralized participatory communications by many individuals was thought to embody the liberal spirit and democratic values.

This contrasts with the mature period of the mass production society, when it was almost universally assumed that the role of central and local government in regulating and controlling the economy would increase. This assumption was shared by Keynesians, socialists, nationalists, militarists, and many people who could not be classified to any particular ideology. There were, of course, some very important exceptions, such as Hayek, who from the early 1940s vigorously opposed the increased role of government in the economy. In his famous book *The Road to Serfdom* (Hayek 1942), he argued that 'planning' would inexorably lead to political totalitarianism, and his arguments always commanded some respect and support, especially in the United States. However, in most countries both the mainstream trend in the economics profession and the dominant political parties favoured some type of Keynesian 'managed economy' or, as in Eastern Europe, outright central planning. Government expenditure, as a proportion of GDP, was almost everywhere much higher than before the Second World War, and this was generally assumed to be necessary, whether for military or for welfare purposes. In developing countries, it was generally assumed that the state had to play a very considerable role in efforts to organize 'catch-up' and promote industrialization, technical change, and economic growth.

Very different ideas have attended the birth-pangs of the 'Information Society' since the 1970s. In the last two decades of the twentieth century it has been quite widely assumed that taxation should be reduced and government expenditures diminished. Moreover, not only conservative and neo-liberal parties and ideologists, but also many erstwhile socialist and social democratic parties, have abandoned their belief in public ownership and central planning and embraced the philosophy of the free market. Margaret Thatcher, prime minister of Britain throughout the 1980s, was undoubtedly one of the most influential exponents of this neo-liberal ideology, even though she later lost the confidence of her own party. She was inspired directly by the ideas of Hayek, whom she greatly admired, and in one sense both the surge of neo-liberalism in Western Europe and the collapse of the centrally planned economies in Eastern Europe can be regarded as a belated vindication of his ideas. However, it remains to be seen how far the tide of deregulation and roll-back of state intervention will flow in the new information society. The weakening of government, which has occurred in the early period of the ICT revolution, has been followed by the resurgence of some tendencies to new forms of regulation and control. The last word has not yet been spoken and many possibilities are still open. No one knows what will be the last stage of cultural and political development in the information society.

We ourselves would accept the view that the characteristics of a pervasive technology do indeed influence government systems as well as corporate management systems. 'Influence', however, is not the same as determinism. The rise of totalitarian political systems and ideologies had, in our view, causes much deeper and wider than simply the prevalence of mass production; and, by the same token, computer networks, and in particular the Internet, do not inevitably or necessarily give rise to 'free' competition or democratic political institutions. The political systems in mass production societies were quite varied, as were the regulatory systems. The gas chambers and furnaces of the holocaust at Auschwitz were a macabre and horrifying example of the application of mass production philosophy as much as is the mass tourism on the Costa Brava. We have argued in Chapter 8 that the rise of nazism owed far more to mass unemployment and the complicity of some sections of big business than to the characteristics of any production system. The way in which any technological system is developed and used is the field of political conflict and ethical arguments, even though some technologies may lend themselves more easily to perverted and sinister applications. The kind of society that emerges from the ICT revolution depends on the strength and programmes of contending social groups and political forces far more than on the technologies.

This can be seen rather clearly from the current debates on taxation and the Internet. It is of course true that one aspect of the reduced power of national governments has been the loss of revenue from certain kinds of tax, especially corporate taxes and income tax. So important has this issue become that the OECD has warned of the danger of competition between governments to reduce taxes, and *The Economist* published a special feature on 'The Mystery of the Vanishing Taxpayer' in its 'Survey of Globalization and Tax' (29 January–4 February 2000: 1–20). This survey concluded that tax competition is a reality and that it could be stopped only with great difficulty. The 'Emerald' Tiger (Ireland) probably owed more to its low tax regime than anything else in its overtaking of Britain in per capita GDP. *The Economist* also considered the argument advanced by Charles Tiebout that tax competition, like other kinds of competition, is a Good Thing: 'Tax competition will put pressure on governments to provide their services efficiently, but that need not mean they have to be minimal' (p. 6).

However, *The Economist* survey does point to a major flaw in Tiebout's argument: whereas capital is mobile, most taxpayers are not, except for the most wealthy. The Internet will make more people mobile, 'rendering the rest even more wretched'. There are many forms of tax avoidance, which are facilitated by a combination of capital mobility and information technology. *The Economist* quotes American studies of tax havens which even in the 1980s showed that they accounted for 3 per cent of world GDP but 26 per cent of the assets and 31 per cent of the net profits. Murdoch's News Corporation, which earned profits of $2.3 billion in Britain since 1987, paid no UK corporation tax. It is not only corporation tax and income tax that can be increasingly avoided by fleet-footed companies and lawyers, but also sales taxes on e-commerce traded goods and services. It is true therefore that the Internet and ICT more generally lend themselves to a weakening of the tax power of governments.

