Technology and Employment in the Electronics Industry

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Luc Soete and Giovanni Dosi

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PREFACE

This monograph on the electronics and electrical engineering industries is a publication resulting from a research programme on technical change and employment (TEMPO) at the Science Policy Research Unit (SPRU) at the University of Sussex. This research programme has been supported by the Social Science Research Council (SSRC).

In the first phase of the programme we concentrated on the development of a satisfactory framework within which to analyse the very complex relationships between technical change, employment and unemployment. This framework is described in a book by Freeman, Clark and Soete and published by Frances Pinter in 1982, *Unemployment and Technical Innovation: a Study of Long Waves in Economic Development*. In that book we attempted to develop the basic ideas of Joseph Schumpeter in relation to successive technological revolutions and their effects on economic growth.

In particular, we attempted to indicate the relevance of these ideas for understanding long-term trends in investment and employment. It is not generally recognised that already in 1930 in his *Treatise on Money* (Vol. 2, p. 85) Keynes had acknowledged this dominant influence of new technological opportunities on investment behaviour:

> In the case of fixed capital it is easy to understand why fluctuations should occur in the rate of investment. Entrepreneurs are induced to embark on the production of fixed capital or deterred from doing so by their expectations of the profit to be made. Apart from the many minor reasons why these should fluctuate in a changing world, Professor Schumpeter's explanation of the major movements may be unreservedly accepted.

However, in his subsequent work, and particularly in *The General Theory*, Keynes did not follow up this basic insight and his followers have usually treated the question of new technology as of secondary importance, or outside their framework of reference.

In our approach, however, growth is not simply *accompanied* by the rise of new technologies, it *depends* on that impetus. We have therefore attached great importance to the identification of the most important new technologies and to the analysis of their specific features. In particular we are interested in the ways in which such technologies diffuse through the various sectors of the economy, lead to the growth of new industries, and both create new employment opportunities and destroy old ones.

It is in this context that the growth of the microelectronics industry and the associated cluster of new information and communication technologies is of quite exceptional importance. And it is for this reason too that Luc Soete and Giovanni Dosi have also concentrated their attention on those characteristics of the newly emerging industries and technologies that have implications far beyond the electronics industry itself, more narrowly defined.

It is relatively rare in history for new technologies to emerge which have that combination of qualities necessary to revolutionise the economic system. These qualities include: (1) a drastic change in comparative costs affecting a wide range of goods and services; (2) a substantial improvement in technical performance, similarly affecting a wide range of goods and services; and (3) a wide variety of new profitable opportunities for investment. Like electric power or steam power in the past, the new microelectronic based technologies satisfy these criteria.

It is more difficult to assess the employment trends associated with the rise of such revolutionary new technologies. An important feature of technical change over the past decade or two has been the tendency for the productivity of capital to fall in most branches of the economy. This has meant that each successive wave of new investment has had diminishing job generating effects and 'jobless growth' has become commonplace in many sectors.

In the past such long-term tendencies, accompanied by falling profitability and sluggish investment behaviour in the main sectors of the economy, have been overcome by two counter-tendencies:

(i) investment in those sectors of the economy still characterised by rather labour-intensive techniques;
(ii) major technological revolutions which brought about a rise in capital productivity, reversing the previous downward trend in many areas.

These counter-tendencies permit profitable new investment on a smaller scale but with more positive employment effects. For these reasons, a particularly important finding of the work of Soete and Dosi is that relating to capital productivity and labour productivity in the computer industry (Section II.7). The very big gains in capital productivity in this industry, accompanied by similar very high gains in labour productivity, offer the prospect of a major impetus to new investments in those sectors of the economy most deeply affected by computerisation. In the communications sector and in scientific instruments there is also a potential for similar productivity gains.

For such tendencies to generate widespread effects throughout the economy, it would be necessary to embark on major infrastructural investment and education/training programmes in order to permit a transformation of the capital stock and the skills of the labour force on a much larger scale. It would also be necessary to make other related advances in the design and development of many other types of capital goods, such as robots, sensors, process instruments and so forth, as well as a large amount of software development.

Whether or not such changes could be made on a requisite scale will depend on an adequate institutional response to the magnitude of the problems. The need for such a post-Keynesian, rather than pre-Keynesian approach to the problems of technology policy and infrastructural investment is evident on every side.

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INTRODUCTION

Microelectronics today is generally considered to be the most important single set of interrelated new technologies. The speed of technical change in microelectronics is indeed exceptional by any standard and is as striking in the practically continuous emergence of new products in very rapid succession, as in the dramatic cost-cutting and scaling-down of the electronic function. The availability in practically unlimited quantities of electronic functions, and the resulting dramatic increase in memory and transmission capacity gives rise to the concept of microelectronics being 'pervasive' technology with potential application in almost every industrial or service sector of the economy. It is the combined process of rapid technical change in microelectronics itself[1] and the diffusion of microelectronics throughout the economy which is often associated with the necessary technology-push for a long-term recovery or upswing in economic growth.

The diffusion of a major and radical new set of technologies such as microelectronics, sometimes identified with a new technological 'paradigm', is however, a slow and uneven process, the speed of which has more often than not been overestimated. The economy-wide diffusion of microelectronics might indeed, and paradoxically, be hampered as much by the existing, not fully depreciated electro-mechanical capital stock as by the rapid rate of technical change in microelectronics itself, where 'adopting' firms might view microelectronic investment as a relatively uncertain, high-risk undertaking, involving a commitment to a quickly out-dated and out-priced technology. Available evidence on the diffusion of microelectronics (McLean and Rush, 1978; McLean, 1980; Freeman, 1982) suggests that the diffusion process has probably been most advanced within the electrical engineering industry itself (particularly within the electronic subsectors), where the substitution of electronic components for electro-mechanical ones and the creation of new electronic sectors was a relatively straightforward process. In order to say something which is more than purely speculative about the overall likely impact of microelectronics, it seems therefore sensible to focus in the first instance on the impact of microelectronics on the electrical engineering industry itself.

Within the context of the United Kingdom, the debate about the future of microelectronics has an additional interesting feature. On the one hand fears have been expressed that the failure of the UK electronics industry to participate in some of the fastest growing sectors of the world electronics market might (see, in particular, NEDO, 1982, p. iv) signal a possible further deterioration in the United Kingdom's international competitiveness; on the other hand, the specific features of microelectronics, in particular its scientific base and the importance of 'software knowledge', have often been proclaimed to be more in line with some of the specific scientific and educational strengths of the United Kingdom. A study on the impact of microelectronics on the UK electrical engineering industry, and in particular its electronic subsectors, seemed therefore in more than one way worthwhile.

An analysis of microelectronics within the 'electrical engineering' sector raises obvious questions as to the 'homogeneity' of that sector, particularly the rapid change in the various subsectors in their adoption of electronics technology. Electronics is of course a form of electrical system (all electrical systems derive from flows of electrons in the form of an electrical current); yet to the extent that electronic circuits handle much smaller currents than traditional electrical currents and incorporate 'active' components, capable of modifying the flow of electricity, it has a quite distinct technological boundary (Cable and Clarke, 1981). The wide variety of electronic devices, from active ones to mechanical ones, is illustrated in Figure 1.

An analysis of the implications for employment and output growth of microelectronics which would ignore the fundamental distinction between the primarily electrical and the primarily electronic subsectors of the electrical engineering industry would consequently be doomed to failure. Unfortunately, neither production nor trade statistics distinguish between electronics and 'other' electrical goods. In many ways, the various (MLH) industries included in the 'Electrical Engineering' Order are all at different levels of 'electronification'. At one extreme one may find industries which are little affected by the change towards electronics, such as those making electric power transmission apparatus; at the other extreme there are industries which have been directly created by the electronics 'revolution' such as those manufacturing electronic computers.

The process of 'electronification' is, however, not just limited to the electrical engineering sector. Various parts of the mechanical engineering sector (numerically controlled metal cutting and metal forming: part of SIC 332/1 and 332/2), instrument engineering (electronic testing and control equipment: part of SIC 354/2; digital watches: part of SIC 352) and other manufacturing sectors (electronic toys and games: part of 1980-SIC 494/1; electronic musical instruments: part of 499/1; etc.) are now more or less electronic industries. In addition, there also exist a number of directly related electronics *service* sectors, such as computer services (1980-SIC = 8394).[2] The *direct* employment effects of electronics indeed can not just be limited to the actual manufacture of electronic commodities and devices (the hardware) but must include the provision of software and other directly related services.

All this makes an analysis of the electrical and electronics industries a difficult undertaking. Separating out the various 'electronic' subsectors, let alone changes over time in the 'electronic' content of the various MLH industries is difficult, if not impossible. The only feasible approach is to identify those MLH sectors which at one moment in time can be identified as predominantly 'electronic'. The 'electronics' industry evolution over time will then be identified with these specific, predominantly electronics industrial subsectors even if in the earlier stages of these industries, the electronics component was practically insignificant.

Table 1 illustrates some of the difficulties faced when trying to separate out the electronics MLH industries from the electrical ones. Depending on one's time perspective, the ideal approach consists either in taking the broadest possible industrial definition of electronics or in limiting the sector to the most well-established electronic subsectors. In this report, we will focus in the first instance on those 'electrical engineering' industries which can be considered as predominantly 'electronic', excluding telecommunications, i.e. MLHs 364, 365, 366 and 367. However, where possible we will include information on MLHs 363, 354, 338 and 1980-SIC = 8394.

Defined in its most narrow form (MLHs 364 to 367), the electronics industry has seen a remarkable growth in output over the post-war period (average annual growth in real terms 1954–81: 7.8 per cent) and even over the last 'recessive' years, the industry has kept much of its growth potential (1973–81: 5.7 per cent). This contrasts sharply (1954-81: 1.1 per cent) with the 'electrical' or even telecommunications part of the electrical engineering industry which saw an overall drop in output of 6 per cent a year

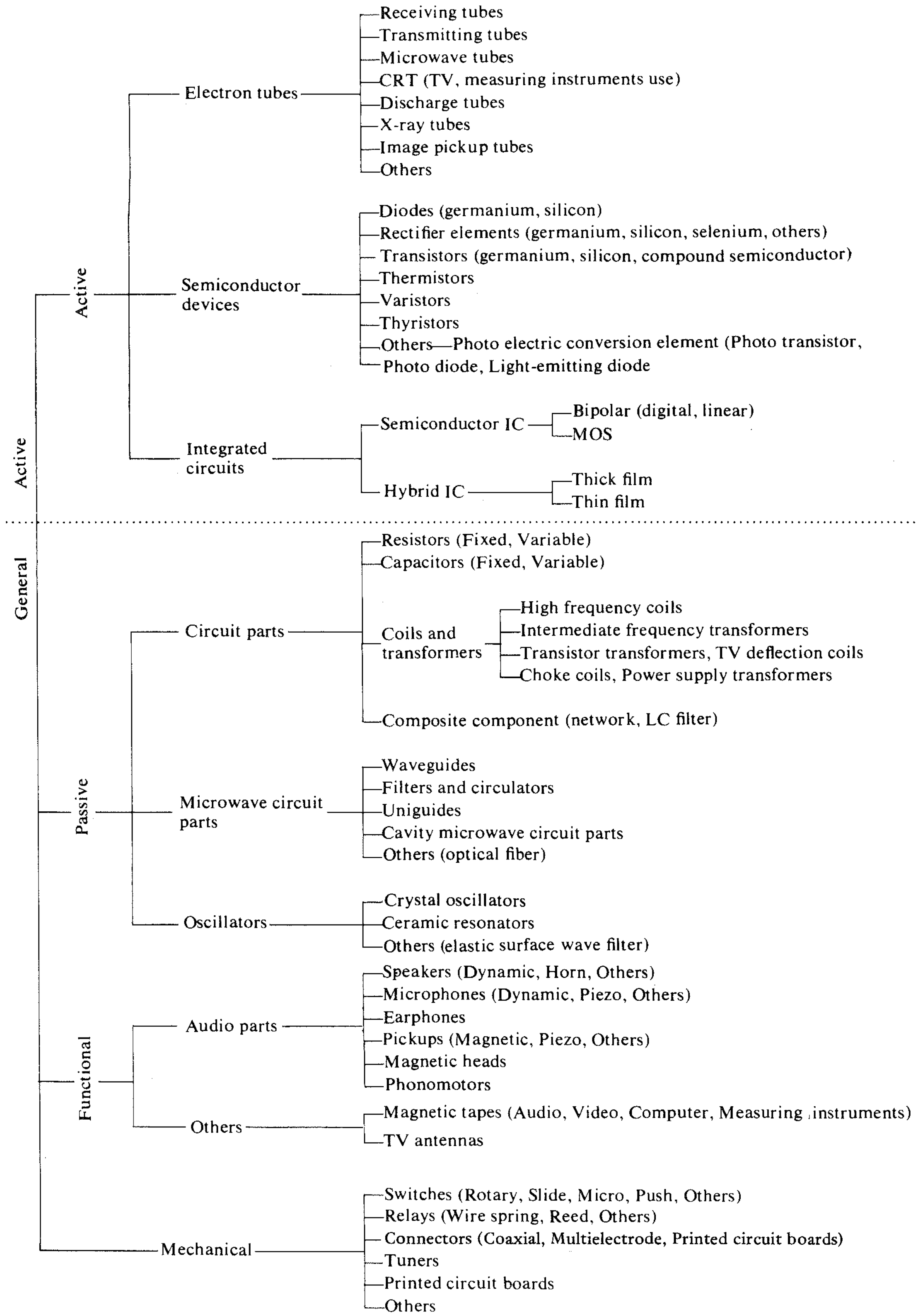


Fig. 1. Electronic devices classification. *Source*: Japan Fact Book, 1979.

Table 1. Separating out electronics and electrical engineering

Predominantly electromechanical	*Moving towards electronics*	*Predominantly electronics*
361 Electrical machinery		
362 Insulated wires & cables		
		363 Telecommunications
		364 Radio and electronic components
		365 Broadcasting and sound reproducing equipment
		366 Electronic computers
		367 Radio, radar & electronic capital goods
	368 Electrical domestic appliances	
369 Other electrical equipment		
Predominantly 'electronic' industries from other parts of the engineering industry		
	351 Photographic equipment	
	352 Clocks and watches	
	353 Medical instruments	
		354 Scientific & industrial instruments
	332 Metalworking machine tools	
		338 Office machinery
		(1980-SIC/8394: Computer services)

(telecommunications: −2 per cent a year) over the period 1973–81. In terms of employment, the electronics industry now employs 307,000 (including computer services 333,000) people, the telecommunications industry 61,000 and the electrical industry 305,000 (all revised figures from the 1981 Employment Census, *Employment Gazette*, December 1982). Until 1970–74 employment grew rapidly in the electronics industry; since then it has stabilised at around 300,000, primarily because of the significant decline in employment in radio, TV and hi-fi equipment industries (MLH 365; from 69,000 in 1973 to 25,000 in 1981) and radio and electronic components (MLH 364: from 153,000 in 1974 to 111,000 in 1981). Both electronic computers (MLH 366: from 50,000 in 1970 to 61,000 in 1981, but including computer services from ±65,000 in 1970 to 87,000 in 1981) and electronic capital goods (MLH 367 from 80,000 in 1972 to 110,000 in 1981) had a significant increase in employment over this period of massive employment displacement in the manufacturing sector. These are two of the very few *industries* in which employment increased over the last decade. Needless to say, they have come to the forefront of both government and academic interest.

The electrical industry (MLH 361, 362, 368, 369), by contrast, has witnessed a significant decline in employment since the mid-1960s, when around 500,000 people were employed in the industry. This trend is grosso modo similar to the overall trend in manufacturing employment. The related mechanical and instrument, predominantly electronics industries (office machinery and scientific and industrial instruments) witnessed a similar decline in employment over the seventies. The same holds for telecommunications.

The picture of rapid output and employment growth in the early phases of the electronics industry, shifting rapidly from subsector to subsector, bears much resemblance to the emergence of the electrical industry at the beginning of this century. Both industries, as will be argued later, can be identified with radically new technological paradigms; the electrical industry following the discovery and industrial exploitation of electricity at the end of the nineteenth century; the electronics industry following the discoveries in solid state quantum physics in the forties. To discuss them together, as will be attempted here, might therefore be less problematic than at first thought.

In the first section of this report we discuss briefly some of the major technological changes as they have affected both industries over the post-war period. The amount of information available on this subject is by any standard enormous; a large number of specialised reviews on the subject now exist and both R & D, patenting and innovation data are available. Our problem has been one of selecting the most relevant information and literature.[3]

By contrast, in the second 'economic' section, and as already hinted at earlier on, the major problem is one of lack of information and finding 'sensible' estimation procedures to 'stick' the scarce data together. It is, to say the least, surprising that so few attempts have been made to construct a consistent series of output, employment, investment and prices (to name a few) for the post-war 'electronics' industry or its various subsectors. One would also have hoped that the 1980-SIC revision, rather than bringing the existing UK SIC just in line with the EEC NACE Classification system, would have tried to separate out in a more systematic way 'electronic' manufactured goods and manufacturing industries, from primarily electro-mechanical ones. Many specialised trade journals, such as for example McGraw-Hill's *Electronics* (the January issues) now provide such a series reviewing year-by-year sales of various electronic products in some of the major countries.

The estimates of gross output, capital and labour productivity for the broad electrical and electronics industries and the various electronic subsectors, attempted in Section II, are, it should be stressed, 'heroic' by any standards, particularly for the pre-1970 period. They are based on various unrelated sets of data and are probably the best one can make at this stage. We have tried to be as explicit as possible about the various estimating procedures. Section II, apart from a few brief references to the international trade performance of the industry, its concentration and the occupational change in electronics, includes also a brief discussion (II.7) on the possible labour-saving bias in technical change which seems to have been an important feature of most manufacturing sectors, the significant exception being electronics.

In Section III a few employment forecasts are given for both the broad electrical and electronics industries and the various electronics subsectors for the 1990s. These are based on a capital-simulation vintage model developed elsewhere (Clark 1980, 1983). Employment forecasts by occupational category are also given.

