THE CARRIER WAVE

New Information Technology and the geography of innovation, 1846–2003

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New IT on the world stage: the fourth Kondratieff upswing

From the start of the fourth Kondratieff, as Chapter 9 has just shown, information technology began to become one of the true carrier waves of world economic development. Just as in the previous era automobiles and electrical machinery had determined the course of high technology economic growth and the relative fortunes of the major industrial powers, so now the laurel would pass to the nation that proved most effective in bringing electronic information systems to the market place. At the outset, around 1950, the outcome of this race was by no means clear. Three at least of the then leading economic powers – the USA, the UK and Germany – had massive inherited scientific knowledge and technological competence in electronics. The most likely outcome might well have been that they shared the prize. In fact, by the end of the long fourth Kondratieff upswing, in the early 1970s, the USA was the undoubted world leader with a new competitor, Japan, coming fast up on the rails. The aim of this chapter is to tell the story of this race, and to try to account for its unexpected outcome.

It is not an easy story to tell. The problems of cross-national data availability and data comparability, that have plagued us earlier, continue to trouble us now. Particularly, rapid technological change marches ahead of the capacities of the official statisticians: new products, new industries – computers, electronic calculators – are not identified until too late. So the result will necessarily be a pastiche drawn from different sources, not a grand canvas from a single hand.

The office equipment industry

The best place to start is with office equipment, because this was an old industry, created through advances in mechanical and electro-mechanical technology at the start of the third Kondratieff (Ch. 6), that now began to be transformed by electronics. It consisted of four major divisions: typewriters, accounting and calculating machinery, document copying equipment, and a miscellaneous category including dictating machines, addressing and franking machines, and letter-opening machines (Hays *et al.* 1969). At the start of the fourth Kondratieff these industries remained almost exclusively electromechanical. Yet at the point where upswing turned to downswing, around 1975, the first signs were observed of technological transformation as the barriers between technologies, once considered impenetrable, began to crumble (Commission of the European Communities 1975): in photocopying the expiry of Xerox patents was already leading to the entry of new firms with new products; electronic calculators were rapidly taking over from mechanical ones; computers were being applied to word processing, and the electronic typewriter had just arrived.

Already, during the previous Kondratieff, the office machinery industry had become increasingly dominated by American firms, followed by one or two European countries such as Germany and Sweden; the UK had fallen behind. And, though British production grew rapidly in the 1950s and 1960s, relatively the country continued to lag. Its share of total output from the 15 leading capitalist economies fell significantly between 1954 and 1966 – indeed more sharply so than its share of total manufacturing production. In typewriters its share fell from about 9% to 3%, taking it from third place behind the USA and West Germany, to sixth place behind Italy, the Netherlands and Canada. Its share of 'other' office machinery fell from 10% in 1954 (when the USA had about two-thirds of total world production) to 4% in 1966: about level with Italy and Japan, but behind Germany and France (Table 10.1).

This is a typically internationalized high-technology industry, with large trade flows between the advanced industrial nations. British exports of office machinery (excluding copiers) increased substantially between the early 1950s and late 1960s (Table 10.2): about 32% of output was exported in 1948, 54% in 1968. The share rose rapidly in the early 1950s, partly due to government exhortation, partly to allocation of materials and minimum export requirements for foreign firms established in Scotland after the war;

Table 10.1 Shares of main producing countries in output of 'other' office machinery, 1954–66[a]

	Percentage share 1954	1960	1966	Value, 1966 ($m)
Canada	4	3	2	(75.0)
USA	67	66	70	4156.4
Japan	1	2	4	250.9
France	5	6	5	322.2
Germany	7	6	8	448.9
Italy	3	4	4	(224.5)
Sweden	3	2	2	111.4
UK	10	8	4	222.3
others[b]	1	2	1	58.7
total	100	100	100	

Source: Hays *et al.* (1969).

Notes:

[a] Excludes typewriters, dictating machines, offset litho and office document copiers; includes electronic computers.

[b] Austria, Denmark, Finland, Netherlands, Norway and Spain.

The figures in brackets are estimates.

In 1966 the value of typewriter production in the 10 leading countries amounted to about $680 million, about one-ninth of the value of other office machinery as listed above.

Table 10.2 Exports and imports of office machinery, UK, 1954 and 1968.

	1954 (£m)	1960 (£m)	1968 (£m)
Exports			
computers[a]	—	1.1	43.6
other machinery[b]	12.2	27.0	47.7
total	12.2	28.1	91.3
Imports			
computers[a]	—	n.a.	51.9
other machinery[b]	6.4	21.0	73.3
total	6.4	21.0	125.2
Net trade balance[c]			
computers	—	n.a.	−8.3
other machinery	+5.8	+6.0	−25.6
total	+5.8	n.a.	−33.9

Source: Hays *et al.* (1969).

Notes:

[a] Includes peripheral equipment for computers.

[b] Includes typewriters; accounting, calculating, adding etc. machines; cash registers; dictating, addressing, statistical machines.