To conclude that large multinational corporations (and even small ones) are the inevitable winners in the information society, and that the provision of welfare services by governments is doomed because of the nature of the new technologies, is somewhat premature. Social and political innovations, have great potential as well as technical innovations, and some could also take advantage of ICT. The Internet does make possible some forms of tax avoidance, but it also makes possible the political mobilization of groups all over the world to combat these practices and the philosophy and values that make them prevalent. As *The Economist* survey points out, 'No representation without taxation' could become an important principle in the twenty-first century. Moreover, entirely new forms of tax, which are redistributive in favour of both poor people and poor countries, are quite feasible. Luxury consumption taxes and pollution taxes can rise. Land taxes and road pricing could ease congestion and pollution problems as well as raising revenue in ways that would be harder to avoid. Finally, the provision of on-line services for health and education over the Internet could be a very powerful stimulus to the *improvement* of the welfare state. There are dangers of social exclusion with all such changes, of course, and the EU Report (European Commission 1997) on *Building the European Information Society For Us All* was right to insist that the universal service obligation must continue to provide for those who are not computer-numerate as well as for the rapidly increasing numbers who have Internet access.

Nor should the possibilities of new forms of *international* tax regimes be excluded. *The Economist* Survey points to proposals for a World Tax Organization to join the family of international organizations. The so-called 'Tobin Tax', named after the American economist who first proposed it, would offer immense possibilities for funding many of the objectives of the United Nations, including both social and environmental objectives, as well as security. According to the estimates of Robin Round (Round 2000), such a tax on speculative movements of capital could raise $150–$300 billion annually if set at a rate of 0.25 per cent. It would have the additional benefit of strengthening the position of governments and weakening the position of speculators in relation to exchange rates.

Finally, taxes on Internet traffic itself should certainly not be forgotten. When a 'Bit Tax' was first proposed by innovative economists such as Soete and Kamp (1996), it met with some strong criticism, notably from the US federal government, for rather obvious reasons; however, state governments within the United States were more sympathetic. It is quite true that there are problems of technical feasibility as well as political opposition, but these problems are not insoluble given the political will at both the national and the international level. Perez (1983) and Mansell (2000) have both quite rightly pointed to the need for bold *institutional* innovations to deal with the manifold social problems of the information society. Whether or not these can be devised and realized, in the sphere of taxation or elsewhere, is mainly a political and cultural question rather than a technical problem.

9.7 The Culture of Virtual Reality

In earlier discussion of culture and social change (Section 8.7) we have emphasized that works of art have a logic and time of their own. They may anticipate the future or recall a nostalgic vision of the past. Nevertheless, the tides of culture production are unintelligible without a consideration of the dominant modes of communication, the changing social structure, and the advent of new technologies.

Nowhere is this more apparent than in the case of the information society. The transformation of the production of works of art from the activity of a bohemian fringe of society to a major industry in its own right was one of the biggest social changes induced by the mass production paradigm. Millionaire artists, actors, sports people, and writers can now rub shoulders on almost equal terms with 'ordinary' millionaires from the worlds of commerce and industry. The entertainment industries are now a fully fledged and essential part of post-modern late capitalism. Information technology has taken this whole process a stage further and added some new dimensions.

In terms of *content*, the crucial alteration introduced in the postwar mass production period was the widespread diffusion of commercial TV. Consequently, the film industry, the epicentre of cultural production since the beginning of the century, was transmuted from a production of episodic and unique pieces, seen by large audiences in unique settings, into a production of flows of images and sounds to be seen simultaneously in private settings. The simultaneous collective experience was transmuted into a simultaneous individualized experience. The continuous flow abolishes the effort of memory and imposes the loss of historicity, mixing news, films, soaps, and contests at the same level of discourse and reducing all sounds and images to bits of *infotainment*. The great consequence of this is the fully used potential for the construction of 'fictive temporalities' and therefore the 'technological appropriation of subjectivity', generating a specific and novel type of media populism that was to become the basis for the entertainment industry (Jameson 1991: 74).

It was when the technology became available for the production of continuous flows of *infotainment* that 'postmodernism' won the day. Contrary to MacLuhan and so many other commentators, its victory did not represent the imposition of a complete universal culture: we do not live in a global village, but in 'customized cottages globally produced and locally distributed' (Castells 1996: i. 341). Each cultural artefact is locally bounded and the production of icons is still mediated by national and regional frontiers: their understanding is largely local. But icons are industrially produced and are

the constitutive bits and clips of our social communication, and this is the triumph of the aesthetics of distraction.

> A new world is taking shape in this end of millenium . . . brought into being a new dominant social structure, the network society; a new economy, the info/global economy; and a new culture, the culture of virtual reality. (Castells 1998: iii. 336).

The social consequences of this dramatic change in culture are still to be fully understood. The growing importance of advertising, the consumption of the discourse of consumption, and the narrative of desire inscribed in publicity constitute the image as the final form of reification of the commodity: the product is identified with its brand or logo. In this critical view, advertising is the dominant form of production of signs in postmodern culture. Fashion and fast food, B-films and remakes, Warhol's pop art, parodies and kitsch, science fiction, music and video reduced to clips populate this universe of pastiche—to use Thomas Mann's concept. Categories of space have replaced categories of time, historical depth has been lost to ephemera, reality melts into thin air, and concentration has been lost to superficial trivia.

Castells notes that in this rather shallow world, drained of spiritual values, cult religions may flourish as never before. Yet, enthusiasts for the vast potential of the new media and the new technology could justifiably respond that ICT offers the possibility for *participation* in creative activities in ways undreamt of and of bringing and enhancing education in every topic to the majority of the world's population. The final outcome depends on political and social changes, which are one of the main topics in the Conclusions to this part of the book.