In conclusion, we discuss briefly the possible 'capital-saving' nature of technical change in (micro) electronics, and the implications of such a tendency for overall manufacturing output and employment growth or displacement.

Note

[1] A theoretical analysis of the dynamics of the world microelectronics industry can be found in another work by one of the authors (cf. Dosi, 1983).

[2] Possibly document copying, duplicating and tabulating services (1980-SIC = 8395/3); hiring out office machinery (1980-SIC = 8340) and television and radio hire (1980-SIC = 8460/1).

[3] We also refer the interested reader to the accounts of the semiconductor industry by Dosi (1983), Sciberras (1978), Tilton (1971), the electronics industry by Freeman *et al.* (1982), McLean (1980), the computer industry by Stoneman (1976), Katz and Phillips (1982), overall implications of microelectronics by McLean and Rush (1978), Sleigh *et al.* (1979), and the various OECD–ICCP Reports (nos. 5 (1981), 6 (1981) and 7 (1982)).

Section I

Technological Change in the Electrical and Electronics Industries

1

THE HISTORICAL SETTING: FROM 'ELECTRICAL' TO 'ELECTRONIC'

The electrical and electronics industry has been one of the most important sources of technological advance since the end of the nineteenth century. From the historical point of view, the industry emerged as a result of the establishment of a 'cluster' of electro-mechanical technologies, following the discovery and industrial exploitation of electricity. Electrical power-generating equipment, engines, basic active and passive components (thermionic valves, cathode-ray tubes, resistors, capacitors, etc.) and industrial components (such as transducers, actuators, controls) led to the development of a cluster of industry producing capital equipment for the generation of electricity, the transformation of electricity into motion, the control of industrial processes and the transmission of information and new consumer durables (such as radios and, later, televisions). Within these clusters of electromechanical technologies, technical change proceeded at a relatively rapid rate and new products and applications emerged on a practically continuous basis.

Closely related to this rapid rate of technical change and essential to the growth of the electrical industry, demand growth was essentially boosted by five factors, namely:

(i) the straightforward substitution of electricity for steam power as a source of industrial energy;
(ii) the increasing mechanisation of production processes, augmenting both the electricity requirement per unit of output and, correspondingly, the demand for electrical capital equipment.
(iii) the development of an electricity grid for household consumption;
(iv) the introduction of new electrical consumer goods (ranging from electric lamps to radios, televisions, refrigerators, washing machines, air-driers, etc.);
(v) the development of a telecommunication network.

Considering the overall growth pattern and evolution of industrialised countries over the present century (and in particular the post-war period), it is obvious that the electrical industry has been an essential part of their dynamics and inner adjustment. The possibility of relatively high rates of growth was facilitated by the relative consistency between the patterns of change in (a) the 'technological system', (b) the productive (economic) structure and (c) social relations in the broad sense. The emergence and development of electrical technologies had the dual properties (which technical change generally presents) of increasing labour productivity, through modernisation of production, and yielding new commodities. On 'macro-social' grounds electrical technologies were an essential ingredient of the establishment of 'Taylorism' and 'Fordism' in production processes. Contextually, the wage-basket (and more generally the consumption-baskets) underwent profound changes and electricity-based commodities (radios, TVs, washing-machines, refrigerators, telephones) became major items of demand, as real wages showed a long-term rising trend.

One of the industrial counterparts of the 'Keynesian era' has been technical progress in the electrical industries (another major industry being automobiles). The economist's way of expressing the 'virtuous circle' between expansion of demand and improvements in the productive processes is by saying that technical progress roughly matched relatively high rates of growth of labour productivity with income elasticities of demand for the corresponding products well above one. On an international level, the diffusion of best-practice techniques of production and, loosely-speaking, 'American' ways of consumption throughout the OECD countries, allowed a rapid growth of international trade in both electrical equipment and electrical consumer durables. The 'foreign trade multiplier' associated with those rapidly growing trade flows contributed to fostering and/or allowing high domestic rates of growth.

It was, however, the emergence of a radically new technological paradigm based on microelectronics and the decreasing trend in income elasticity of demand for the traditional electrical consumer durables in the high-income OECD countries, which were going to have a paramount influence on the structure and dynamism of the electrical industry.

Since the first invention of the computer and the transistor in the 1940s, rapid and radical technological developments took place and led to the development of new electrical devices based on (a) semiconductor (instead of thermionic valve) technology and (b) digital processing of information. It is important to notice that as the traditional electromechanical cluster of technologies found its scientific ground in the scientific discoveries of classical physics in electricity, microelectronics has been made possible largely by the scientific development of quantum physics (and in particular that branch analysing solid state atomic properties).

In another work, one of us (Dosi 1983) has argued that the semiconductor development led to a radically new *technological paradigm*, determining a trajectory of technical progress whose essential dimensions were the miniaturisation of the electronic components, the decreasing costs per component, the increasing speed of processing of electrical signals, the increasing reliability and, in addition, a few ancillary dimensions such as electrical noise immunity, frequency range, heat dispersion, etc. Semiconductor developments, it is well known, were at the core of the microelectronics revolution affecting, to different degrees, all subsectors of the electrical industry and, more generally, the entire range of manufacturing industries. Three innovations in semiconductors were fundamental. First, the transistor (1948) (a solid-state amplifier) could increasingly substitute for thermionic valves—transistor technology could already reduce the size and the energy consumption per active electronic component. Second, the integrated circuit (1960–1) allowed the manufacturing on a single chip of a great number (from a few hundred to several thousands) of components (e.g. transistors). This is done by means of diffusing on a surface of silicon the required 'impurities', yielding the desired electrical properties of the corresponding minute area and by properly linking these areas through circuit connections. Finally, the microprocessor (1971) represented the development of an integrated circuit with such a degree of complexity as to embody a complete processing unit (i.e. a miniaturised but complete computer).

The microelectronics revolution had three fundamental consequences on user sectors. Firstly, it increased by several orders of magnitude the amount of information flow that could be processed and it reduced by similar orders of magnitude the time required to do so. Clearly, this was not just a quantitative improvement but it allowed new operations to be performed, such as the handling in real time of complex sets of information which would have been technically and/or economically unfeasible with previous technologies.

Secondly, it allowed a many-fold decrease in the cost per unit (bit) of processed information. Thirdly, and as a consequence of the previous two points, the set of potential adopters was increased enormously, together with the economic incentive to do so. These features corresponded to what is generally referred to as the *pervasiveness* of microelectronics technology.

A recent contribution by Freeman (1982) discusses at length the patterns of diffusion and the depth of impact of microelectronics throughout industrial and service sectors. As regards the factors recognised as affecting the rate of diffusion of innovation, Freeman showed that:

(i) the differential profitability of the adoption of microelectronics is generally very high;
(ii) the scale of investment related to the adoption is not very high, except when microelectronics implies a complete re-design of complex systems;
(iii) there are significant technical advantages stemming from microelectronics-based products (smaller size, lower energy consumption, greater reliability, etc.);
(iv) the environmental acceptability is very high (unlike other technologies such as nuclear energy);
(v) from a behavioural point of view, a relatively fast change in the economic agents (entry of new companies and other new 'Schumpeterian' spin-offs) provides a very conducive environment for the diffusion of microelectronics.

Let us briefly illustrate some of these points. Table 2 shows the price index of semiconductors for the United States until 1976. The decrease in unit *current* prices has

Table 2: US Indices of shipments, productivity and prices in the semiconductor industry —1958-76 (1972 = 100)

	S_p	S_c	$VA_{m\text{-}h}$	$P_{m\text{-}h}$	I
1958	.5	9.3	36.8	1.8	2114.0
1963	4.6	25.4	41.5	8.1	555.6
1964	6.7	26.5	45.5	12.5	392.8
1965	11.3	33.7	47.0	17.6	298.4
1966	19.6	41.5	48.4	24.5	215.4
1967	21.9	42.2	47.5	26.1	192.7
1968	31.8	48.7	51.9	35.4	152.9
1969	49.5	58.2	52.3	43.8	117.5
1970	45.1	55.5	59.2	46.6	123.0
1971	50.0	59.1	81.2	71.8	118.2
1972	100.0	100.0	100.0	100.0	100.0
1973	158.5	134.9	107.3	120.4	85.1
1974	189.9	159.2	115.3	123.0	83.8
1975	172.3	121.2	140.8	203.3	70.3
1976	249.5	165.4	161.1	235.9	66.2

S_p = Shipments at constant prices
S_c = Shipments at current prices
$VA_{m\text{-}h}$ = Value Added per man-hour of production worker (at current prices)
$P_{m\text{-}h}$ = Productivity per man-hour of production worker (estimates)
I = Price index of semiconductor output.

Source: Calculated on the basis of data from the US Department of Commerce, *Census of Manufactures*, and *Annual survey of Manufactures*, various years. Own elaboration for the price index and value added deflation. For the procedures, see Dosi (1983).

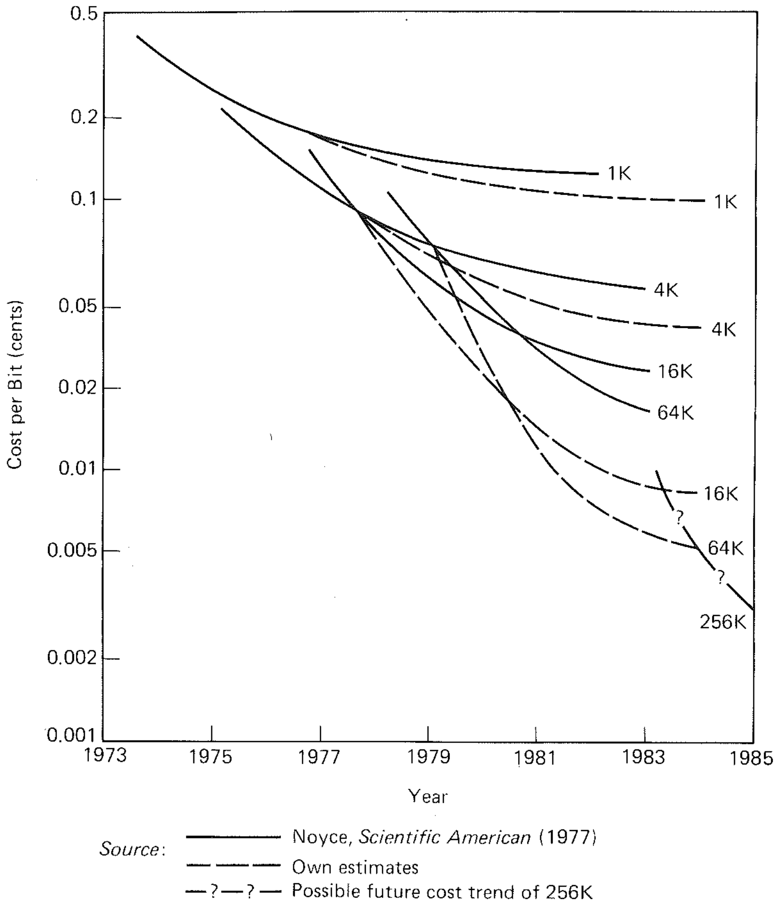


Figure 2: Semiconductor memory cost per bit

occurred at an average of 16 per cent per year. The diminution of real unit prices (in terms of the GDP deflator) is some 5 per cent higher than that value. Moreover, it should be emphasised that the index is not hedonic and in particular does not account for the increasing number of logical units per circuit. Figure 2 shows the trend in costs per logical unit in semiconductors. The decline of the cost per bit (binary digit) of random-access-memory (RAM) has been phenomenal: since 1970 at an average rate of more than 35 per cent per year. Figure 2 also illustrates the fact that if anything, the predictions made about the likely evolution of the cost of RAM, particularly 16K and 64K, when the diagram was initially published in 1977, were too pessimistic, rather than too optimistic; the dotted lines indicate our own estimates of the actual cost per bit for the 16K and 64K RAM. The increase in 'K' indicates that the dramatic decline in cost per bit has been accompanied by a continuous further integration of the number of bits into an integrated circuit: from 256 bits to 1,024 bits or 1K in the early seventies, to 4K (4,096 bits), 16K (16,384 bits) and the present 64 or 65K (65,536 bits). So-called 'sampling' of 256K (262,144 bits) is currently under way in both Japan and the United States and one expects that by 1987 sales of 256K dynamic RAMs will have achieved their peak.

In Figures 3 and 4 and the underlying Tables 3 and 4, two different sets of *computer*[1] performance indices are represented. Figure 3 and Table 3 represent just one performance

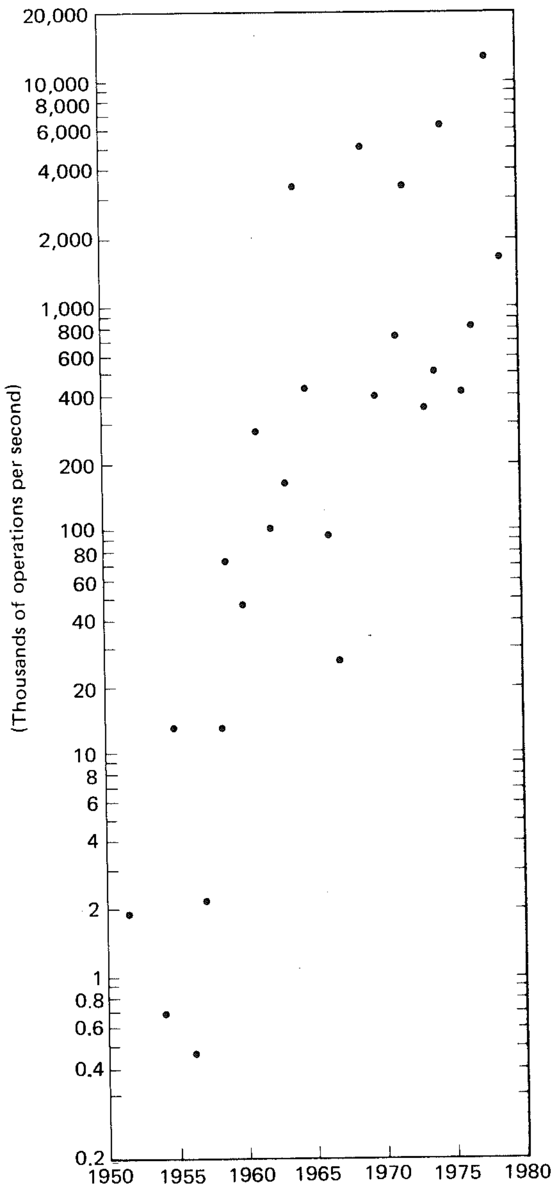


Figure 3: Maximum addition rate for computers introduced in each year. *Source*: See Table 3

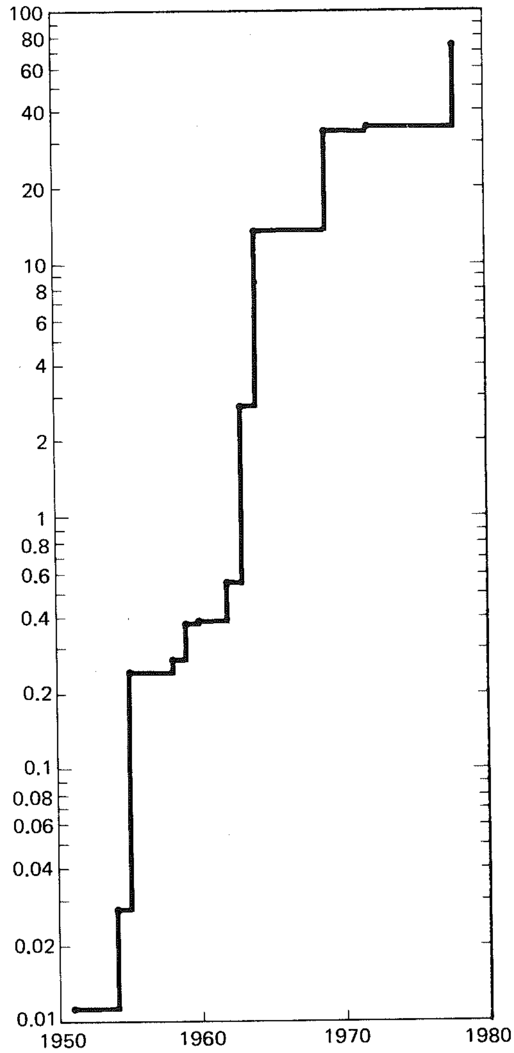


Figure 4: Computer performance index. *Source*: See Table 4

Table 3: Maximum addition rate for computers introduced in each year—1951–79

Computer	Year of introduction	Addition rate (thousands of operations per second)
UNIVAC U1	1951	1.90
IBM 650	1954	.69
IBM 704	1955	13.89
CDC LGP-30	1956	.44
UNIVAC U2	1957	2.27
IBM 709	1958	13.88
IBM 7090	1959	76.30
CDC 1604	1960	46.30
IBM 7030	1961	285.70
IBM 7094	1962	100.00
CDC 3600	1963	166.70
CDC 6600	1964	3,333.30
UNIVAC 1108	1965	434.80
IBM 360/44	1966	100.00
BGH 3500	1967	26.70
BGH 6700	1969	5,000.00
DEC PDP-11	1970	416.60
IBM 370/165	1971	714.30
UNIVAC 1110	1972	3,333.00
DEC 11-40	1973	352.00
HP 21MXM	1974	526.30
IBM 370/168	1975	6,250.00
IBM S1/5	1976	413.20
IBM 370/148	1977	807.80
IBM 3033	1978	12,500.00
IBM 4341	1979	1,667.00

Source: The Futures Group, Glastonbury, Ct., preliminary report to the Science Indicators Unit, National Science Foundation, August 1980, quoted in Science Indicators—1980.

variable applicable to computer technology: the number of *addition* commands per second, including memory access, for the 'best' computer introduced to the market in each year.