[c] Exports versus imports; import and export data may not be entirely comparable.

it remained fairly stable from 1954 to 1962, then again rose. In 1968, total exports of office machinery were £91 million, including £15 million for copiers and £43 million for computers.

Despite a growing absolute level of exports and share of exports in national output throughout the 1950s and 1960s, the UK's share in the OECD countries' exports of office machinery over this period (including computers, but excluding document copiers) declined from about 14% in 1954 to 11% in 1966. In 1954 the UK's share of OECD exports was comparable to that of Germany, both countries sharing second place behind a clear lead by the USA. By the mid-1960s, the USA's share had fallen from about 40% to 30%, Germany had increased its share, but the UK had slipped down to the level of France and Italy (Hays *et al.* 1969). This comparison is based on data that includes electronic computers, in which at the time the UK was performing relatively well.

Accompanying this falling share was a dramatic increase in the import of such equipment into the UK. The share of imports in total consumption of office machinery (excluding computers) increased from about 23% in 1954 to almost 66% in 1968 (ibid.); this increased penetration affected almost all sub-sectors of the mechanical and electromechanical office machinery industry. A survey of some major office machinery users in the late 1960s, which sought to identify the possible reasons for purchasing imported goods, instanced the absence of home-produced equivalent machinery, the greater efficiency of imported products, and the lower prices of imports.

For this weak performance on the international stage there are a number of explanations. A critical one was that, in comparison with other major industrial countries, the UK was slow and ineffectual in mechanizing office work. This process did not start anywhere until the turn of the century, first with typewriters, followed by calculators in the 1920s, more sophisticated accounting and statistical machines in the 1930s, and document copying and dictating machines after World War II (ibid.). But the rate of diffusion in the UK was slow, in comparison not merely with the USA but also with major European countries (ibid.). Not only did most of the new technologies originate in the USA; American companies started to apply them commercially and on a large scale, even when they originated elsewhere.

European countries such as Germany, Sweden, and France were relatively quick to follow the American lead, even though, as in the Swedish case, their home market might be much smaller than the British. Even in the 1920s and 1930s it was estimated that the average German firm was better mechanized than its British

Table 10.3 Estimated sources of office machinery supply in the UK, 1964–6.

Type of machine	Percentage of total by value (responding firms) British-owned firms	Foreign-owned firms	Imported
typewriters	37.6	33.8	28.6
accounting machines	2.0	89.7	8.2
adding and calculating machines	8.5	61.9	29.5
cash registers	5.3	72.6	22.1
dictating machines	2.3	39.2	58.4
document copiers	23.0	19.1	57.8
duplicators	69.3	15.5	15.2
statistical and other	39.8	31.8	28.4

Source: Hays *et al.* (1969).

counterpart. In the mid-1960s, usage of office machinery per head of the labour force was three times as high in the USA as in the UK, in Sweden twice as high, in Germany two-thirds greater and in France one-third greater. The ratio of typewriters to population was estimated as 1 to 5 in the USA, 1 to 30 in continental Europe and 1 to 55 in the UK. One of the main reasons was that, at least until 1939, labour for office work was relatively abundant and cheap (ibid.), an explanation that has frequently been raised for the poor technological 20th-century performance of British industry generally (Kirby 1981). It suggests a very important conclusion: that a high rate of *process* innovation among home consumers may spur a high rate of *product* innovation among producers, which in turn may produce a base for exports.

One outcome is that even British domestic production has been dominated by overseas-based, especially American, firms (Table 10.3). These seem to form the spearhead in most aspects of technical development, and their productivity is considerably higher on average than that of British-owned firms (Hays *et al.* 1969, Commission of the European Communities 1975). By the late 1960s, foreign-owned firms accounted for about 60% of the employment and about 75% of output of the industry (Hays *et al.* 1969). In 1972, 7 of the 9 largest office machinery manufacturers in the UK were overseas-based companies; 12 of the top 20 enterprises were subsidiaries of foreign firms (Commission of the European Communities 1975).

The origins of this dominance lay in the initial introduction of most of the major new products. In most cases this occurred in the USA or other foreign countries, so that initial production in the UK

was by the subsidiary of an overseas firm. This was early true of typewriters, where American and German firms dominated (Clapham 1938, Hays *et al.* 1969, Prais 1981). Business and accounting machines, similarly, were largely produced in the UK by American firms; thus cash registers were first produced in the USA by the National Cash Register Company, which set up a subsidiary in the UK as early as 1895 and started production on a substantial scale in the UK at Dundee in 1946; Burroughs set up factories at Strathleven in 1951 and Cumbernauld in 1958, and Remington Rand established a factory in Glasgow. The Dictaphone Company began business in the UK in 1947 in order to import dictating machines made by the American firm of Dixon Brothers, and later assembly and complete production facilities were established at Acton, moving thence to East Kilbride. It remained wholly American owned, and by the late 1960s there was no British owned or controlled production of dictation equipment (Hays *et al.* 1969).