Figure 4 shows the result of using a 'composite' performance index, developed in Table 4. This index is based on a combination of three performance variables: computer speed; cost per operation and memory capacity. The actual equation used for developing this index is given in Table 4. Figure 4 illustrates the result of using this 'composite' performance index for those computers with a higher index value than any previously introduced ones. The picture emerging from Figures 3 and 4 (both on semi-logarithmic scales) shows the dramatic increase in computer performance over the last three decades, with the development of second (1959) and third (1964) generation computers and the subsequent 'incremental' improvements in integrated circuits, memory organisation and access.

Table 4: Performance indices of computers with higher indices than any previous computer, by year of computer introduction—1951–78

Computer	Year	Speed (Kops/sec)	Cost (Kops/$)	Capacity (Kbytes)	Index
UNIVAC U1	1951	0.27	7	8	0.011
IBM 650	1954	0.29	45	20	0.027
IBM 704	1955	3.79	50	192	0.246
IBM 709	1958	10.23	91	192	0.265
IBM 7090	1959	45.47	443	197	0.378
CDC 1604	1960	20.40	374	256	0.381
IBM 7094	1962	95.90	842	197	0.526
CDC 3600	1963	74.90	849	2,048	2.731
CDC 6600	1964	4,090.00	33,988	1,280	13.694
BGH 6700	1969	8,886.00	81,540	6,144	34.170
CDC CYB/76	1972	10,220.00	38,632	5,770	35.479
IBM 3033	1978	19,019.00	65,932	16,384	72.675

State-of-the-art factors

Factor	Units	Weight
X_1: Speed	Kops/sec	$K_1 = 0.5$
X_2: Cost	Kops/$	$K_2 = 0.3$
X_3: Capacity	Kbytes	$K_3 = 0.2$

$$\text{Index} = 100\left[K_1\left(\frac{X_1}{X_1^*}\right) + K_2\left(\frac{X_2}{X_2^*}\right) + K_3\left(\frac{X_3}{X_3^*}\right)\right]$$

X_1^* = minimum value of the parameter
X_1^* = 19,019 Kops/sec (IBM 3033)
X_2^* = 739,300 Kops/dollar (HP21MXM)
X_3^* = 16,384 Kbytes (IBM 3033)

Source: The Futures Group, Glastonbury, Ct., *Research into Technology Output Measures*, Report to the Science Indicators Unit, National Science Foundation, November 1980, p. 123, quoted in Science Indicators—1980.

If one compares these price and performance trends with the corresponding trends in valve-based and more generally electromechanical components and devices, it should come as no surprise that the economic incentive to substitute microelectronics for traditional technologies has been extremely powerful. All this in addition to the quite independent trend of microelectronics to create new products and/or improve upon the performance characteristics of existing products.

Thus, in the sample of electrical and instrument engineering establishments surveyed by Northcott and Rogers (1982), more than 50 per cent were using microelectronics in their products and 60 per cent in their processes, while the overwhelming majority of non-users were seeing some future possibility of application. Significantly, among the advantages of microelectronics most often cited by the same sample were better control of production processes, better quality products, more efficient use of labour, greater speed of output, lower production costs and more efficient use of capital, materials and energy.

Elsewhere, one of us (Dosi, 1983) has put forward the hypothesis that in general microelectronics-based techniques[2] are *superior* to traditional (electromechanical) techniques for every income distribution.[3] As a consequence, one is observing today a dual process of diffusion of microelectronics within the set of potential adopters and the rapid expansion of that set itself. The diffusion process is, however, deeply inter-linked with technical progress in the semiconductor industry itself, in software 'written' into the components and applicative software, and in the user-industries. The process is far from completed, but as Table 5 shows, the introduction of semiconductor components has already gone quite far. In many respects, microelectronics diffusion induces new 'technological complementarities' and 'technological imbalances' akin to those suggested by Rosenberg (1976). These complementarities and imbalances are a powerful vehicle for further technical change.

Table 5: Domestic integrated circuits market as a percentage of electronic domestic production—1978

	Japan	United States	Western Europe
Data processing	5.4%	3.6%	3.2%
Information technologies	4.2%	2.4%	1.3%
Measurement, control and regulation instruments	4.1%	1.8%	1.9%
Energy technologies	0.6%	1.0%	0.5%
'Brown' goods (a)	3.8%	2.5%	3.2%
'White' goods (b)	0.7%	0.7%	0.2%
Automative electronics	0.3%	2.8%	0.4%
Leisure electronics (c)	4.5%	3.9%	2.9%
TOTAL	3.3%	2.4%	1.7%

(a) Televisions, hi-fis, etc;
(b) Washing machines, refrigerators, etc;
(c) Electronic games, etc.

Source: Siemens, quoted in Schenk (1981).

The emergence of a new technological paradigm, first in terms of the establishment of a cluster of electro-mechanical technologies in the late nineteenth century and later in terms of the so-called microelectronic revolution, has been contextual to the emergence of new companies, both in electrical engineering, electronics and the new areas opened up by microelectronics (computers, software, industrial controls, electronic instruments, computer-aided design, etc). Whereas the establishment of the electromechanical technologies has been associated with the emergence of a quite stable international oligopoly, composed of a rather small number of highly diversified and international firms,[4] the 'microelectronics' revolution has been a factor of paramount importance in the first major disruption of the international electrical oligopoly since the beginning of the century. Indeed, while the emergence of the electromechanical sector was accomplished by rapid technical change and the emergence of new products and applications, the pattern of progress appears to have been cumulative and less disruptive in a way which has allowed a relative stability in the 'pecking order' between countries and firms. Firms diversified through most of the spectrum of electrical technologies and were able to sustain a relatively high rate of technical progress and new product developments, exploiting both the 'synergies' between different electromechanical areas and economies of scale. One can think of firms like Siemens in Germany and General Electric, Westinghouse and RCA in the United States.

In relation to the microelectronics revolution, the big electromechanical companies (especially the American ones) originated a substantial number of the fundamental innovations in microelectronics;[5] however, new 'Schumpeterian' firms were the most successful in exploiting them and producing further advances. The case of the so-called 'Fairchildren' (the spin-offs from Fairchild), Zilog, Mostek, AMD, Intel, etc. in semiconductors; DEC, Amhdal, Apple, etc. in minicomputers, are the best known out of a rather large group of mainly American, new-born companies which built their impressive growth on innovative dynamism. In Europe such a pattern, with a few exceptions, did not occur.

Overall though, the 'microelectronics revolution' has tended to devalue the old stock of experience and technical expertise in several areas of electromechanical technology, threatening the technological advantages of the established firms based on appropriation and internalisation, which represented one of the structural grounds of stability of the international electromechanical oligopoly.

The pattern of economies of scale has also been changing. While dynamic economies (learning-by-doing, etc.) and static economies of scale are important in standard semiconductor manufacturing, in mainframe computers, in electronic telecommunication equipment and generally in most electronic activities, the economies of scale in electromechanical assembly have declined in importance.

All these factors represent in many ways the technological determinants of a disintegration of the traditional electromechanical oligopoly and the slow rise of a new electronic one, based on inter-linkages and synergies in production, application and interfaces of microelectronics technologies. Obviously, the major actors in the old oligopoly have tried with differing degrees of success to face the new challenge (one can think of Philips, Siemens, Olivetti, and the big Japanese companies), but there is little doubt that at the end of the process new companies will have joined the major group of electronic producers. The suggestion underlying this picture is that one is presently witnessing the switch from an old technological paradigm to a new one, opening dramatic new possibilities of change in the international structure of supply, the relative technological position between countries and the pattern of international competitiveness.[6] In the electrical industry, and despite two world wars, these conditions have not occurred since the turn of the century. Reintegration around the new technology, however, is not a univocal process and is coupled with the emergence of a great number of specialised companies. Both dynamics of 'Smithian' specialisation in new activities, on the one hand, and the integration of new or reformed oligopolies around differential capabilities of mastering microelectronics and its interfaces on the other hand, are in many ways complementary processes.

Notes

[1] The most important semiconductor user industry.

[2] It is interesting to note that quite often microelectronics-based products are an equipment input into 'downstream' productive activities so that, for example, the microprocessor is a product for the semiconductor industry but an input into computers, industrial controls, etc. On the other hand, the latter are inputs in other manufacturing activities.

[3] See a more rigorous definition of univocal 'superiority' of one technique in Dosi (1982).

[4] On the history of this oligopoly, see Passer (1953), Newfarmer (1979) and Freeman (1974).

[5] For a more detailed analysis, see Braun and MacDonald (1978). Golding (1971), Dosi (1983).

[6] For an argument along these lines in relation to the future of 'newly industrialising countries', see Soete (1983).

2

THE UK INDUSTRY: ITS TECHNOLOGICAL PERFORMANCE

(a) In terms of expenditure on research and development

The strength of a technology-dependent industry, such as the electrical engineering industry, is largely based on its engineering R & D. In terms of research and development for instance, the amount spent by the private electrical engineering sector outstrips by far its total investment expenditure. This is, as Table 6 illustrates, in the first instance the result of the heavy commitment to research and development of the electronics industry.

Table 6: R & D expenditure carried out within private industry and financed by private industry and total net capital expenditure (£ millions, current prices)

	1968	1972	1975	1978
Total electrical engineering (Order IX)				
R & D expenditure	148.6	193.9	315.1	680.4
Company funded R & D	104.4	111.2	166.7	348.8
Total net capital expenditure	92.9	121.7	222.4	406.4
– *Electronics* (MLHs 363 to 367)				
R & D expenditure	116.7	160.3	250.6	591.1
Company funded R & D	73.2	84.2	113.3	278.9
Total net capital expenditure	42.4	57.7	119.4	227.9
of which *electronic computers* (MLH 366)				
R & D expenditure	23.0*	27.8	50.4	125.3
Company funded R & D	17.1*	19.0	42.6	103.7
Total net capital expenditure	6.0	6.7	11.7	36.4
– *Other electrical industries* (MLHs 361, 362, 368, 369)				
R & D expenditure	31.9	33.6	64.5	89.3
Company funded R & D	31.2	27.1	53.5	69.8
Total net capital expenditure	50.5	64.0	103.0	178.5

* 1969

Source: *Business Monitor* MO14, Table 7 for R & D Data, Table 6 for Private Industry funded R & D; 1968 and 1972: R & D Expenditure, *Studies in official statistics* No. 21 and 27 *Business Monitor* PA 1002 for Investment data.

In electronics *privately funded* R & D surpasses even total investment expenditure, the 1975 recession being the one exception. This is even more so for electronic computers, where privately-funded R & D expenditure is on average more than three times higher than total net capital investment.

The commitment to R & D in the electronics industry is also evident from the R & D/ Gross trading profits ratio, which stood in 1968 at no less than 68.5 per cent (compared with 20.5 per cent for the other 'electrical' industry), reflecting the need for electronic firms to invest a large proportion of their profits in order to remain competitive and to keep apace with the rapid rate of technological change in the industry.

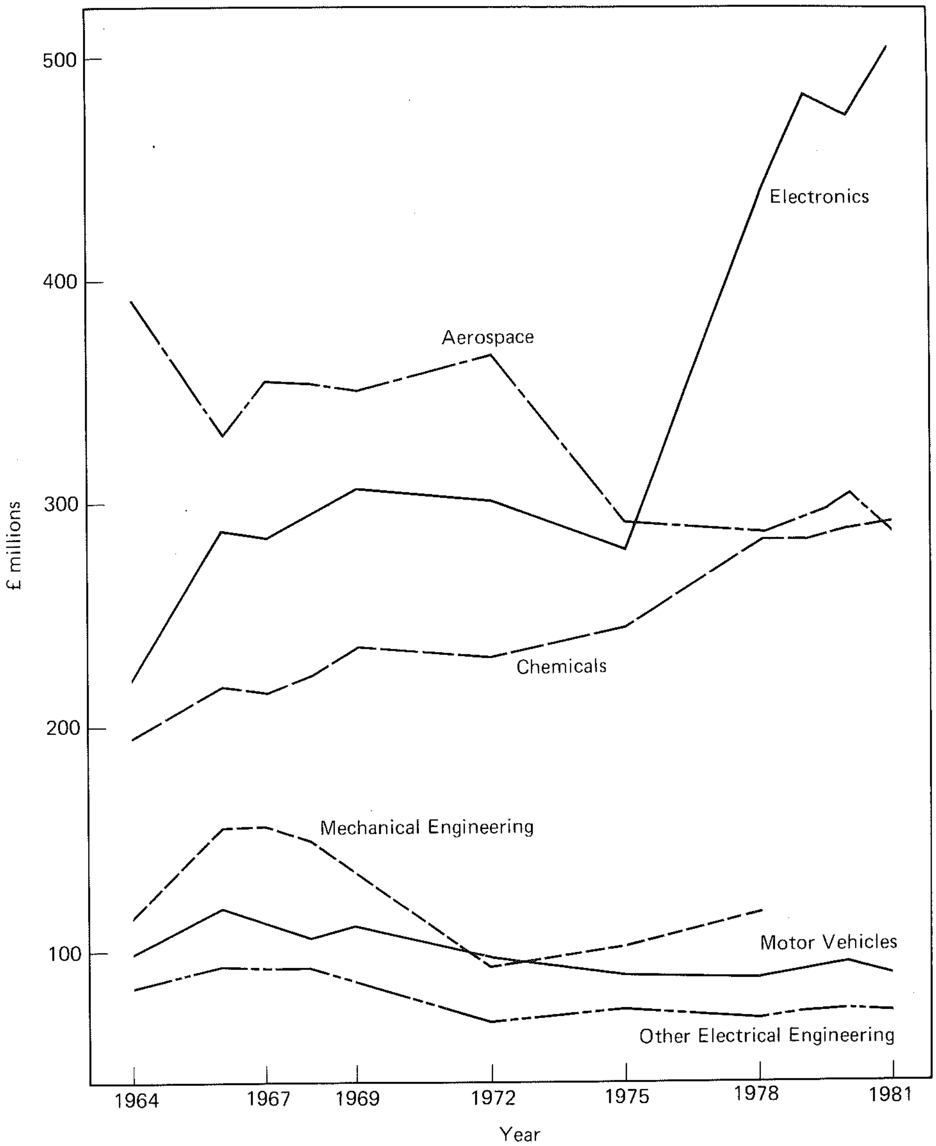


Figure 5: UK expenditure on R & D performed in industry (1964–81: constant 1975 prices)

Total industrial research and development expenditure on electronics has indeed shown a remarkable growth, since statistics were first collected in 1958. As indicated in Table 7, while the deep recession of 1975 led to a fall in the amount spent on electronics R & D in real terms, the figures for the most recent years show a stronger commitment to R & D, despite the deepening of the recession. More than 12 per cent of gross output (sales) is now devoted to R & D in the electronics industry (more than 16 per cent in the electronic computer sector). Figure 5 compares the evolution of electronics and electrical R & D (in constant 1975 prices) with other broad industrial sectors. Electronics is now by far the most important sector in terms of total R & D expenditure. Since 1975 it has overtaken aerospace as the most important R & D sector. It now (1981 figures) represents more than 30 per cent of total UK R & D expenditure.

However, as already indicated in Table 6, the largest part of electronics R & D work carried out within the private sector is government-funded. Government funds for electronics R & D have increased at a more rapid rate than private industry funds. The present share of government funding in the electronics industry stood in 1978 at 53 per cent and has shown a steady increase since 1968. More than 90 per cent of this relates to Defence. Table 8 provides some information for the Defence content of total government spending and some estimates for Defence spending in the electronics industry. These figures point towards the overriding importance of the 'military' factor in government support in the United Kingdom for electronics R & D. This emerges even more clearly from the broad international comparisons attempted in Tables 9 and 10.

Table 9 compares total UK R & D expenditure in the various engineering subsectors with similar figures for some of its major industrial competitors. All figures are in million US dollars at 1975 prices and at 1975 'purchasing power parity' exchange rates. In terms of total R & D carried out within the business enterprise sector, the United Kingdom performance in electronics and computers compares relatively well with its major industrial competitors; in computers, it even outstrips Japanese growth in R & D expenditure. The most striking feature is the slow growth, and very often decline, in the other parts of the engineering sector, which seems to be the major cause for concern (particularly the decline in instrument R & D, in which the United Kingdom has lost its comparative lead over Japan, Germany and France, which it still held in the early seventies).

Table 10 compares in a similar way *privately funded* R & D (own funds)[1] expenditure in the United Kingdom and the major OECD countries for the same engineering subsectors. The picture emerging from Table 10 puts much of the optimistic trend in electronics R & D in perspective. While privately-funded R & D expenditure in the UK electronics industry has remained practically constant over the seventies (only electronic computers have witnessed rapid growth), it has been growing rapidly in other countries. The United Kingdom private industry now spends less on electronics R & D than France or any other of its major industrial competitors.

Some of the official R & D data available also provide a clue as to the diffusion of 'electronics' research. Thus, as indicated in Table 11, of the £279m spent on R & D in electronics in 1975,[2] £27.8m came from firms having their principal activity outside manufacturing (primarily communications). Within manufacturing, instrument engineering firms spent more than half of their total R & D (£36.7m) on 'electronics' (£19.9m), illustrating in many ways the point raised in the introduction about the increasing tendency towards 'electronification' of parts of the instrument engineering sector.

Table 7: Industrial expenditure on R & D in the UK: electronics and electrical product groups

	1958*	1961	1964	1966	1967	1968	1969	1972	1975	1978	1979	1980	1981
Electronics (MLHs 363 to 367)													
£ million—at current prices	24.6*	55.2	78.1	111.6	114.7	127.9	141.1	179.0	279.0	650.2	824.9	970.4	1145.1
—at constant 1975 prices	n/a	n/a	221.9	287.6	285.1	296.8	308.5	301.5	279.0	441.9	484.7	475.2	508.2
—of which non-Government funded	n/a	n/a	115.4	166.8	156.8	184.0	188.2	162.8	133.9	198.6	n/a	n/a	n/a
In %—of total UK R & D	8.3	n/a	16.3	19.6	19.3	20.3	21.1	22.2	21.6	29.1	30.9	30.1	31.9
Electrical (MLHs 361, 362, 368, 369)													
£ million—at current prices	39.9*	39.6	28.9	37.0	37.6	39.7	39.5	40.1	73.0	101.0	123.3	148.5	163.4
—at constant 1975 prices	n/a	n/a	82.3	93.3	91.8	91.4	85.0	67.9	73.0	68.6	71.5	72.2	71.5
In %—of total UK R & D	13.4	n/a	6.0	6.5	6.3	6.3	5.9	5.0	5.6	4.5	4.6	4.6	4.5

*The 1958 figures for electronics do not apparently include MLH 363, telecommunications, which are included in the electrical figure.

Source: 1958–1978: Business Monitors MO14, and CSO, Studies in Official Statistics No. 21 and 27
1979–1981: CBI

Table 8: Industrial R & D expenditure in the UK by source of funding and application: civil or defence (£ millions)

Year	TOTAL INDUSTRY					ELECTRONICS				
	Total	Company Funded	Government Funded			Total	Company Funded	Government Funded		
			Total	Of which Defence	Of which Civil			Total	Of which Defence	Of which Civil*
1955	187	60	127	118	9	n/a				
1958	266	112	154	142	12	24.6				
1961	378	223	155	n/a	n/a	55.2	n/a	n/a		
1964	493	313.6	165.2	n/a	n/a	78.1	40.6	37.5		
1966	585	392.9	170.6	151	19.6	111.6	64.7	46.9		
1967	611.5	410.2	178.0	131	47.0	114.7	63.1	51.6		
1968	648	427.0	191.5	124	67.5	127.9	79.3	48.6		
1969	694	444.8	216.5	129	87.5	141.1	86.1	55.0		
1972	838.5	507.2	277.3	n/a	n/a	179	96.7	82.3		
1975	1352.3	853.3	505.7	369.7	136	279	133.9	145.1	n/a	n/a
1978	2341	1475.7	797	646.1	150.9	650.2	338.4	311.8	300.7	11.1
1979	2673.5	1593.0	1080.5	875.3	205.2	824.9	387.7	437.2	421.7	15.5
1980	3518.7	2134.4	1384.3	1146.3	238	970.4	456.1	514.3	483.3	31.0
1981	3943.3	n/a	n/a	n/a	n/a	1145.1	538.2	606.9	n/a	n/a

* These figures refer to 'Electrical, electromechanical and electronic engineering' in the Tables classifying government expenditure on R & D by EEC objective, and are consequently probably an overestimation of the 'electronics' government *civil* funding component.

Source: As in Table 7 and *Economic Trends*, August 1982 and September 1983 for government funded and defence R & D.

Table 9: Absolute level of resources devoted to R & D in the engineering industry: major OECD countries: 1970 and 1979 (in million 1975 ppp/dollars)

	United States			Japan			Germany			France			United Kingdom		
	1970	1979	1970–79 Average Annual Growth Rate	1970	1979	1970–79 Average Annual Growth Rate	1970	1979	1970–79 Average Annual Growth Rate	1970	1979	1970–79 Average Annual Growth Rate	1969	1978	1969–78 Average Annual Growth Rate
Aerospace	7,172	6,573	−0.97	—	—	—	286	387	3.4	556	733	3.1	831	782	−0.7
Electrical	2,134	2,152	0.09	533	824	4.8	1,147	1,683	4.3	575	125	3.8	187	171	−1.0
Electronics	3,673	3,773		680	1,077	5.1					685		558	859	4.8
Sub-total: electrical engineering	5,807	5,925	0.2	1,213	1,901	5.0	1,147	1,683	4.3	575	810	3.8	745	1,030	3.6
Instruments	1,018	1,592	5.0	49	237	7.5	61	127	8.1	30	40	3.2	90	64	−3.8
Machinery	2,382	1,503	6.6	430	571	3.2	310	988	12.9	160	287	−0.7	256	201	−2.7
Computers*		2,800		137	228	5.7				146			122	265	8.6
Motor vehicles	2,184	3,449	5.6	465	1,142	10.0	600	841	3.8	263	434	5.6	259	239	−0.9
Shipbuilding		—		98	204	9.0	4	13	13.1	5	4	12.2	25	34	3.4
Other		118			16						11		—	—	—
TOTAL 'BERD' (Business Enterprise R & D)	24,817	29,475	1.9	4,892	8,161	5.7	4,081	6,678	5.5	2,713	3,681	3.4	3,599	4,275	1.9

* includes office machinery

Source: Calculated from OECD Science and Technology Indicators, DSTI/SPR/81.27
Table 2.39 and Annex 1, Tables 29, 45 and 46

Table 10: Absolute level of private resources devoted to R & D in the engineering industry (own funds only, in million 1975 ppp/dollars)

	United States			Japan			Germany			France			United Kingdom		
	1970	1979	1970–79 Average Annual Growth Rate	1970	1979	1970–79 Average Annual Growth Rate	1970	1979	1970–79 Average Annual Growth Rate	1970	1979	1970–79 Average Annual Growth Rate	1969	1978	1969–78 Average Annual Growth Rate
Aerospace	1,669	1,777	0.70	—	—	—	3	32	26.30	135	230	5.92	25	146	19.61
Electrical	2,758	3,416	2.38	525	816	4.90	963	1,428	4.38	286	110	6.88	173	136	−2.76
Electronics				675	1,064	5.06					421		298	294	−0.15
Sub-total: electrical engineering	2,758	3,416	2.38	1,200	1,880	4.99	963	1,428	4.38	286	531	6.88	471	429	−1.04
Instruments	750	1,422	7.11	111	232	8.19	53	111	8.21	n/a	31	—	72	51	−3.83
Machinery	2,023	1,165	6.01	419	560	3.22	230	876	14.86	n/a	212	—	203	178	−1.46
Computers*		2,311		140	224	5.22							67	140	8.19
Motor vehicles	1,754	2,903	5.90	463	1,136	9.97	549	802	4.21	252	416	5.57	258	210	−2.29
Shipbuilding		—		92	152	6.70	—	5	—	2	3	20.8	9	22	9.93
Other		79			16		—	5	—		10		—	—	—
Privately Funded BERD	14,146	19,748	3.55	4,819	7,998	5.63	3,285	5,309	5.33	1,736	2,614	4.55	2,303	2,693	1.74

* includes office machinery

Source: as in Table 9

Table 11: R & D Expenditure in electronics and electrical engineering by principal product of the enterprise—1975 (in £ million)

Principal Product of the firm \ Product Group	Electronic Computers	Other Electronics	Electrical Generating Machinery	Other Electrical	All Product Groups
Mining	—	0.1	—	—	13.4
Food, Drink & Tobacco	—	—	—	—	63.4
Petroleum Products	—	—	—	—	22.5
Pharmaceuticals	—	—	—	—	48.8
Plastics	—	—	—	—	3.4
Other Chemicals	—	—	0.1	—	167.6
Metal Manufacture	—	—	1.0	—	38.5
Mechanical Engineering	0.7	0.6	0.1	0.3	45.3
Instrument Engineering	3.7	16.2	—	0.8	36.7
Electronics	45.7	179.3	13.8	30.5	305.8
Electrical Generating Machinery	—	0.3	11.6	—	13.5
Other Electrical	—	0.4	—	6.1	31.3
Motor Vehicles	—	0.2	0.1	—	76.2
Aerospace	—	2.0	—	1.0	276.2
Ships	—	—	—	—	2.5
Metal Goods	—	0.1	—	0.1	10.9
Textiles and Clothing	—	—	—	0.1	21.6
Stone, Clay and Glass	—	0.3	—	0.1	19.6
Paper and Printing	—	—	—	—	5.0
Wood and Furniture	—	—	—	—	1.1
Other Manufacturing	—	0.5	—	0.3	20.0
TOTAL MANUFACTURING	50.1	200.0	26.7	39.3	1223.9
Utilities	—	—	7.0	—	39.6
Transport, Storage	—	—	—	—	8.3
Communications	—	27.3	—	—	37.1
Banking, Insurance and other Commercial and Engineering Services	0.3	0.1	—	—	0.9
Other	—	—	—	—	16.3
TOTAL SERVICES	0.3	27.4	7.0	—	102.2
TOTAL BUSINESS ENTERPRISE SECTOR	51.0	228.3	33.8	39.4	1340.1

Source: OECD, ISY 1975 and *Business Monitor* M014, Table 11

(b) In terms of 'patenting' activity

R & D data provide, of course, only a picture of the input side of industrial innovation. While patent data are one of the most directly available, and historically reliable output indicators of industrial innovation, they are unfortunately difficult to interpret. Particularly for the most recent years, with the possibility of filing (since 1978) both a European patent with United Kingdom application and a national United Kingdom patent, comparisons over time of the number of patent applications or patents granted in electronics patent classes become rather spurious. Furthermore, a large number of the patents filed in the United Kingdom originate from abroad. As an output indicator of the technological performance of the UK electronics and electrical industry, domestic patent data consequently do not provide a very reliable picture of the technological evolution in the UK industry.

Analysis of the number of United Kingdom patents granted in the United States provides a better insight into the actual technological performance of the UK industry. Detailed comparisons of the number of 'foreign' patents granted in the United States certainly enable one to make a number of international comparability claims, to the extent that all patents have undergone a similar screening process and that the United States technology market can indeed be considered of sufficient importance in attracting all patents of a certain quality.

'Foreign' patenting activity in the United States has consequently been used on various occasions as a 'quality-patent' indicator, particularly suited for international comparisons (Pavitt, 1982, Soete and Wyatt, 1983). Table 12 provides information on the number of United Kingdom patents granted in the United States in the electrical and electronics industries over the period 1963–81. The picture emerging from Table 12 confirms the worrying trend in *privately funded* R & D and puts in perspective much of the positive *total* R & D trend given earlier.

Both in absolute terms and as a percentage of total foreign patents granted in the United States, there has been a dramatic decline in the UK position, particularly since the early seventies. As compared to the overall United Kingdom position, in terms of so-called 'revealed technological advantage' indices,[3] the electrical and electronics industries no longer represent an actual UK comparative advantage (i.e. > 1.00).

Underlying the figures in Table 12 there is a dramatic increase in patenting activity of some of the United Kingdom's major competitors, and particularly Japan.

It must be stressed again, however, that patent statistics, even allowing for the foreign 'quality' improvement, are difficult to interpret. Particularly in relation to microelectronics, with the problems surrounding the granting of software protection, patenting data might provide a misleading picture. Nevertheless, the patent data in Table 12 seem to conform to the overall specific features of the UK electronics industry: its heavy commitment to *military* electronics technology—as such less patentable—and its possible technological weakness in electronics 'hardware', in contrast to the often proclaimed 'software' strength.

(c) In terms of 'innovation' data

1. *Electronics*

A large amount of data on significant and less significant innovations, indices of technical performance (see for example Figures 2–4, and Tables 3 and 4) and other technological

Table 12: UK patents granted in the USA—1963–81

	Electrical Equipment			Office & Computing Equipment			Communication Equipment & Electronic Components		
	Number	As a % of Foreign Patents	Comparative Advantage Index	Number	As a % of Foreign Patents	Comparative Advantage Index	Number	As a % of Foreign Patents	Comparative Advantage Index
1963–65	626	21.4	1.03	201	22.7	1.09	814	28.5	1.37
1966	300	20.4	1.05	78	19.7	1.01	319	20.9	1.08
1967	286	19.4	1.00	79	18.9	0.97	326	21.6	1.11
1968	271	20.3	1.09	62	15.4	0.83	261	19.2	1.03
1969	377	20.9	1.13	102	20.9	1.13	397	20.9	1.13
1970	384	18.9	1.11	78	16.6	0.98	366	17.7	1.04
1971	472	17.6	1.13	128	17.1	1.10	456	16.6	1.07
1972	350	14.9	1.10	95	12.0	0.88	352	13.5	0.99
1973	331	13.2	1.05	87	11.7	0.93	325	11.6	0.92
1974	333	12.4	1.01	89	11.0	0.90	340	12.2	0.99
1975	294	12.5	1.04	87	11.1	0.92	344	12.3	1.02
1976	275	12.4	1.08	87	10.5	0.91	331	11.6	1.01
1977	249	10.9	.98	73	9.4	0.84	307	11.0	0.99
1978	254	10.8	.99	81	10.4	0.95	319	11.5	1.05
1979	197	11.3	1.11	56	8.4	0.83	204	9.2	0.90
1980	176	7.8	.79	84	8.9	0.90	250	5.9	0.60
1981	202	7.9	.85	79	7.7	0.83	278	9.2	0.99

Source: Office of Technology Assessment and Forecast, Patent and Trademark office, US Department of Commerce, special report for SPRU.

performance indicators exist, quite uniquely, for the electronics sector. The magazine *Electronics*, for instance publishes every year a 'Technological Update', giving an overview of what it considers to have been major technological changes in the industry.

In Table 13 we present a detailed list of key world innovations for the semiconductor industry, which classifies innovations in product and design on the one hand (Part A), and process on the other hand (Part B). Most recent years have been left out because of the time lag needed to judge the importance of an innovation.

These data, just like the previous ones on 'technological performance' point towards the continuous rapid rate of technical change in the electronics industry, which seems to show little sign of levelling off. The lack of British firms in Table 13, and the more recent 'appearance' of Japanese firms is, however, a significant feature.

From a United Kingdom perspective, these data provide insufficient information about the present technological position of UK firms and the actual diffusion and rate at which these various major innovations have been taken up in the UK. There is a widespread belief, and also some evidence, that European countries are lagging behind in microelectronics technologies. The United Kingdom seems, to that extent, no exception.

British companies are almost entirely absent from several semiconductor fields, while the outcome of the INMOS attempt to leapfrog in very-large-scale-integration (VLSI) still remains doubtful. In a few specialised areas there is a group technological base (e.g. Uncommitted-Logic-Arrays developed by Ferranti). The United Kingdom experienced in the sixties and seventies a wave of foreign (American) investment. One of us (Dosi, 1981) has argued that this will appear to yield a 'second-best' outcome in terms of both national technological strength and international competitiveness. In computers, a UK company (ICL) is one of the only two European companies to manufacture mainframe computers.[4] Despite the fact that ICL's world market share is small compared to the American (or even Japanese) giants, its presence will, however, allow a domestic participation to this rapidly developing technology.

In minicomputers, the relatively poor British performance is essentially a sign of an average technological lag and of the incapability of exploiting the 'virtuous circle' between developments in semiconductors, computers and software. In microcomputers the picture is changing rapidly from a level of relatively low competition with a significant UK position (Sinclair, Acorn, etc.) to a far more competitive market, with the entry of the Japanese and United States large mainframe computer firms. As regards electronic office equipment generally, British producers have, however, been almost entirely left out of a race involving the big American and Japanese oligopolies and a few Continental companies, such as Olivetti and Nixdorf.

In 'brown' consumer electronics the United Kingdom industry lagged behind the Japanese leaders (and also the main Continental producers) in terms of product developments, degree of integration of utilised components, automation of manufacturing process and economies of scale. However, that part of the industry which survived the Japanese competition has nearly caught up with best-practice process and product technology. As regards new consumer products (such as video-recorders), the British industry presence is rather weak, except for some Japanese assembly and some joint-venture activities between British and Japanese companies. Much brighter spots are military electronics and areas within electronic instruments,[5] where the United Kingdom remains close to the technological frontier and has produced several major world innovations.

Table 13: World key innovations in the semiconductor industry

A. *Product Innovations* *

Innovation	Firm	First Production
Point contact transistor	Western Electric (a)	1951
Planar transistor	Fairchild	1960
Epitaxial transistor	Western Electric	1960
Integrated circuit	Texas Instruments/Fairchild	1960–61
MOS transistor	Fairchild/RCA	1962
Emitter-coupled logic	Motorola	1963
Light-emitting diode	Texas Instruments	1964
TTL integrated circuit	TRW/Sylvania/TI	1964
MOS integrated circuit	General Microelectronics/ General Instruments	1965
Magnetic bubble memory	Western Electric (b)	(1968–77)
CMOS IC	RCA	1968
Schottky TTL	Texas Instruments	1969–70
CCD (charge coupled device)	Fairchild	1969
1–K MOS RAM	Intel/AMS	1969
3 transistor cell dynamic RAM (1K bits)	Intel	1971
Microprocessor	Intel	1971–72
Uncommitted logic arrays	Ferranti	1973–74
1 transistor cell dynamic RAM (1K bits)	Intel/Mostek/TI	1974
16–K MOS RAM	Intel/Mostek	1976
Micro computer (8048)	Intel	1977
64–K RAM	Fujitsu	1978

B. *Process innovations*

Innovation	Firm	Date of Introduction
Single crystal growing	Western Electric	1950
Oxide masking and diffusion	Western Electric	1950
Planar process	Fairchild	1960
Beam lead	Western Electric	1964
Ion implantation	Mostek	1970
Schottky junction	TI	1970
Integrated injection logic	Philips	1973
Plasma etching	Standard Telecom Labs (UK)	1974
Deep ultra-violet photolithography	Perkin-Elmer	1977

Source: Selected from Dosi (1983)

* There is a significant ambiguity in the classification of some innovations between either processes, products, or both. We classified as 'product' innovation whenever a specific 'new process' could be considered as strictly contextual to new products (e.g. as in the case of the integrated circuit or MOS).

(a) Western Electric, the manufacturing branch of AT & T, undertook the proper production. The product was, however, first developed at Bell Labs.

(b) First prototype in 1968; actual commercial production started only around 10 years later.