In mechanical and electromechanical punched card machines, production in the UK between the wars was undertaken by two companies: the British Tabulating Machine Company, manufacturing under licence from IBM, and Powers-Samas, under licence from Remington Rand. After the war the agreements were terminated because of pressure from the British government to save dollars (and avoid American Anti-Trust legislation); at last, a number of British firms entered this field, which gradually merged into the growing computer industry. In addressing machinery, although a relatively unsophisticated machine was produced in the UK as early as 1900, the field was dominated by American and other foreign firms after the invention of the Addressograph machine in the USA in 1930.

The major exception seems to be duplicating machinery, although this had ceased to be a leading technology by the 1960s. The rotary stencil machine, the oldest type of duplicating equipment, appears to have been a British invention, and the three leading British firms in the 1960s, Gestetner, Roneo and Ellams, began production towards the end of the 19th century (ibid.). British firms continued to be involved in the production of electronic stencil-cutting devices, and the spirit duplicating field was shared by indigenous and foreign firms. The use of offset litho machines for office duplicating purposes began with German-built machines, but during World War II indigenous firms began production with government support; afterwards, production was shared between British firms working under American licences and foreign-owned firms (ibid.). In the field of electrostatic copying equipment, which grew rapidly in the 1960s, the major British producer was Rank-Xerox, owned jointly by the Xerox company of the USA and the British Rank Organization.

There was one postwar British innovation: in 1961 a British company, Sumlock-Comptometer, produced and marketed one of the first electronic desk calculators, the Anita. For several years it was estimated to command half the British market. The firm was taken over by another British firm, Lamson Industries, later in the 1960s.

There are a number of reasons for this foreign dominance (ibid.). Firstly, as already seen, American firms pioneered the technology and brought it to the UK. Secondly, in the 1960s, foreign-owned production was extended to some of the most mature and established products such as typewriters, with overseas firms buying out British concerns or setting up concessionaires to import their products. Thirdly, in the more sophisticated products, foreign firms were sophisticated technologically, with higher R&D levels than their British equivalents. Fourthly, regional policy encouraged the establishment of foreign firms, especially in Scotland. Fifthly, the single-product nature of most British firms, combined with the economic advantages of diversified production and product ranges, provided an additional incentive for the absorption of indigenous firms by larger, more diversified, international organizations. Sixthly, the structure of demand for many of these products is such that direct selling by foreign manufacturers is not practicable; the establishment of local subsidiaries, agencies or concessionaires becomes a preferred option. And seventhly, foreign firms had good sales organizations in the UK, sensitive to user needs in the development of new products, and lending equipment on a trial basis (ibid.).

Underlying the competitive power of the foreign companies, however, were also some basic and only too familiar facts. They tended to be large, well integrated companies offering a wide range of products, with a good and extensive servicing back-up; so that once they had sold their systems to major buyers they could rely on their continuing loyalty. In the face of competition from such established giants, entry by newcomers would indeed have been difficult. They had more capital equipment per employee, and consequently higher productivity. All this was true whether they were operating factories in the UK, or in their home country. In fact, had they not established British subsidiaries, the UK's export performance would probably have been worse, and its import penetration problem greater, than it actually was in the 1960s. And, when some of the multinationals began to transfer operations to other European countries at this time, the fact began to show in the

performance of the British office equipment industry as a whole (ibid.).

Electronics capital goods

The early growth of the electronics industry was based on consumer goods such as radio and television, although the interwar era did see the emergence of electronics capital goods in the form of radio transmitting equipment (both civil and military), as well as some application of electronics in telephone communications systems and in new fields such as radar. But the real growth of electronics capital goods came only after 1950. Between the mid-1930s and the mid-1960s electronics production grew worldwide at over 10% per year (in constant prices). But, from the late 1950s, the growth rate for consumer goods (primarily radio and television receiving sets and music recording and reproducing sets) began to slip behind that of capital goods, which was achieving approximately 15% per annum (Wilson 1964, NEDO 1967, 1968, 1970, Freeman *et al.* 1965).

It is not always easy to define or to measure this group of industries, because of the rapid pace of technological change and the fact that capital and consumer goods use many of the same components and are even produced in the same plants (NEDO 1968, 1969, Freeman *et al.* 1965). But the following classification, based on Ministry of Aviation and other official sources of the 1960s, is a useful guide:

(1) electronic computers (or data processing equipment): digital and analogue computers and their peripheral equipment.

(2) radar and other electronic navigational aids: ground, marine and airborne radar systems and other electronic navigational aids and guidance systems, missile and satellite tracking and detection equipment and sonar.

(3) radio communications and public broadcasting and ancillary equipment: radio communications equipment for ships, aircraft, police, ambulances and services equipment; transmitters, aerials, audio and video studio recording equipment, monitoring and studio equipment, and relay and repeater systems for radio and television broadcasting systems.

(4) electronic and nucleonic measuring and testing equipment: electronic testing and measuring including oscilloscopes, signal generators, spectrometers, radiation detectors, computer

and component testing equipment, sound and vibration measuring equipment.

(5) industrial electronic control equipment: machine-tool control equipment, other electronic control equipment including detectors of foreign bodies, crack and strain detectors, counting, weighing and sorting equipment. This subsector produces key elements of the 'tertiary' or 'control' mechanization equipment which only begins to experience a rapid rate of diffusion from about 1960 (Blackburn *et al.* 1985).

(6) other electronic capital goods: a wide range including electronic welding and heating equipment, electronic medical equipment, electronic simulators and training aids, electron microscopes and ultrasonic equipment.

(7) telecommunications equipment. Although much of this equipment was predominantly electromechanical rather than electronic throughout this period, some studies include it within electronics capital goods (Freeman *et al.* 1965). It includes telephone and telegraph apparatus, telephone sets, switchboards, teleprinters, telewriters, telegraph and telephone testing equipment.

Though all these divisions grew during the fourth Kondratieff upswing, there were significant differences in rate, timing and geographical distribution. Here we shall consider merely some representative examples.

Radar and associated products

These have been closely affected by military demand, though air traffic control created a major civilian market also (Freeman *et al.* 1982). By the mid-1960s, this was the largest single category of electronics capital goods production in both the UK and the USA. Although the UK appeared to have a slight technological lead down to 1940, with Germany and France also having strong technological capacity, by 1950 the USA commanded a clear lead in levels of production and shares of world exports, with the UK in second place; West Germany and Japan had negligible shares because of postwar limitations on their defence industries.

American dominance reflected the strength of domestic military demand, which according to one estimate was no less than 90% of the total market of all the advanced capitalist economies in the mid-1960s; on this basis, it also commanded more than half of total world exports in the late 1950s and early 1960s (Freeman *et al.* 1965). By the mid-1960s the UK produced about 5% of the

advanced capitalist economies' total output, but commanded about 29% of total exports. Some British firms such as Marconi and Decca were particularly successful in marine and airborne radar and navigation systems in this period, exporting a very high proportion of their output. It was estimated that outside the American continent about three-quarters of the ships in the world equipped with marine radar had British systems and that most of the civilian airports were similarly equipped (ibid.). British firms were in fact so strong in this field that they were able to license French, German and other electronics firms.

Computers

Even in the mid-1960s, despite extremely rapid rates of growth since the mid-1950s and especially since the emergence of 'second generation' machines incorporating transistors from about 1958, computers still stood second to radar in importance within this category (Harman 1971, Margerison 1978). The origins of the industry, in the late 1940s and early 1950s, lay in research and development work in universities, government and industrial research laboratories, especially in the USA and the UK, to a lesser extent in Germany, France, the Netherlands and Italy. Much of this work was sustained by the enthusiasm of groups of scientists and engineers and by sponsorship from a variety of government agencies.

The general commercial view in the USA, at least down to 1950, was that there was little or no market. Thomas J. Watson Senior, the head of IBM, despite his long acquaintance with business needs for data processing, felt that a few machines could deal with the total needs of those requiring complex calculations; nor was there any broad demand among major life assurance companies, telecommunications firms, aircraft manufacturers and others who were informed about the emerging technologies (Katz & Phillips 1982, Freeman *et al.* 1982). For IBM's 650 computer, sometimes described as the Model T of the industry, the engineers forecast a sale of 200, whereas the firm's product planning department forecast no sales at all. After its introduction in November 1954, 1800 machines were sold (Harman 1971).

Thus much of the enormous progress in computing technologies in these early postwar years came through military and other government support, including grants to universities; industrial support played a relatively minor rôle. Among those who first saw the commercial potential of computers were the pioneers Eckert and Mauchly, who made great efforts to interest financiers and private companies after their dismissal from the University of Pennsylvania in 1946 because of their commercial activities. They experienced serious difficulties; Remington Rand, which acquired their firm in 1950, tried to cancel all outstanding contracts because it took such a pessimistic view. Yet from this time it became clear that there was a commercial potential for computers. In the USA the Korean war increased military and other government support, leading to IBM's keen interest and full involvement. IBM now soon demonstrated that the computer industry could be extremely profitable; it rapidly became one of the most profitable and fastest-growing companies in the world, accounting for between 60 and 70% of world computer sales throughout the period 1950–80. Only in minicomputers and specialized systems was its share of the world market significantly below 60%. By the mid 1960s, only in the UK and Japan among the larger capitalist economies did its share of installations fall below half (OECD 1969, Harman 1971, Stoneman 1976, Freeman *et al.* 1965, 1982).

During this period there was limited swarming as a number of new as well as established electronic firms entered the industry; by 1960 there were about 26 firms in the USA, 7 in the UK, 3 in Germany, 2 in Holland, one each in France and Holland engaged in the design, construction and sale of computers (Margerison 1978). An international survey around 1970 suggests that there were about 39 firms active in the computer industry in the USA; among the other major countries there were 7 significant domestic computer firms in Japan, 4 in Germany, one each in the UK, France, Italy, the Netherlands, Sweden, Norway, Denmark, Israel. Many of these 'home producers' had licensing ties with the larger American firms (Harman 1971). Many other firms entered the industry in the 1950s but had bowed out by the late 1960s. Thus, though limited swarming occurred in the 1950s and 1960s, not much of it proved profitable.