2. *Electrical engineering*

Evidence for the 'other' electrical engineering sector is limited. Table 14 provides an overview of the major technical changes in the various subsectors of the electrical industry. It can be easily seen that most of the advances in the electrical industry originate directly or indirectly from the microelectronics revolution. Other factors of change, however, are independent. Among these, certainly the major one is the emergence of power-generation equipment based on nuclear energy. Despite a rather low rate of diffusion of the new technology, essentially due to environmental and social factors, it corresponds none the less to a profound change in energy sources. Moreover, nuclear technology constitutes a major factor influencing the international structure of the heavy electromechanical industry:[6] high economies of scale and long lead-times, associated with the present stagnant rates of growth, expectation of low income elasticities of demand for electricity and the political question marks on nuclear plans in several OECD countries are inducing a re-organisation of the sector with a fast concentration process.

Other subsectors of the electrical industry underwent significant, although much less spectacular, technological advances, in fields like passive components, 'traditional' consumer goods, heavy electrical engineering, by means of the use of new materials, relatively incremental progress in electrical engines, generators, actuators, transducers, etc.

We have already hinted at the changing role of scale economies. A tentative overview of their role could be as follows:

(i) they have been increasingly important in heavy electromechanical engineering and also in some consumer products (such as white goods and TVs);

(ii) although the traditional, scale advantages in commodities which are undergoing a process of change from an electromechanical to an electronic nature (e.g. office equipment) seem to be withering, new scale advantages are emerging in electronic products, such as telecommunications, semiconductors, electronic controls, computers;

(iii) in several areas, there appear to be significant scale economies, or at least high minimum thresholds in R & D;

(iv) the overwhelming majority of electrical sectors experience 'dynamic economies' (i.e. learning-by-doing, in the strict manufacturing sense and as a somewhat cumulative process of technological learning and progress).

Notes

[1] These data consequently do not include R & D payments from *abroad*, which in a sector such as computers (including office machinery) have been important in the case of the United Kingdom. Thus, in 1978, £44.3m. was funded from abroad as compared to a total R & D figure in computers, including office machinery, of £143m. of which privately funded—own UK funds—accounted for £76m. and government-funded for £22.6m. This explains the apparent inconsistency between the UK computer figures given in Tables 9 and 10 (in 1975 $) and the figures given in Table 6 (in current £).

[2] OECD data have been used (only available for 1975) because they provide a more detailed breakdown than the *UK Business Monitor* data (Table 11).

[3] The United Kingdom share of the electrical and electronics sectors, weighted by the overall UK share of all foreign patents granted in the United States (for more detail, see Soete, 1980, and Soete and Wyatt, 1983).

[4] The other one being CII, in France, formerly a joint venture with Honeywell.

[5] See Rendeiro and Shepherd (1981).

[6] For a thorough analysis, see Surrey and Walker (1981).

Table 14: An overview of major technological advances in the non-military electrical industry

SUB-SECTORS	MAJOR TECHNOLOGICAL ADVANCES
Components	– Solid-state (semiconductor) components: integrated circuits, microprocessors, very-high-integration memories – New materials in passive components (Tantalium, ceramic, dielectric materials) – In manufacturing: automation of assembly and testing; (semiconductors): planar process, plasma etching, Ion implantation, Electron beam – New components: liquid crystal devices, magnetic bubble memories, solid-state photovoltiac cells, flat screens, optical fibers, new sensors, light-emitting diodes–(to come: superconductor components)
Data processing and office equipment	1st, 2nd, 3rd, 4th generation computers corresponding to increasing integration in components, increasing memory and processing capability; mini- and micro-computers; 'intelligent' terminals, interfaces, computer/telecommunication and computer/office equipment; word-processors; magnetic storage (to come: the 'electronic office')—Advances in software
Producer equipment and instruments	Electronic process controls, numeric controls for machine tools (NC, DNC, CNC), computer-aided-design (CAD) and computer-aided-manufacturing (CAM), robotics-laser-based instruments; electronic optical instruments; electronic microscope; electronic scanners; gas cromatography; mass spectrometers; atomic absorption spectrometers; advances in analog/digital interfaces; environment control equipment
Power generation equipment	Economies of scale in equipment manufacturing and power generation, electronic controls, nuclear energy reactors (BWR, PWR, AGR, AECL; to come (?): fast-breeder reactors)
Telecommunications	'Time-division' switching; stored-programme control computers; packet-switching; fully digital systems; transmission: improvement in coaxial cables; optical fibers; microwaves; satellite transmission. User equipment: Private Branch Exchanges (PABX); modems; multiplexors, facsimile; viewdata; Teletext.
Consumer	'Brown goods': colour TV: improvements in the product (flat screen, remote control, etc.). In manufacturing: automated component insertion; use of integrated circuits and thick film technologies; economies of scale. – increasing use of semiconductor integrated components in hi-fi equipment – new products: electronic games, digital watches, video-recorders, video discs and video players 'White' goods: refrigerators; higher efficiency products; smaller compressor units; plastic insulation – washing-machines: electronic automation of cycles; horizontal rotating drum – in production processes: partial automation in manufacturing and testing and assembly line production, exploitation of economies of scale.

3

COMPARATIVE TECHNOLOGICAL ADVANTAGES BETWEEN COUNTRIES

Technological and industrial dynamics between firms and countries are influenced by the degrees of *technological opportunity* and *private appropriability* of technological advances.[1] It is difficult to express any broad judgement on the state of these variables in the electrical and electronics industry. A few comments, however, can be made. First, it is obvious that the microelectronics revolution has enormously increased the technological opportunity in almost every sector of the electrical industry (with the possible exception of parts of heavy electrical engineering and white goods). Second, the patterns of private appropriation have undergone far-reaching changes. As often happens at the beginning of new technologies and industrial activities, the trajectories of progress are relatively uncertain and so are the possibilities for any individual firm to stabilise its technological advantage *vis-à-vis* competitors. Certainly, significant degrees of private appropriation have occurred: innovators have grown big very rapidly, quite often also enjoying relatively high oligopolistic profits. The point, however, is that radical technical progress, technological convergence between different subsectors, trial and error procedures in the innovative search, and absence of high investment requirements in several electronic technologies, have all been factors which decreased the degree of control of any one company upon the future technological developments and, thus, allowed a relatively fluid industrial structure. Finally, the private appropriability of 'software' technology remains problematic, covered only by copyright protection. This might well explain the 'spurt' of new entrants in the 'software' electronics area.

It should be clear from this whole discussion that the technology factor is of paramount importance in determining the relative competitiveness of companies and firms. Technological advantages are—to some extent—appropriated by individual companies as a differential asset *vis-à-vis* competitors. However, one should not forget the role of untraded interdependencies and context conditions in providing a conducive innovative environment for an entire cluster of companies: the most obvious example is the so-called 'Silicon Valley', where inter-firm 'synergies', flows of information, technological stimuli, etc., provide a very powerful and self-generating technological advantage.

The microelectronics revolution and the commercial exploitation of nuclear energy have been linked with conspicuous changes in the pattern of technological leads and lags between countries.

We have already mentioned that historically the international electromechanical oligopoly has been characterised by a stable German/American leadership. As regards the United Kingdom, she used in fact to occupy a relatively comfortable position of close follower and in some areas even of one of the technological leaders (e.g. in military equipment). Technological, institutional and macro-economic factors however, induced major changes in the 'technological pecking order' between countries in the post-war period. First, a process of international technological diffusion from the United States to most other OECD countries took place within the traditional electrical and electromechanical sectors (both in producer and consumer goods). The process broadly conforms to product-life cycle arguments. OECD countries, while enjoying wage rates below the American ones, had increasingly similar patterns of consumption and already had a developed infrastructure of skills, so that the virtuous circle provided by high rates of accumulation and investment (with the associated diffusion of best-practice techniques and rising productivity) led to an environment for 'creative imitation', a catching-up process and autonomous innovations. Second, a complex set of factors (including huge military and space programmes, the existence of 'bridging institutions' between pure science and technological research, scientific advance originated domestically, a dynamic industrial environment) brought about the American technological leadership in the new microelectronics technologies, and especially in semiconductors and computers. In this area, the average European technological lag almost certainly increased in the sixties and early seventies, while only in the second part of the seventies did the European countries make a more determined attempt at catching up, generally sponsored by public policies.

Third, the post-war period saw the entry of Japan as a major electrical and electronic producer. The remarkable fact about Japan's entry is that despite being a late entrant into the industry it succeeded in a fast process of imitation in *both* traditional electrical fields and the microelectronics field. Of equal importance has been the fact that Japan has been extremely swift in the diffusion of microelectronic applications in existing products and processes (e.g. TVs) and in developing new microelectronic ones (e.g. robotics, machine tools controls, video recorders, etc.). Elsewhere, Dosi (1981) has argued that the Japanese success story was primarily the result of the interplay between institutional factors (such as the strategies of Japanese companies, the nature of the 'social contract' between social groups and between them and the State) and explicit public policies (such as policies on technology transfer, controls of imports and foreign investments, and guidance on the allocation of investments via the financial system).

Fourth, the degrees of imitative/innovative success of the various OECD countries have been widely uneven, within both the electromechanical and microelectronics fields. In power-generating equipment (especially nuclear power), a small group of European countries[2] and Canada have reached a near-parity position *vis-à-vis* the United States, while others still depend heavily on American licences. In 'brown' consumer electronics, European technological levels have historically been high. However, the ability to face the mounting Japanese challenge is very uneven. Possibly only Philips (and perhaps in a few areas, Grundig) has remained on the technological frontier. Conversely in 'white' goods, the switch of trade competitiveness towards southern Europe (in particular, Italy) has been contextual to an increased Italian innovativeness in both the manufacture and development of new 'white' goods.

Fifth, newly industrialising countries (NICs) have extended electrical and electronic technologies. To some extent this has been due to the re-location of lines (or stages) of production by multi-national companies (especially in the Far East). However, an important part is played by 'autonomous' processes of technological catching-up (e.g. in Korea, Taiwan, Hong Kong, Singapore, Brazil, Spain). Elsewhere,[3] it has been argued that the transition to a new technological paradigm allows—other things being equal—a faster rate of diffusion of the new technologies in 'new' countries, due to the absence of commitments to the old technologies, in terms of investments, skills, market position in the old products, etc.

Notes

[1] A thorough account of these variables in industrial economies is in Nelson and Winter (1982). See also Dosi (1983).

[2] Especially France, Germany, Switzerland—cf. Surrey and Walker (1981).

[3] cf. Soete (1982, 1983).

4

BY WAY OF CONCLUSION: THE ROLE OF GOVERNMENT POLICY

The distinction between electronics and electrical engineering, which has been much emphasised in what has been said above, has, of course, emerged only gradually over time. Just as the growth of the electrical industry was boosted by the straightforward substitution of electricity for steam power at the beginning of this century, the growth of electronics has been boosted dramatically by the substitution of better, more sophisticated and cheaper electronic components for the older electrical ones, opening up possibilities for both better, cheaper and more sophisticated existing and totally new products. This trend is most clearly illustrated by looking at the technological change within a specific commodity. In Figure 6 the major events in the development of television, since George Carey first put forward his ideas in 1875, are depicted. The figure illustrates both the clustering of related television innovations, which occured all through the post-war period, and TV's own pattern of technical change strongly influenced by the microelectronic revolution. The saturation of most Western markets in the seventies by radios, TVs and many domestic electrical and electronic appliances, combined with a dramatic increase in competition from some late industrialisers has, however, led to a significant slowdown in both output and employment in this highly innovative sector. The result has been a much 'slimmed' industry, which appears to have caught up with world best-practice levels, but is largely composed of subsidiaries of Japanese multinationals, and only two more or less British firms.

No wonder microelectronics and the application of electronics technology have come to the forefront of Government concern and that of its policy-makers. Every country in the world now has a special electronics information or support scheme.

In the United Kingdom, apart from the heavy commitment of defence funds to electronics R & D, Government (*civil*) support for R & D in the electronics industry has been low in comparison to some of its major competitors,[1] particularly Japan, France and Germany.

The 'cornerstone' of the Government's campaign to increase the use of microelectronics in manufacturing has been the microelectronics application project (MAP). Initially financed at £15m it has been further funded by £40m, and this has been extended from November 1982 for another three years at the rate of £30m. While specific support for ICL has been stopped since 1976, INMOS was created at a cost of £25m, and a further grant of £25m in 1980. Various other schemes have been introduced in more recent times.

'CADCAM awareness', launched in 1982, is a three-year awareness scheme aimed at promoting the application of computer-aided techniques for both design and manufacture in the mechanical and electrical sectors (so far £2.5m has been allocated to capital grants). A similar three-year 'CADMAT awareness' scheme was launched in February 1982, aimed at computer-aided design, manufacture and testing in the electronics industries (so far £1.2m has been committed to capital equipment grants); 'Robot support' was launched in April 1981, providing grant aid for the manufacture or application of robotic devices (£3.9m in 1982); 'Software products', managed by the National Computing Centre, was relaunched in April 1982 (£10m for the three years up to 1985) and aims at encouraging the development and marketing of innovative software products in the United Kingdom computing services industry; the 'FMS scheme' was announced in June 1982 (budget £35m); the 'MISP'—microelectronics industry support programme—consisting of a support scheme for the development, design and manufacture of custom-made and industry-specific microchips and standard integrated circuits in the United Kingdom, was launched in June 1982 (£55m allocated); and the 'Fibre Optics scheme' was launched in July 1981 (£25m for five years, increased to £40m in December 1982), in order to support the development, launching and application of new products and processes.

At first sight there seems to be no clear overall policy in relation to microelectronics behind these various independent support schemes. They are primarily aimed at so-called 'awareness', trying to improve and speed up the diffusion of 'electronics' technology in the various manufacturing sectors rather than straightforward support for R & D as in most other OECD countries. Such a policy points, however, to a major paradox in the present 'technological paradigm'/microelectronics revolution argument. Why indeed is it that firms (and UK firms in particular) not only have to be made aware of vastly superior new microelectronic technology, but have actually to be supported in applying these technologies? This surely cannot be simply explained in terms of the traditional slowness of diffusion of major innovations. After all, much of our previous argument pointed towards the high profitability of microelectronics adoption and the relatively low levels of investment required (admittedly far higher in CADCAM, FMS and Robotics), all crucial factors in speeding up the rate of diffusion and adoption of new technologies.

There are many reasons for this apparent paradox, some of which relate to the specific UK situation, and its proclaimed overall weakness in *applying* its own invention and innovations, at which it is often said to excel. One of the major factors underlying the slow rate of adoption and the need to support the diffusion of microelectronics technologies relates in our view, however, to the overall demand situation and in particular demand expectations, heavily influenced as they are by the current recession/depression, and the changing international competitiveness environment.

The diffusion of innovations as distinct from the mere occurence of innovations is certainly a more 'demand'-determined phenomenon. Even confronted with radically more profitable new technologies, firms might well decide to postpone investment decisions, or opt for more secure, technologically more established, less risky investment in periods of low output growth. In some ways one can think of the diffusion of innovations as the 'accelerator' component of technical change; reinforcing the contribution of 'pure' or 'real' technical change in periods of rapid growth and having the opposite effect in periods of slow growth.[2]

In the following economic section we consider in somewhat more detail the economic implications of this rapid rate of technical change, as exemplified in the 'microelectronic revolution', for the performance of the UK electronic and electrical industries.

Notes

[1] For a detailed overview and a set of specific UK policy proposals, see the Electronics EDC-1982 Report, NEDO (1982).

[2] See Soete and Turner (1983) for a more formal discussion on this point.