Though several European governments did try to keep national producers afloat, by the late 1960s most had been forced to withdraw or amalgamate. By then the only significant non-American producers designing and developing their own equipment in Europe (other than the UK) were making small scientific computers or specialized systems. In Japan the share of American-owned firms was lower than in Europe, largely as a result of state policies (OECD 1969, Harman 1971, Freeman *et al.* 1965). Thus the computer industry in this period was an extreme example of Schumpeter's Mark 2 model (Freeman *et al.* 1982).

The clear American leadership during the 1950s and 1960s stemmed from the size of the domestic market. By 1965 the USA had an estimated 20 000 computers installed; Japan had 1840, West Germany 1603, the UK 1160 and France 1061. Thus the USA had 105 computers per million of population in 1965, Western Germany had 29, France 22, the UK 21 and the Netherlands and Japan 19 (Freeman *et al.* 1965). As earlier in mechanical and electromechanical information, the USA took a clear lead in mechanizing or automating information handling. Although there were no satisfactory comparative statistics for production and trade in computers even by the mid-1970s, one survey suggested that American domestic production amounted to about US $1 billion by 1964, representing about 71% of the total combined production of computers in the five leading countries, the USA, the UK, West Germany, France and Japan (ibid.). The American industry's exports of electronic data-processing equipment amounted to $218 million in 1964: almost three-quarters of the combined exports of the five leading countries. Its dominance in this subsector was more pronounced than that in the electronics capital goods sector as a whole.

Radio communications and public broadcasting etc. goods

During the late 1950s and 1960s, this subsector represented almost as large a market as electronic computers. And here again the USA dominated, with about three-quarters of world production and almost 60% of world exports in the mid-1960s. Again the data on world production shares and exports substantially understate the rôle of American companies. International Telephone and Telegraph was one of the leading manufacturers and exporters in this field as well as in telephone equipment; the company employed 185 000 people in 1964, 128 000 of them in Europe where subsidiaries included Standard Telephone and Cables (STC) in the UK and Standard Elektrik Lorenz (SEL) in Germany (ibid.).

British production in this field was about one seventh that of the USA in 1958, falling back to about one-twelfth by 1964; by then its percentage share of total production of the five leading countries was 6.4%, slightly ahead of West Germany and France, and its share of world exports was somewhat higher at 14.2%. Racal was one specialist British firm which enjoyed very rapid growth and export markets in this field, as did Plessey and Marconi. Other European firms with a strong export performance in this field included Philips, Telefunken, Siemens, CFTH, Pye and Redifon (ibid.). From the late 1950s Japanese firms experienced fairly rapid growth of production and exports in this field.

The public broadcasting and studio equipment element in this category was relatively small compared to the specialist radio communications market. Here the USA accounted for about 60% of world output and about 40% of world exports by the mid 1960s. As in the other category of radio communications equipment, European firms had fairly strong technology and patent positions, with a considerable degree of two-way licensing with American firms. The major European firms, such as Telefunken, Marconi, Siemens and CFTH, all enjoyed a strong position in world export markets. This indeed was the one area of electronic capital goods where there are significant exports from Europe to the American market (ibid.).

Summary

By the mid-1960s the clear picture was one of absolute American dominance, albeit with some variation between subsectors (Table 10.4). This dominance is all the greater if account is taken of the contribution of American companies in other countries through subsidiaries, technology licensing agreements and the like.

Table 10.4 shows that in the mid-1960s the American share of total electronic capital goods production in the five leading countries was almost 82%; its share in each of the subsectors ranged from 91% in radar and navigational aids to a 'low' of 61% in industrial electronic control equipment production. The UK's share of total production in this sector was second highest, but it was a long way behind at 6%. Within the different subcategories, the UK's highest share was 12.6% in industrial electronic control equipment followed by 9.0% in electronic data processing equipment. France was in third position with 5.1% of the total; West Germany was fourth with 4.2%, Japan fifth with only 2.8%. By this time Japan's capital goods and consumer electronics industries were beginning to grow rapidly; their relative international position would improve markedly over the following years, as we will see in Chapter 11.

Table 10.4 Production of electronic capital goods, national shares, 1964.

	USA	UK	West Germany	France	Japan
Electronic data-processing equipment	70.8	9.0	7.4	7.7	5.1
radar and navigational aids	90.9	4.4	0.5	3.4	0.8
radio communication and broadcasting etc.[a]	76.5	6.4	6.3	6.0	4.9
electronic testing and measuring[b]	73.5	8.2	8.2	7.4	2.7
industrial electronic control	61.3	12.6	13.8	11.1	1.2
other electronic equipment not elsewhere classified	82.3	4.1	5.1	4.1	4.4
total electronic capital goods	81.9	6.0	4.2	5.1	2.8

Source: *National Institute Economic Review*, **34**, 1965, 42.

Notes:
[a] Includes radio communications equipment, public broadcasting, transmitting and ancillary equipment.
[b] Electronic measuring, testing and analysing instruments, including nuclear instruments and controls.

In terms of shares of total electronics capital goods exports, the USA again commanded a leading position with about 60% of the total. It commanded a 75% share of world exports of electronic data-processing equipment and 70% of the other electronic equipment category; its lowest share of the five countries' total exports was in industrial electronic control equipment with 29%. The UK was again in second position behind the USA, commanding 14.5% of the total exports of the five countries, a much higher share than of total production. Among the subcategories, its largest export share was in industrial electronic control equipment, where it had 35.8% of the five countries' combined exports, and in radar and navigational aids, where it had 29.1%. Western Germany was in third place, with 12.7% of the total; France was in fourth position with 7.3%, Japan in fifth with 5.0% (ibid.).

Telecommunications equipment

Throughout the fourth Kondratieff upswing telecommunications remained a far from fully electronic technology. Yet it was one of the basic information technology industries. Even then, there was a two-way flow of technological innovation between it and electronics; a process that began to accelerate in the mid-1960s.

The production of telecommunications equipment, like that of so much other information technology, was overwhelmingly dominated by the USA (Table 10.5). But, though American production far exceeded that of the next four countries and indeed amounts to approximately two-thirds of the five countries' total production, it was primarily for domestic markets. Indeed, British exports well exceeded those of the USA in both 1958 and 1964. This was not due to any technological or organizational weakness on the American part; it is explained by barriers to trade created by the traditional structures of national telecommunications service systems, and by related political and national security considerations.

Table 10.5 Telecommunications equipment: estimated production and exports, major countries, 1958–64.

	USA ($m)	UK ($m)	West Germany ($m)	France ($m)	Japan ($m)	Total ($m)
Production						
1958	1297	146	171	90	70	1779
1964	1956	270	386	218	252	3091
Exports						
1958	46.0	65.9	35.9	8.9	7.3	164.0
1964	38.8	92.5	91.8	17.1	13.6	253.8

Source: National Institute Economic Review, **34**, 1965, 44.

In almost every developed country, telecommunications services have historically been organized as a monopoly, usually state-run, and equipment sales have also been highly concentrated. Western Electric, the largest American manufacturer and part of AT&T until the 1984 breakup, focused almost exclusively on domestic sales to Bell System operating companies. Therefore, although its innovations have offered continuing improvements to telephone services in the USA, there has been little export spinoff.

Thus, trade figures tend to understate the performance of American firms and technologies in this industry since the war (Freeman *et al.* 1965, US National Research Council 1984). Particularly, they fail to show that American firms have enjoyed success in foreign markets through their subsidiaries. For example, International Telephone and Telegraph (ITT) has historically enjoyed a strong position in Europe. In 1925 ITT acquired International Western Electric, which held a strong patent position in European telephony and had developed close ties with service provider organizations. ITT capitalized on these ties and subsequently attempted to develop similar ties in less developed countries. Although they have in some cases shared a common core technology, ITT subsidiaries have often presented themselves as relatively autonomous (US National Research Council 1984).

Nevertheless, it remains significant that the telecommunications industries in the UK and West Germany exported considerable shares of their total output and commanded rather high shares of the total exports of the leading producing countries, with the Japanese industry beginning to expand fairly rapidly from the mid-1960s. In the 1950s the major British producers were GEC, AEI and Marconi (the latter two later taken over by GEC), Plessey, Thorn and two subsidiaries of foreign firms, STC and Ericsson. By the 1970s the major indigenous producers were GEC, Plessey, Thorn-GTE (a joint USA–UK venture); the major foreign-owned firms were STC, PYE-TMC, Ericsson, and IBM which supplied a major share of the private exchange market from the mid-1970s (Hills 1984).

Electronic components and semiconductors

As seen in Chapter 9, it took over a decade for the transistor to make a major impact on electronics outside military applications; for much of the fourth Kondratieff upswing, more traditional electronic valves and similar components, involving relatively labour-intensive processes, constituted the major part of the electronic components industry (Wilson 1964). Yet the emerging semiconductor sector of the industry represented a key field for the development of electronics, and thus of New IT, at this time (OECD 1968).

Before World War II, European researchers kept abreast of their American counterparts in electronic component innovation. Some of the most important advances in valves and tubes were made by firms such as Philips, Telefunken, GEC, AEI (BTH) and Marconi, and by European universities. There was a strong two-way flow of licensing and patenting agreements across the Atlantic (Maclaurin 1949, Sturmey 1958, Freeman *et al.* 1965). Yet by the postwar boom era this position had changed completely; almost all the important inventions and innovations were being made in the USA. This was not simply because the crucial inventions – the transistor, the integrated circuit, the computer-on-a-chip – took place in the USA. Invention was only the first step in the commercial production of smaller, more reliable, compact and energy-efficient components; successful mass production needed massive research and development resources and the accumulation of a wide range of minor process and product innovations through what Rosenberg (1982) terms 'learning by doing and learning by using'.