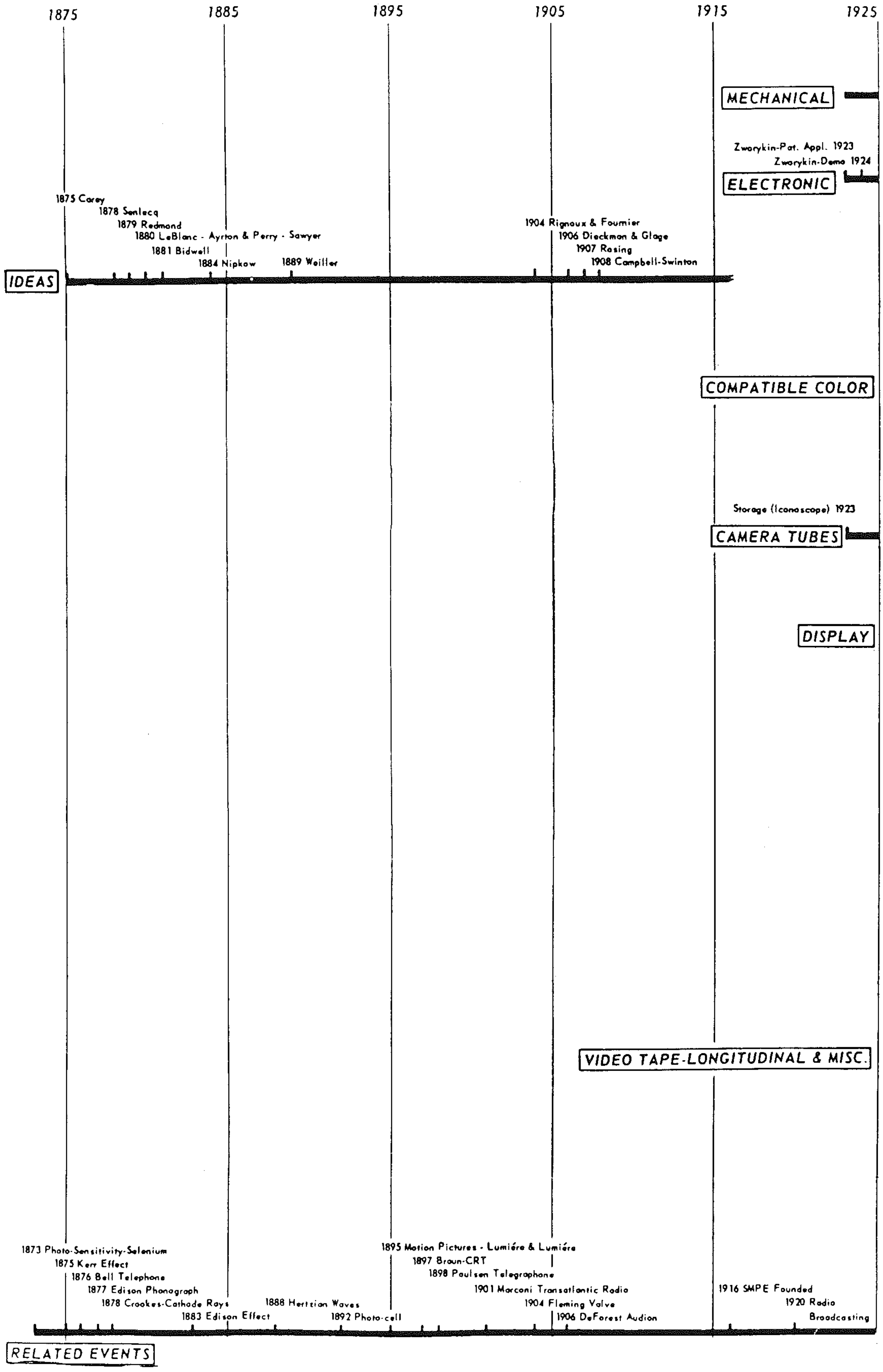
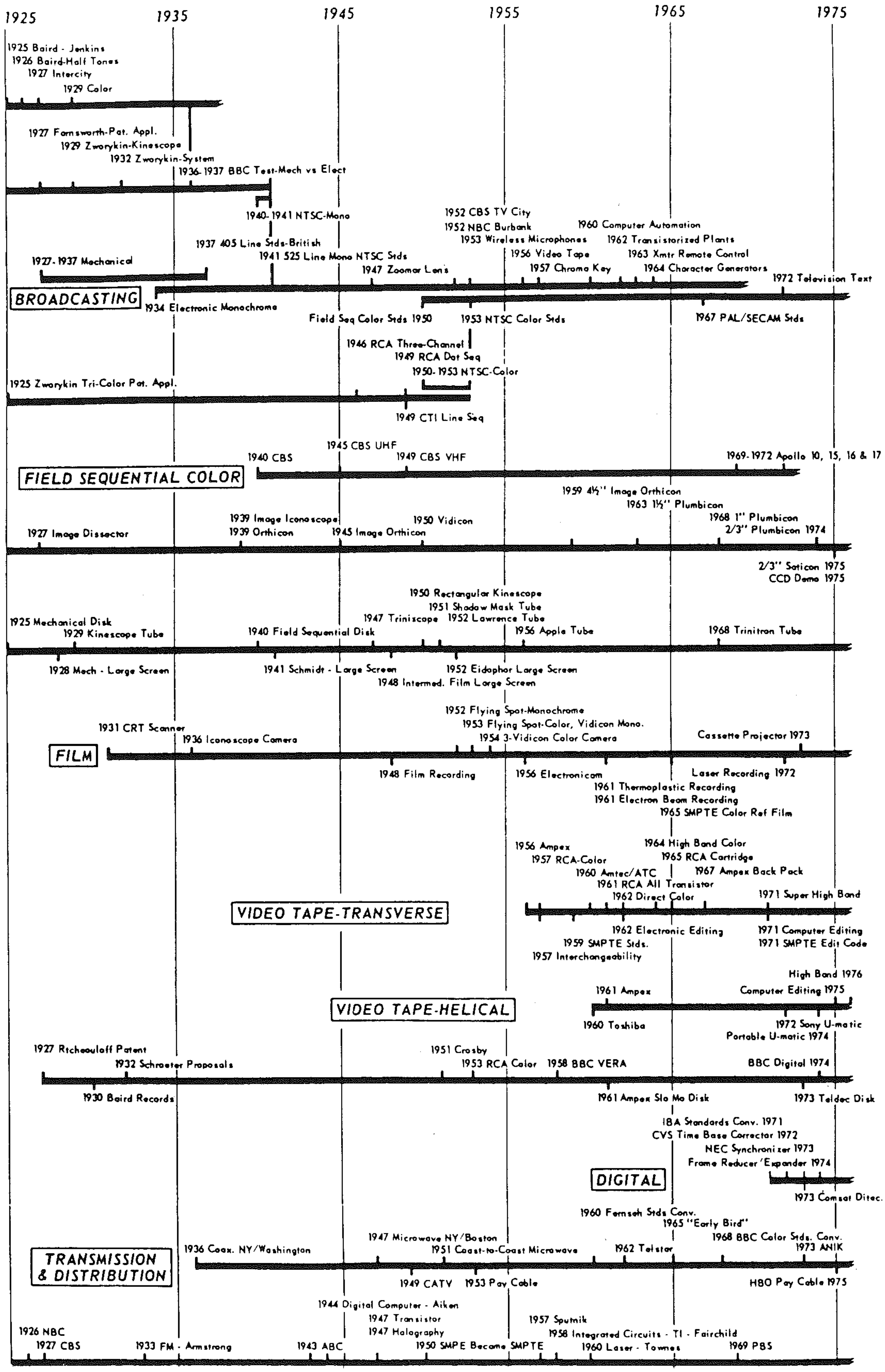


Figure 6: The development of television. *Source*: *SMPTE Journal*, Vol. 85, July 1976.



1925
1935
1945
1955
1965
1975
1925 Baird - Jenkins
1926 Baird-Half Tones
1927 Intercity
1929 Color
1927 Farnsworth-Pat. Appl.
1929 Zworykin-Kinescope
1932 Zworykin-System
1936-1937 BBC Test-Mech vs Elect
1940-1941 NTSC-Mono
1937 405 Line Stds-British
1941 525 Line Mono NTSC Stds
1927-1937 Mechanical
1947 Zoomar Lens
1952 CBS TV City
1952 NBC Burbank
1953 Wireless Microphones
1956 Video Tape
1957 Chroma Key
1960 Computer Automation
1962 Transistorized Plants
1963 Xmtr Remote Control
1964 Character Generators
1972 Television Text
BROADCASTING
1934 Electronic Monochrome
Field Seq Color Stds 1950
1953 NTSC Color Stds
1967 PAL/SECAM Stds
1946 RCA Three-Channel
1949 RCA Dot Seq
1950-1953 NTSC-Color
1925 Zworykin Tri-Color Pat. Appl.
1949 CTI Line Seq
1945 CBS UHF
1940 CBS
1949 CBS VHF
1969-1972 Apollo 10, 15, 16 & 17
FIELD SEQUENTIAL COLOR
1959 4½" Image Orthicon
1963 1½" Plumbicon
1968 1" Plumbicon
2/3" Plumbicon 1974
1939 Image Iconoscope
1939 Orthicon
1950 Vidicon
1945 Image Orthicon
1927 Image Dissector
2/3" Saticon 1975
CCD Demo 1975
1950 Rectangular Kinescope
1951 Shadow Mask Tube
1947 Triniscope
1952 Lawrence Tube
1925 Mechanical Disk
1929 Kinescope Tube
1940 Field Sequential Disk
1956 Apple Tube
1968 Trinitron Tube
1928 Mech - Large Screen
1941 Schmidt - Large Screen
1952 Eidophor Large Screen
1948 Intermed. Film Large Screen
1952 Flying Spot-Monochrome
1953 Flying Spot-Color, Vidicon Mono.
1954 3-Vidicon Color Camera
1931 CRT Scanner
1936 Iconoscope Camera
Cassette Projector 1973
FILM
1948 Film Recording
1956 Electronicam
Laser Recording 1972
1961 Thermoplastic Recording
1961 Electron Beam Recording
1965 SMPTE Color Ref Film
1956 Ampex
1957 RCA-Color
1960 Amtec/ATC
1961 RCA All Transistor
1962 Direct Color
1964 High Band Color
1965 RCA Cartridge
1967 Ampex Back Pack
1971 Super High Band
VIDEO TAPE-TRANSVERSE
1962 Electronic Editing
1959 SMPTE Stds.
1957 Interchangeability
1971 Computer Editing
1971 SMPTE Edit Code
High Band 1976
Computer Editing 1975
1961 Ampex
VIDEO TAPE-HELICAL
1960 Toshiba
1972 Sony U-matic
Portable U-matic 1974
1927 Richeouloff Patent
1932 Schroeter Proposals
1951 Crosby
1953 RCA Color
1958 BBC VERA
BBC Digital 1974
1930 Baird Records
1961 Ampex Slo Mo Disk
1973 Teldec Disk
IBA Standards Conv. 1971
CVS Time Base Corrector 1972
NEC Synchronizer 1973
Frame Reducer/Expander 1974
DIGITAL
1973 Comsat Ditec.
1960 Fernseh Stds Conv.
1965 "Early Bird"
1968 BBC Color Stds. Conv.
1973 ANIK
1947 Microwave NY/Boston
1951 Coast-to-Coast Microwave
1962 Telstar
TRANSMISSION & DISTRIBUTION
1936 Coax. NY/Washington
1949 CATV
1953 Pay Cable
HBO Pay Cable 1975
1944 Digital Computer - Aiken
1947 Transistor
1947 Holography
1957 Sputnik
1958 Integrated Circuits - TI - Fairchild
1926 NBC
1927 CBS
1933 FM - Armstrong
1943 ABC
1950 SMPE Become SMPTE
1960 Laser - Townes
1969 PBS

Section II
Employment and Economic Performance in the Electrical and Electronics Industries

5

OUTPUT AND EMPLOYMENT TRENDS IN THE UK ELECTRICAL AND ELECTRONICS INDUSTRIES

Separating out electronics from total electrical engineering only partially solves the 'heterogeneity' problem of the electrical engineering sector. Within electronics itself, both output and employment growth rates differ significantly between the electronic consumer sector, the electronic components sector and the electronic computers and capital goods sectors. The consumer sector saw an absolute decline in output over the period 1974–81 and a dramatic fall in employment over the same period; the components sector recovered from the severe output drop in 1975–76, largely at the expense of employment, while both the computer and capital goods sectors continued to display a pattern of rapid output and moderate employment growth.

Table 15 contains the output information available in constant 1975 prices for each of the MLH sectors included in the electronics industry in its narrow form, and the various 'related' MLH sectors, including computer services, while Table 16 provides information on the employment (Great Britain) levels in each of these MLH sectors.[1] Employment in the electronic consumer and component sectors has been falling significantly since 1973–74, after having witnessed a significant and steady rise since the data were first collected. Telecommunications, scientific and industrial instruments and office machinery saw their employment levels fall earlier. In these industries 'electronification' seems to have gone hand-in-hand with rapid labour displacement. Finally, the employment and output statistics available on 'computer services' illustrate the rapid emergence of that sector, growing at more than 8 per cent a year[2] and now employing nearly half the number of people employed in the 'computer manufacture' sector, MLH 366.

Unfortunately, little information in relation to output and possible deflators exists for the period prior to 1970. Figures 7, 8 and 9 represent the evolution in gross output (at 1975 prices) and employment for the total electrical engineering industry and its electronics and electrical subparts. The data underlying these figures are based on the Warwick Institute for Employment Research data for the total electrical engineering industry, and on estimates based on the value and volume indices, published by the Ministry of Aviation (Basic Statistics) for 1954–56 to 1964 for the electronics industry. For the missing years an electronics price deflator has been estimated, using the ratio of the electronic price deflator to the Warwick overall electrical engineering price deflator for the period 1954–64. The 'other electrical' industry figures have been obtained by subtracting the electronics estimates from the total electrical engineering industry.

Table 17 contains more detailed information about gross output (at 1975 prices) and the pre-1970 price-deflators used for the overall electrical sector and the electronics subsector.[3] The picture emerging from Figures 7, 8 and 9 strongly confirms the need to separate out electronics and 'other' electrical engineering. Both in terms of output and employment, the *electronics* industry has witnessed an extremely rapid growth, contrasting sharply with the electrical industry which saw its output fall at an average rate of 6 per cent over the period 1973–81. The importance of the shift from electrical

Table 15: Gross output in the electronics industry (£m in 1975 prices)

Year	MLH 338 Office Machinery	MLH 354 Scientific & Industrial Instruments	MLH 363 Telecomm-unications	1980 MLH 8394* Computer Services	MLH 364 Electronic Components	MLH 365 (2) Electronic Consumer Goods	MLH 366 Electronic Computers	MLH 367 Electroni Capital Goods
1970	196.7	648.7	527.5	n/a	702.8	293.2	349.1	878.1
1971	180.0	667.5	598.8	116.9	698.9	368.9	338.0	816.7
1972	191.6	644.1	576.1	124.5	809.2	516.8	321.9	780.9
1973	212.7	674.0	630.4	151.8	976.7	639.9	415.0	783.4
1974	214.4	729.1	619.9	163.2	1023.6	583.5	571.0	820.1
1975	203.8	749.2	603.5	163.3	782.6	494.5	554.1	852.5
1976	195.6	749.2	525.0	192.4	829.6	459.9	570.7	886.6
1977	197.7	771.7	434.5	202.9	946.9	445.1	676.0	971.9
1978	136.5	816.6	410.4	228.7	1033.0	504.4	892.1	1006.0
1979	154.9	846.6	428.5	257.7	1095.6	519.2	1318.8	1048.6
1980	142.7	809.1	513.0	269.7	1173.9	494.5	1451.7	1065.6
1981	122.3	756.7	537.1	275.9	1134.8	573.6	1401.9	1057.1
(1982)p	(128.4)	(711.7)	(513.0)	(289.8)	(1205.2)	(667.6)	(1629.1)	(1014.5)
Average Annual Growth Rate 1970–1981	−4.32	1.40	0.16	8.57	4.36	6.10	12.64	1.69
Average Annual Growth Rate 1974–1981	−8.02	0.53	−2.05	7.47	1.47	−0.24	15.58	3.63

* Billings to clients for work done, in constant 1975 prices, using the overall UK GDP-deflator

p: provisional

Source: *Trade and Industry*, *British Business*, various issues

Table 16: Employment in the electronics industry (Great Britain in thousands)

Mid-Year (June)	MLH 338 Office Machinery	MLH 354 Scientific & Industrial Instruments	MLH 363 Telecommuni-cations	MLH 3894 ** Computer Services	MLH 364 Radio & Electronic Components	MLH 365 Electronic Consumer Goods	MLH 366 Electronic Computers	MLH 367 Electronic Capital Goods
1959	32	87	53		84	27	25	62
1960	35	94	57		92	30	27	67
1961	39	100	61		93	30	28	69
1962	38	101	64		102	33	31	75
1963	37	103	67		103	34	31	76
1964	34	100	69		114	37	34	83
1965	37	104	76		112	37	34	83
1966	38	105	85		117	38	35	86
1967	33	107	87		118	38	37	89
1968	31	104	83		125	41	38	93
1969	35	102	78		134	44	41	99
1970	34	107	86	n.a.	132	44	51	96
1971	36	106	84	14.9	128	48	50	94
1972	30	101	85	15.3	127	61	50	80
1973	29	105	88	17.5	136	69	46	80
1974	30	102	87	19.5	153	63.5	44.5	86.5
1975	25	98	87	19.6	128	55	43	89
1976	23	94	73	20.7	124	50	44	90
1977	23	98	67	21.0	129	52	43	91
1978	22	97	65	22.3	128	50	46	94
1979	(23)	(97)	(63)	23.9	(128)	(45)	(49)	(95)
1980	(20)	(94)	(68)	26.2	(121)	(43)	(44)	(101)
1981 *	17	87	61	25.8	111	24.5	61	110
1982 *	16	85.5	59	24.6	108	23	60	108

* September revised figures based on the 1981 Census of Employment; ( ) unrevised figures
** Personnel Employed

Source: 'Employees in Employment Industry', *Department of Employment Gazette*
Business Monitor. SDO9 and *British Business* (14 September 1979) for Computer Services

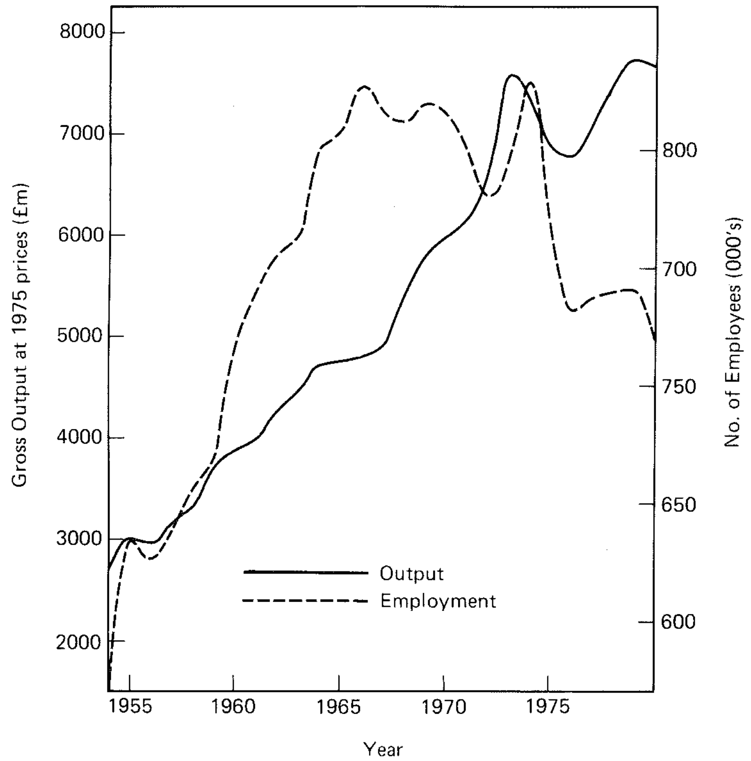


Figure 7: Output and employment in electrical engineering. *Source*: Institute of Employment Research