As with computers, governmental military and space programmes played a major rôle at this critical stage. Throughout the 1950s about two-thirds of the total R&D work of the large American electronics and aircraft firms was state financed (Freeman *et al.* 1965). By 1955 the American government was buying 22% of all semiconductor production and accounted for 35% of the value of the semiconductor market (Braun & Macdonald 1982). Indeed, the government purchased almost all the 90 000 transistors produced in the USA in 1952. It has been estimated that in 1955 total state

R&D funding to the American semiconductor industry amounted to $3.2 million whereas production refinement funding for transistors and diodes totalled about $4.9 million (ibid.). Defence requirements accounted for about a third of the value of all semiconductor sales in the USA in the mid-1950s and grew to about half by the late 1950s; the share decreased to 30% by 1966, to 24% by 1972 and to about 10% later in the 1970s (ibid.)

Initially, the established electronics firms may have benefited most from these expenditures, but by the late 1950s a large share of the military market went to the newer semiconductor firms, a fact that may have been essential for their growth (ibid.). The military market was particularly valuable because of its enthusiasm for the latest and best components at almost any price. This meant that new, expensive products could be tested and sold. Some had no civilian applications; many others had, and components engineered to meet stringent military requirements could be adapted for less stringent civilian ones. There can be little doubt, then, that military R&D support and procurement contracts helped firms to gain production experience and lower costs, thus speeding up the 'learning curve' among American semiconductor manufacturers (Freeman *et al.* 1965, OECD 1968, Tilton 1971, Braun & Macdonald 1982).

But, of course, military expenditures are only part of the story. Large industrial R&D resources, together with easy access to Bell Laboratories patents in return for a relatively small fee and the availability of venture capital for new firms led by personnel who had spun off from established firms, all played a part in the phenomenal advance of the technology and growth of the industry in the USA. The American semiconductor industry since the war is often cited as a classic demonstration of the importance of new, initially small, firms using new technologies and managerial techniques, overcoming the technical and managerial conservatism of existing firms through radical innovations and building new industries: the Schumpeter Mark I model of swarming and growth. Certainly, compared to the mainframe computer industry, new firms have played a greater rôle in the American electronic components industry. There were a large number of new entrants between the mid-1950s and the late 1960s, accompanied by major changes in firm shares of domestic and international production. But the mushrooming process may have ceased in the USA by the late 1960s: it is estimated that there were about 15% fewer firms in the industry in 1980 compared to a decade before (Braun & Macdonald 1982). It is also important to note that the large established American electronics firms with large R&D resources were responsible for about half the major innovations from 1950 to 1980 and for more than half the patented inventions and process innovations (Freeman *et al.* 1982).

There was no similar swarming of new firms in the semiconductor industries of Europe or Japan. In the UK and other European countries very few new small firms entered the semiconductor industry; the international diffusion of the new technologies came largely through subsidiaries of American firms or through large established indigenous electronics firms (OECD 1968, Tilton 1971, Sciberras 1977, Braun & Macdonald 1982). Down to the late 1960s, the American semiconductor industry was about the only international one; in other nations, firms were largely concerned with retaining a share of their own domestic markets (Braun & Macdonald 1982). It was estimated that, in 1970, American firms had 56.5% of the world semiconductor market, European firms 16.1% and Japanese firms 27.1% (Braun & Macdonald 1982).

After a relatively slow start compared to the USA, semiconductor consumption in Britain, West Germany, France and Japan rose quite quickly from about 1960. Simultaneously, between the late 1950s and the early 1970s, American semiconductor firms launched a major programme of establishing their own factories in countries such as the UK, France, West Germany and to a lesser extent Japan. This brought a decline in the share of consumption supplied by imports from the USA. Thus between 1968 and 1972 direct exports from the US to these four countries increased by 102% and the value of the produce of American assembly and fabrication plants rose by about 360% (ibid.). The percentage share of their combined semiconductor consumption that came from American imports rose from 11% in 1960 to 32% in 1967 and fell to 18% in 1972. The cumulative number of American-owned semiconductor fabricating and assembly plants in these four countries rose from 9 in 1960 to 18 in 1967 to 52 in 1972 (ibid., see also Tilton 1971). Additionally, many indigenous firms manufactured under licences from American firms like Texas Instruments, Fairchild and Western Electric (Bell Laboratories). With the exception of Philips, European semiconductor firms were largely excluded from competing in the markets for mass-produced semiconductor components and were largely confined to their national markets or to the production of specialized and customized product for niche markets (Sciberras 1977).

Compared to Europe, the major mechanism of semiconductor technology transfer from the USA to Japan in the 1960s and early 1970s was licensing agreements between Japanese and American firms. Until 1974 Japanese government policies were strongly opposed to the establishment of subsidiaries by foreign-owned firms, and overseas companies were generally not allowed to take controlling interests in Japanese firms. The Japanese government controlled the terms of the licensing agreements between Japanese and foreign firms, promoted R&D programmes and spread the findings throughout selected parts of the industry, seeking thus to maintain a balance between the benefits of large oligopolistic firm structures and those of competition (Tilton 1971, Braun & Macdonald 1982). For these and other reasons, Japan's semiconductor production, consumption and exports grew quite rapidly throughout the 1960s and 1970s, mostly through indigenous firms. In 1977, for example, although firms based in the USA accounted for 51% of European production of discrete semiconductors and integrated circuits, they accounted for only 10.7% of Japanese production. The 1970s witnessed a significant growth of the Japanese semiconductor industry, still largely using American technology; but in more recent years Japan has begun to establish a lead in the production of certain types of semiconductors, thus causing much concern to US firms and policy makers (US National Research Council 1984).

The late 1960s also witnessed a major expansion of overseas investments by American (and later other) semiconductor firms to less developed countries, especially the so-called Newly Industrializing Countries (NICs) of Asia and Latin America. The major reason was the search for cheap labour for what was still a relatively labour-intensive industry; the light weight per unit value and relatively cheap transport costs of these components also facilitated this new international division of labour. Most of such plants were confined to the particularly labour-intensive assembly operations; the more complex and technology-intensive fabrication processes remained in the developed countries.

Curiously, since the mid-1960s there has also been a reverse investment flow, from Europe and Japan into the American industry (Braun & Macdonald 1982, OECD 1985). Part of the reason has been to acquire a more direct line of access to the latest technologies and to tap into the more intangible but nevertheless informal networks of information that have played a major rôle in the dynamism of the American industry (Rogers & Larsen 1984). Another has been to facilitate access to what remains the largest single semiconductor market in the world (OECD 1968).

It is difficult to generalize about the international structure and geography of the industry at the end of the fourth Kondratieff upswing (ibid.). Within the more traditional product lines the major producers showed much greater equality in terms of

Table 10.6 Electronic component production, major countries, 1965.

	Tubes ($m)	Semiconductors ($m)	Passive components ($m)	Total ($m)
USA	1019	1012	1259	3290
Japan	137	140	390	667
UK	n.a.	208	454	(662)
Germany	122	47	404	573
France	96	59	264	419
Italy	n.a.	25	n.a.	(92)

Source: OECD (1968).

Note: Because of great differences in national definitions, these data should be regarded as rough estimates only. Data for passive components are probably too high except for the USA.

indigenous technological capacity, relative levels of production, and trade performance than in the growing semiconductor subsector. In receiving tubes, the Netherlands and West Germany enjoyed an international leadership position for some products, whereas Japan appeared to have a strong position in certain kinds of passive components. But in the dynamic area of semiconductor technologies and associated industrial activities and firms, the USA commanded a clear lead (Table 10.6). The 'technological gap' in innovation of a particular technology in different industrialized countries may have narrowed over the 1960s (ibid., Braun & Macdonald 1982); yet enormous differences remained between the American semiconductor industry and those in other advanced industrial economies. The narrowing of the gap, in large measure, occurred through the transfer of American technology via either direct exports, licensing agreements or direct investment. By the end of the 1960s, the Japanese industry had begun to advance particularly rapidly; and there was already a significant relocation of investment and employment into a select number of less developed countries.

Conclusion

Overall, then, the fourth Kondratieff upswing saw a significant shift in the international division of labour within the information technology industries. Very rapidly, the USA achieved undisputed world hegemony; Europe in general, the UK in particular, found its earlier position eroded. In the older mechanical and electromechanical office equipment industries, the UK found itself increasingly displaced, above all by the USA, partly also by its European neighbours. In electronic capital goods, too, the USA had a clear lead both technologically and entrepreneurially. The UK maintained a position in computers, but was still far behind the USA. In electronic components British producers found themselves reduced to specialist niches; the Americans, again, were clearly in the lead. Japan was just emerging as a presence in several of these lines; some areas, such as component assembly, were being located in NICs. At the end of the upswing, just after 1970, the stage was already set for the next act of the drama.

11

Information technology in the world economy: the fourth Kondratieff downswing

Some time in the early 1970s, triggered by the oil supply crisis of 1973–4, the long fourth Kondratieff boom gave way to the downswing. In the advanced industrial economies generally, employment growth in manufacturing – which had been slowing markedly during the later upswing years – was succeeded by stagnation, even by decline. The impact of this transition varied from one national economy to another, depending on their structural strengths or weaknesses: in the UK, where factory employment was already contracting, it shrank faster; in Japan, which still enjoyed vigorous growth, it slowed. But everywhere the change was evident.

It raises a critical question, central to this study. In such a transition, do the advanced-technology industries contradict the prevailing trend? Do they perform an historic function as the carrier wave, the precursor of the next Kondratieff upswing? Most studies of long waves, oddly, avoid this question. The major exception, the work of Freeman *et al.* (1982), suggests a contrary hypothesis: new technologies contribute new jobs, through product innovation, only in Kondratieff upswings; in the downswings, by aiding process innovation, they actually displace jobs and contribute to rising unemployment, even while their output continues to grow. In support, the Freeman group cite empirical data for the USA, the UK and Germany (ibid.).

Their argument seems to contradict the evidence from previous long waves, especially the third, when the then advanced-