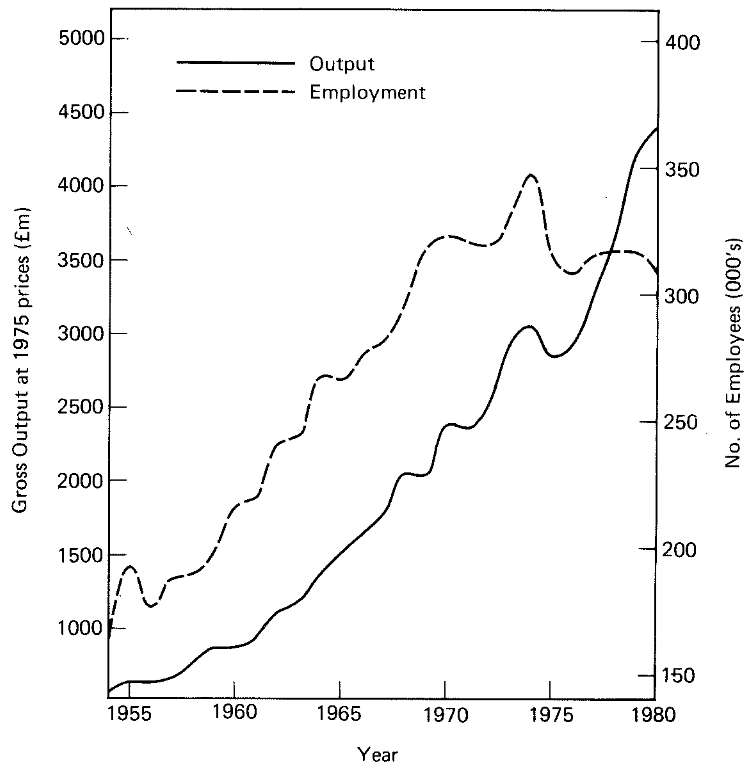


Figure 8: Output and employment in electronics. *Source*: own estimates, see text

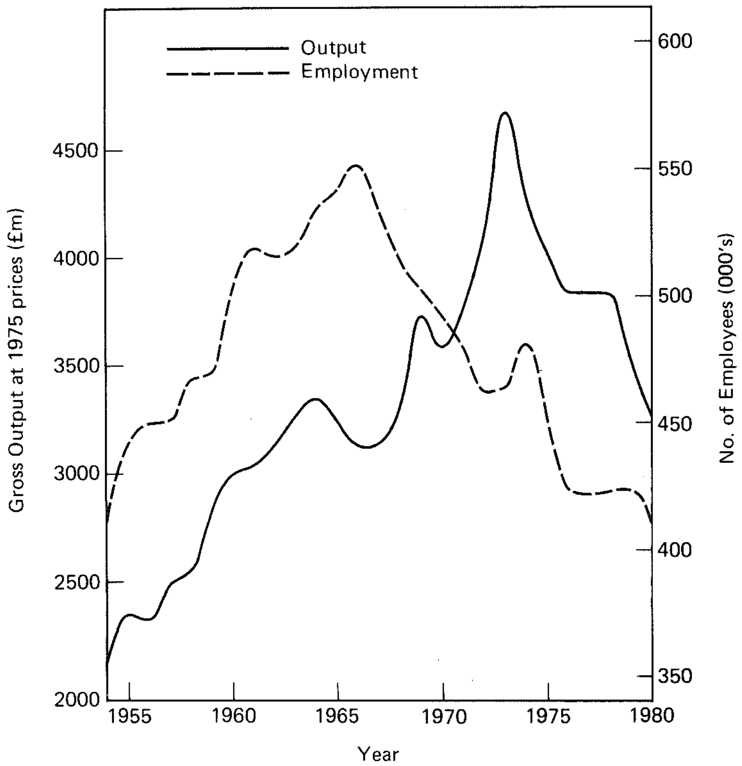


Figure 9: Output and employment in other electrical. *Source*: own estimates, see text

to electronics is most obvious in terms of the output contribution of each sector to the overall electrical industry. In 1954 electronics output represented approximately 20 per cent of the total; in 1981 this figure had risen to ± 60 per cent. Figure 10, using Census data, illustrates the importance of this shift over the period 1963–79, for the various MLH-sectors included in both the electronics and electrical industry. The shares given in Figure 10, based as they are on current sales, probably underestimate the importance of the shift towards electronics and electronic computers in particular.

In terms of employment, the electrical industry peaked in 1966, after which its employment fell at an average annual rate of 2.74 per cent. It is now below the 1954 level. In electronics employment peaked in 1974 at 348,000; it has since fallen to the present level of 297,700 (1982), though as mentioned before, this trend is far from uniform as between the various electronics subsectors.

Only limited data, which are generally outdated, exist in relation to industrial concentration. Table 18 brings together the available concentration data for some of the major products within each of the electronics and electrical subsectors. Concentration, identified in terms of the share of the total sales of the largest five enterprises, is high and seems to have been rising over the sixties and seventies in both electronics and electrical engineering. It has risen significantly in a number of product groups in the electronic consumer sector (the exception being television receiving sets), the electronic capital goods sector, telecommunications, electrical consumer goods, and other electrical equipment goods.

The figures for the electronic computer sector suggest a decline in concentration, though one really needs more up-to-date data to substantiate this trend. One may indeed expect that with the deepening of the recession over the post-1977 period and the ensuing

Table 17: Output in the electronics and electrical industries (£ millions)

Year	In 1975 Prices			1970 Price Indices	
	Total Electrical Engineering	Electronics (364–367)	Other Electrical (361, 362, 363, 368, 369)	Total Electrical (1970 = 1.00)	Electronics (1970 = 1.00)
1954	2693	564	2129	0.5934	0.7159
1955	2998	642	2356	0.6227	0.7513
1956	2956	634	2322	0.6450	0.7508
1957	3165	672	2493	0.6474	0.7858
1958	3320	769	2551	0.6506	0.7849
1959	3697	872	2825	0.6570	0.7346
1960	3876	873	3003	0.6634	0.7480
1961	3977	940	3037	0.6815	0.8140
1962	4252	1114	3138	0.6944	0.8113
1963	4449	1186	3263	0.7148	0.8266
1964	4724	1366	3358	0.7373	0.8200
1965	4759	1514	3245	0.7668	0.8414
1966	4795	1664	3131	0.8007	0.8654
1967	4915	1782	3133	0.8106	0.8721
1968	5375	2069	3306	0.8592	0.9058
1969	5787	2045	3742	0.9045	0.9364
1970	5987	2403	3584	1.0000	1.0000
1971	6140	2368	3772		
1972	6660	2543	4117		
1973	7617	2936	4681		
1974	7341	3071	4270		
1975	6879	2856	4023		
1976	6782	2937	3845		
1977	7113	3273	3840		
1978	7507	3664	3843		
1979	7746	4221	3525		
1980	7683	4418	3265		
1981	7251	4356	2895		

Source: Total electrical engineering: Institute of Employment Research, Warwick University.
Electronics: estimated from *British Business*, Trade and Industry, EDC, Ministry of Aviation

increased pressure for structural change, the structure of the various electronic and electrical industries has undergone further significant changes.

Notes

[1] Except for electronic consumer goods, for which the employment data also include employees in 365.1, gramophone records and tape recordings.

[2] The latter are based on 'total billings to clients for work done' as published in *Business Monitor* SDQ9. The use of the overall GDP-deflator probably underestimates the actual real growth of 'computer services'. This might explain why the trend in growth is somewhat lower than the growth trend for the electronic computer manufacturing industry.

[3] Estimates of gross output for the post-1970 period are based on the DoI volume indices, published regularly in *British Business* and given in Table 15.

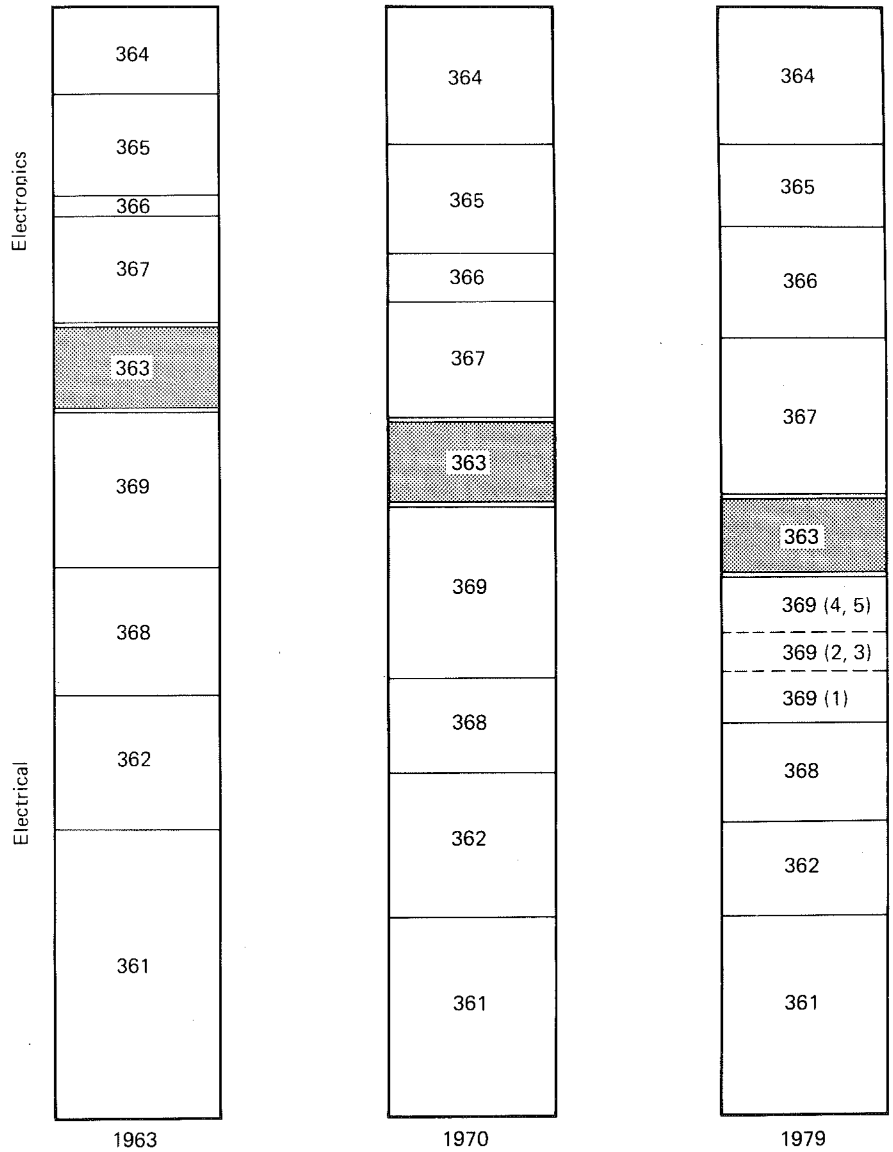


Figure 10: Share of the electronics and electrical subsectors in total electrical engineering sales.
Source: Census of Manufactures, *Business Monitor*

Table 18: Industrial concentration in electronics and electrical engineering (sales by largest 5 enterprises as a % of total sales)

	ELECTRONICS	1963	1968	1975	1977
364	Electronic valves and tubes; semiconductor devices	76.2	84.2	79.7	81.5
	Passive components	35.3	33.5	38.7	42.6
365	Television receiving sets	81.6	92.7	85.0	80.8
	Radio receiving sets	57.9	74.7	83.5	89.8
	Gramophones, record players, tape recorders	50.3	75.7	72.4	81.3
366	Electronic data processing equipment	73.3	87.2	82.0	76.0
367	Radio communications equipment	63.7	81.0	85.6	89.3
	Radar and electronic navigation aid equip.	72.2	74.6	82.8	83.6
	Electro-medical apparatus	65.8	67.1	69.4	75.2
Electronics: Weighted Average		65.1	72.7	77.1	75.4
	ELECTRICAL				
361	Generators and turbines	n.a.	86.8	89.1	87.8
	Transformers	45.0	76.7	68.8	70.4
	Starting and controlling gear	47.9	52.6	55.3	50.0
	Switchgear	60.9	77.4	65.6	63.0
	Fuses	58.0	69.0	78.0	70.8
	Traction and non-traction motors	56.4	64.6	69.9	68.0
362	Telecommunication cables	91.7	98.2	95.3	95.3
	Power transmission cables	n.a.	90.5	86.7	87.5
	Other insulated wires	n.a.	79.1	79.8	80.0
363	Telegraph and telephone installations	94.0	96.4	98.9	99.5
	Line apparatus	96.2	99.9	92.7	86.0
368	Cooling apparatus	60.0	85.9	73.8	72.4
	Heating apparatus	43.3	45.5	51.2	42.7
	Refrigerators and freezers	71.9	79.7	98.8	98.8
	Vacuum cleaners	94.9	94.5	94.0	93.4
	Washing machines	85.2	86.9	96.2	96.2
369	Electrical equipment for motor vehicles	70.1	74.0	82.2	84.7
	Batteries and accumulators	78.7	84.1	93.0	92.0
	Electrical lamp bulbs	71.7	86.6	91.7	94.0
	Electrical light fittings	38.0	47.3	52.7	53.5
Electrical: Weighted Average		66.4	79.2	76.9	79.9

Source: *Business Monitor*, PO 1006

6

TRENDS IN PRODUCTIVITY AND INVESTMENT

The post-war evolution in labour productivity and investment in the electronics and electrical industries is given in Figures 11 and 12. Electronics labour productivity growth shows at present little sign of slowing down (a 6.8 per cent annual growth rate over the 'recessive' period 1974–81, compared with a 4.7 per cent growth rate over the period 1954–74), illustrating in many ways the crucial importance of technical change not just for increased demand for electronics output, but also in terms of 'internal' productivity growth. The importance of the 'embodied' technology factor for the electronics industry is also illustrated by the large and widening gap between best-practice labour productivity and average labour productivity in the electronics industry, with only a slight tendency for the gap to remain constant over the recent years. The electrical industry (Figure 12), by contrast, has suffered severely from the recession; its labour productivity fell by 3 per cent a year over the period 1973–81. In absolute terms, labour productivity in electronics is now nearly twice as high as in the electrical industry.

In terms of investment though, the electrical industry remains as important, if not

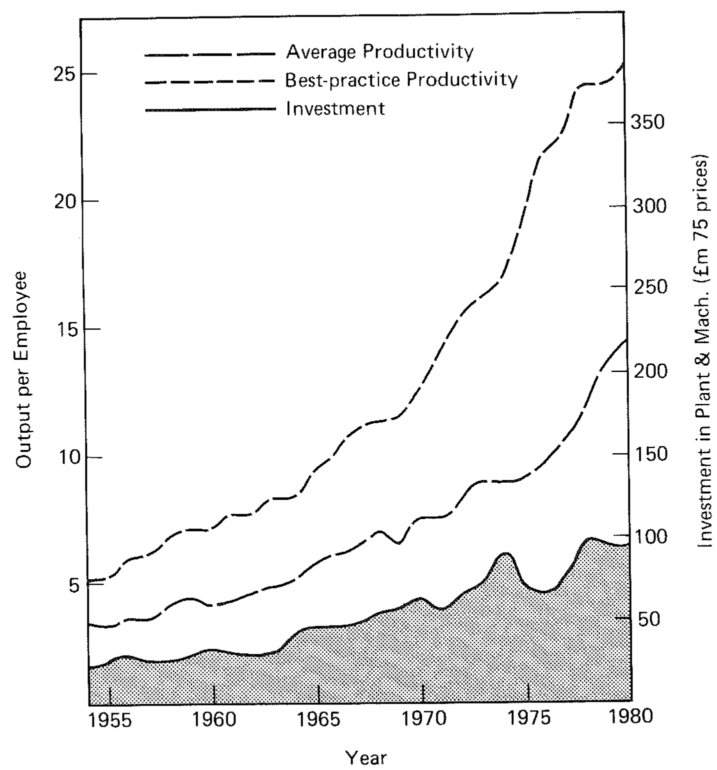


Figure 11: Investment and labour productivity in electronics. *Source*: own estimates, see text.

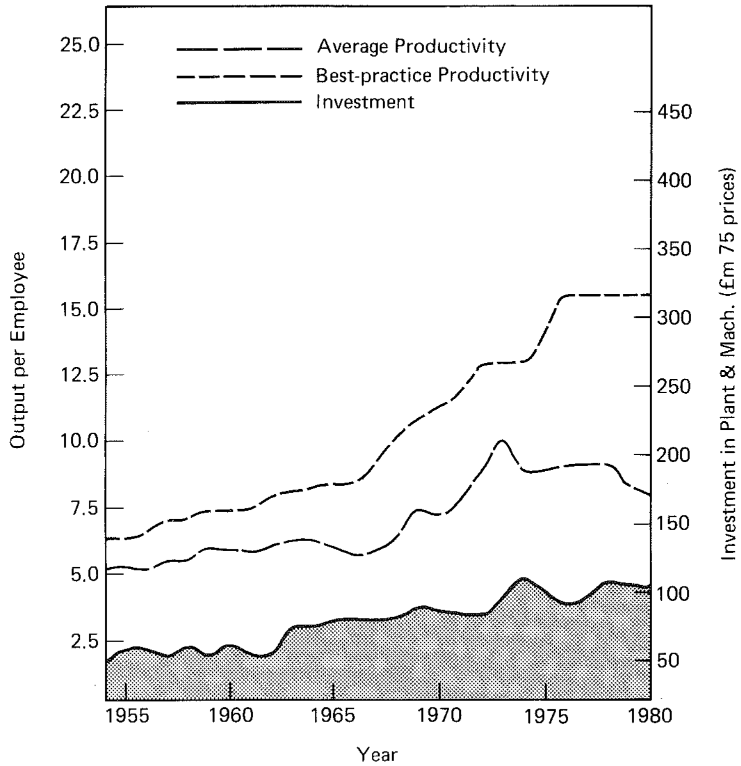


Figure 12: Investment and labour productivity in other electrical. *Source*: own estimates, see text.

more important than the electronics industry. The high investment levels in the electrical industry accompanied by falling productivity growth suggest large-scale over-capacity in particular areas of the electrical industry.

Figure 12 provides some information about labour productivity growth in the various subsectors of the electronics industry, for the period 1960–82. The figures for 1960–70 have been estimated using various EDC and Ministry of Aviation estimates. The overall electronics price deflator has been used for all the sectors. Detailed information about gross output in the various subsectors for the period 1959–82, underlying the trends in labour productivity in Figure 13, is given in Table 19. Apart from the rapid growth in labour productivity in electronic computers, Figure 13 illustrates the dramatic productivity growth in electronic consumer goods over the most recent years, pointing directly to the effect of Japanese foreign investment in the sector, particularly in colour TV receiving sets, and the accompanying restructuring of the industry, emphasised earlier in Section I.

The rapid productivity growth in the various electronics industries is, of course, not only the result of technological change. There are many other factors, ranging from short-term labour-hoarding effects to more straightforward demand-related factors such as economies of scale. Using a model to interpret the so-valled Verdoorn Law, Turner (1983) has tried to separate and estimate the contributions of some of these factors to overall manufacturing productivity growth in the United Kingdom, Germany (FR) and the United States. The analysis can, however, be applied in a relatively straightforward manner to any industrial sector.

Let $\hat{P}$ represent labour productivity growth and $\hat{Q}$ output growth in, respectively, the

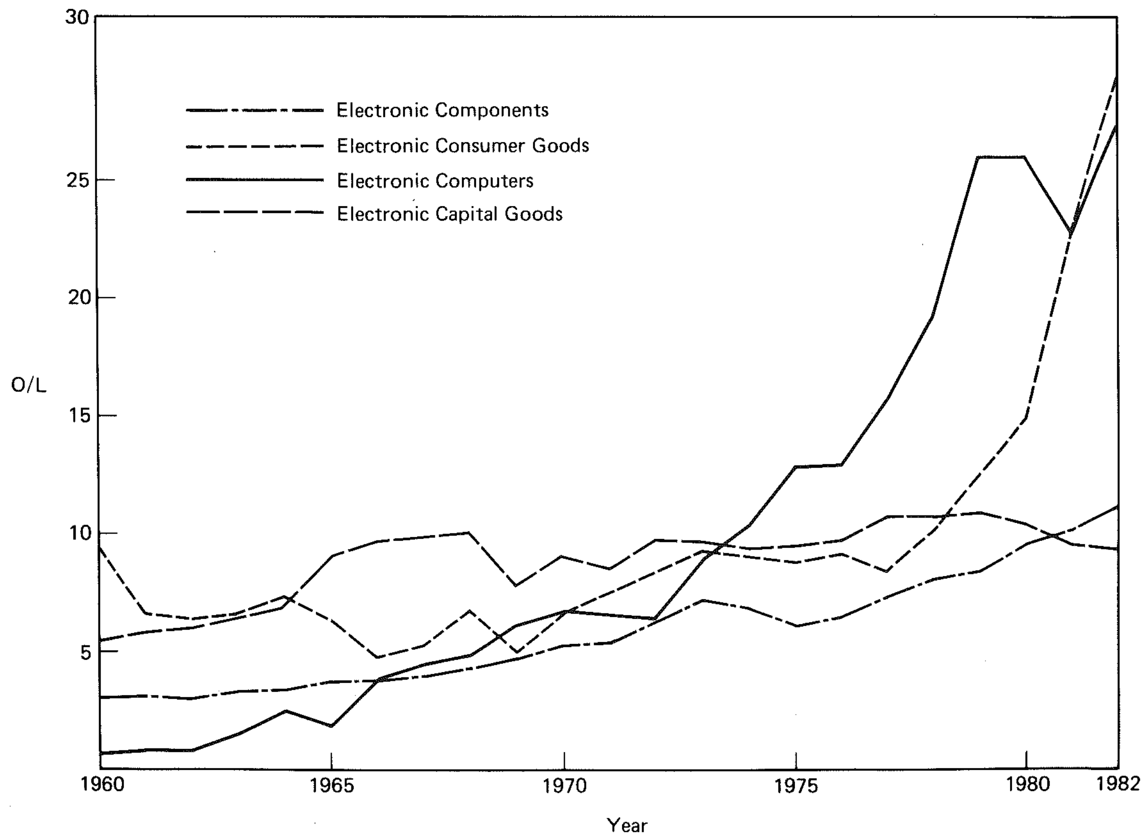


Figure 13: Labour productivity (gross output per employee) in the electronics subsectors—1960–82.
Source: own estimates, see text

electronics and the electrical sector (the analysis has also been carried out for the overall electrical engineering sector) for the period 1954–81. In the model developed by Turner three separate factors are considered to be determining productivity growth: a returns-to-scale factor, a technical change factor and a short-term labour-hoarding factor. This is specified as follows:

$$\hat{P} = \left(\frac{\alpha - 1}{\alpha}\right)\hat{Q} + \lambda\left(\frac{\hat{Q} - \bar{\hat{Q}}}{\alpha}\right) + \left(\frac{m + \beta\gamma}{\alpha}\right).$$

where α measures the returns-to-scale of labour,
m is the rate of disembodied technical change,
$\beta\gamma$ is the rate of embodied technical change (γ the rate of investment and β the returns to scale of capital) or $m + \beta\gamma$ measures the rate of total technical change,
$\bar{\hat{Q}}$ is the long-term growth rate of output and
λ measures the 'stickiness' of the labour force in response to changes in demand. In an ideal world, with employment immediately adjusting, $\lambda = 0$.

In the *long term* it can be assumed that 'labour stickiness' will not influence productivity growth, $\hat{Q}$ being equal to $\bar{\hat{Q}}$; or

$$\hat{P} = \left(\frac{\alpha - 1}{\alpha}\right)\hat{Q} + \left(\frac{m + \beta\gamma}{\alpha}\right).$$

Table 19: Estimated gross output in the electronics subsectors (£ millions in 1975 prices)—1954–81

Year	Electronic Components MLH 364	Electronic Consumer Goods MLH 365 (2)	Electronic Computers MLH 366	Electronic Capital Goods MLH 367
1954	119	206	n.a.	226
1955	139	272	n.a.	219
1956	152	218	n.a.	264
1957	168	255	n.a.	249
1958	191	267	12	295
1959	227	325	16	329
1960	277	280	17	363
1961	297	201	21	378
1962	306	211	26	445
1963	347	220	47	492
1964	385	267	84	572
1965	430	231	65	743
1966	453	189	135	831
1967	472	201	168	872
1968	553	281	189	948
1969	655	220	251	794
1970	708	293	349	878
1971	699	369	338	817
1972	809	517	322	781
1973	977	640	415	783
1974	1024	584	471	820
1975	783	494	554	853
1976	830	460	571	887
1977	947	445	676	972
1978	1033	504	892	1006
1979	1096	519	1319	1049
1980	1174	494	1452	1066
1981	1135	574	1402	1057
1982	1205	668	1629	1014

Sources: EDC, Ministry of Aviation, *British Business/Trade and Industry*

Results for this long-term equation are given in Table 20 for the overall electrical engineering, the electronics and the other electrical sectors.

For the overall electrical engineering sector (Column A), the average annual productivity growth ($\dot{P}$) is 3.3 per cent, which is primarily accounted for by the rate of technical change

$$\frac{m + \beta\gamma}{\alpha} = \frac{0.036}{0.658} = 5.5\% \ .$$

With decreasing returns to scale ($\alpha = 0.65$), the 'economies of scale' contribution to productivity growth has been negative:

Table 20: Turner's Verdoorn Model: results

	A ELECTRICAL ENGINEERING (MLH 361–369)	B ELECTRONICS (MLH 364–367)	C OTHER ELECTRICAL (MLH 361–363, 368, 369)
α	0.658*	0.682*	0.908*
$m + \beta\gamma$	0.036*	0.062*	0.022*
$\bar{R}^2$	0.98	0.99	0.74
λ	0.712*	0.717*	0.814*
$\lambda\bar{\hat{Q}}$	0.029	−0.565	−0.016
$\bar{R}^2$	0.73	0.66	0.71
$\bar{\hat{Q}}$	4.1%	7.9%	2.0%
$\bar{\hat{P}}$	3.3%	5.4%	2.2%
$\frac{m + \beta\gamma}{\alpha}$	5.5%	9.1%	2.4%
$\frac{(\alpha - 1)}{\alpha}\hat{Q}$	−2.1%	−3.7%	−0.2%
$\frac{\lambda}{\alpha}(-0.01)$	1.1%	1.05%	0.9%

* significant at the 1% level.

$$\left(\frac{\alpha - 1}{\alpha}\right)\hat{Q} = \frac{-0.34}{0.658} \times 4.1 = -2.1\%.$$

A similar, more extreme picture emerges for electronics, where the contribution to the long-term productivity growth ($\bar{\hat{P}} = 7.9\%$) of technical change is even higher:

$$\frac{m + \beta\gamma}{\alpha} = \frac{0.0620}{0.682} = 9.1\%$$

with even more significant decreasing returns to scale

$$\left(\frac{\alpha - 1}{\alpha}\right)\hat{Q} = -3.7\%$$

The other electrical sector shows insignificant returns to scale

$$\left(\frac{\alpha - 1}{\alpha}\right)\hat{Q} = -0.2\%$$

with again technical change

$$\frac{m + \beta\gamma}{\alpha} = 2.4\%$$

accounting for most of the long-term productivity growth ($\bar{\hat{P}} = 2.2\%$).

The *short-term* fluctuations in productivity are given by:

$$\hat{P} = \frac{\lambda}{\alpha}(\hat{Q} - \bar{\hat{Q}}).$$

Results are also given in Table 20. If actual output growth is, for example, 1 per cent below the long-term output growth $\bar{\hat{Q}}$ or $(\hat{Q} - \bar{\hat{Q}})$ is equal to -0.01, then productivity growth will be reduced by $((\lambda/\alpha) \times (-0.01))$ or 1.05 per cent in electronics and 0.90 per cent in electrical, suggesting that 'labour stickiness' is slightly more important in the electronics than in the electrical sector.

The explanation of productivity growth attempted here is obviously rather speculative and depends to a not insignificant degree upon the assumed independence between the various explanatory variables. In particular, the assumed independence between returns-to-scale and technical change seems to be open to debate. Nevertheless, the fact that most of the electrical and electronics industry's productivity growth cannot simply be accounted for by demand, i.e. output growth, is undeniable and points towards the crucial role of supply factors, in particular technical change, in having brought about productivity growth in both industries.

7

TECHNICAL CHANGE AND CAPITAL AND LABOUR-SAVING BIASES

A crucial argument underlying much of the debate about the employment impact of rapid technical change concerns the nature and possible 'biases' of technical progress. In econometric vintage models, for example, it is generally assumed that technical change 'embodied' in new investment is of the so-called 'purely labour augmenting' type, leading in the first instance to gains in *labour* productivity, without affecting capital output ratios, generally assumed to have remained constant. Purely *labour* augmenting technical change conforms to the Harrod concept of a pattern of 'neutral' technical change and has the advantage of being easily integrated in steady state growth models. The early overall manufacturing post-war evolution of both labour and capital productivity fits well with such a picture. Through the late sixties though, labour productivity gains in most industries seem more and more to have been accompanied by an increasing capital-output ratio pointing towards the possibility of a tendency to a labour-saving bias (in the Harrodian sense) in technical progress. This tendency appears to have been further reinforced in the late seventies, though it could well be argued that within the present recession (long-term) capacity under-utilisation (or underestimation of actual scrapping) overestimates significantly the most recent official capital stock estimates. The overall post-war trend in capital-output ratio suggests, however, that an upturn in economic growth might well be hampered by the large and increasing amount of capital needed to produce a given level of output, affecting, other things being equal, profitabilities and through that, the propensity to invest.

There are major conceptual difficulties in representing these various labour and capital-saving biases of technical change. Past trends in labour and capital productivity do not allow one to separate out 'purely' capital/labour substitution phenomena (traditionally referred to as movements along a given production function) from 'real' technical change (shifts in the production function itself). We will, let the reader be warned, ignore for the time being these 'conceptual' difficulties and assume that over a relatively long period such as the post-war period, most productivity gains relate to technical change, rather than 'purely' capital/labour substitution. Such an assumption also seems reasonable in view of our reliance in the last forecasting section of our report on vintage models, in which the 'coefficients of production' are assumed to be 'fixed' (clay/clay). Furthermore, to the extent that 'best-practice' productivity levels can be identified, most of the subsequent analysis will be in terms of the possible biases in 'best-practice' labour and capital productivity growth rather than in terms of average productivity growth.

In Figure 14 the post-war growth in best-practice capital and labour productivity of some of the major United Kingdom industrial sectors (Order III to XIX) is presented graphically.[1]

It seems reasonable to identify quadrant I in Figure 14 with a tendency towards *labour-saving biased* technical change, and quadrant III with a tendency towards *capital-saving biased* technical change, whereas quadrant II represents the area of labour

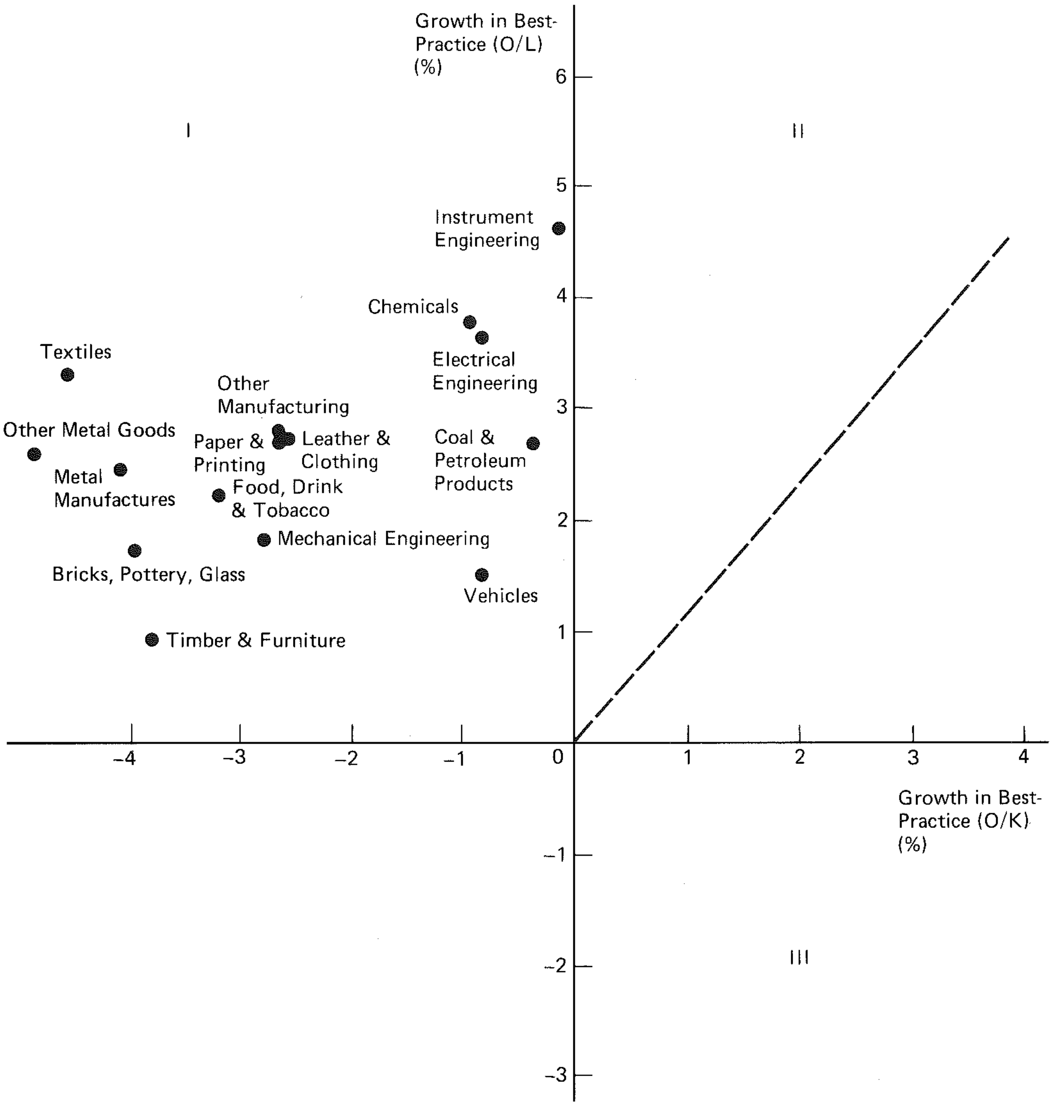


Figure 14: Post-war growth in best-practice labour and capital productivity in the UK manufacturing sectors (Order III to XIX; 1954–80)

augmenting technical change which could be identified in the 'modified' *Harrodian* sense suggested above with a capital-saving bias and in the *Hicks* sense with both a labour- and capital-saving bias (neutrality corresponds to the 45° constant K/L-line with only the area under the 45° line corresponding to capital-saving biased technical change). Figure 14 lends further support to the argument that in many sectors of the economy technical change, approximated here by 'best-practice' productivity levels, has been of a labour-saving kind. This seems to be particularly the case for food, drink and tobacco; metal manufacture; mechanical engineering; metal goods; textiles; leather and clothing; bricks and glass; timber and furniture; paper and printing; and other manufactures. Only in the cases of coal and petroleum products; instrument engineering; chemicals; electrical engineering and vehicles can one observe a relatively 'neutral' pattern of growth in best-practice labour and capital productivity.

Figures 15 and 16 compare the trend in these growth rates over the sixties and seventies.[2] A clear further shift in the labour-saving bias of best-practice productivity growth is observable across practically all industries. Such a pattern points towards the relatively limited future employment growth prospects of an increase in economic growth and the possible implications for capital shortage.

How does such a pattern fit in with the emergence of a radically new technological system such as (micro) electronics?

Figure 17 provides the same information as in Figure 14 but splits out the electrical engineering sector in electronics and other electrical engineering. The specific 'technical change' feature of the electronics industry emerges most strikingly from Figure 17, where electronics is the *only* sector in Quadrant II, the area in which best-practice labour and

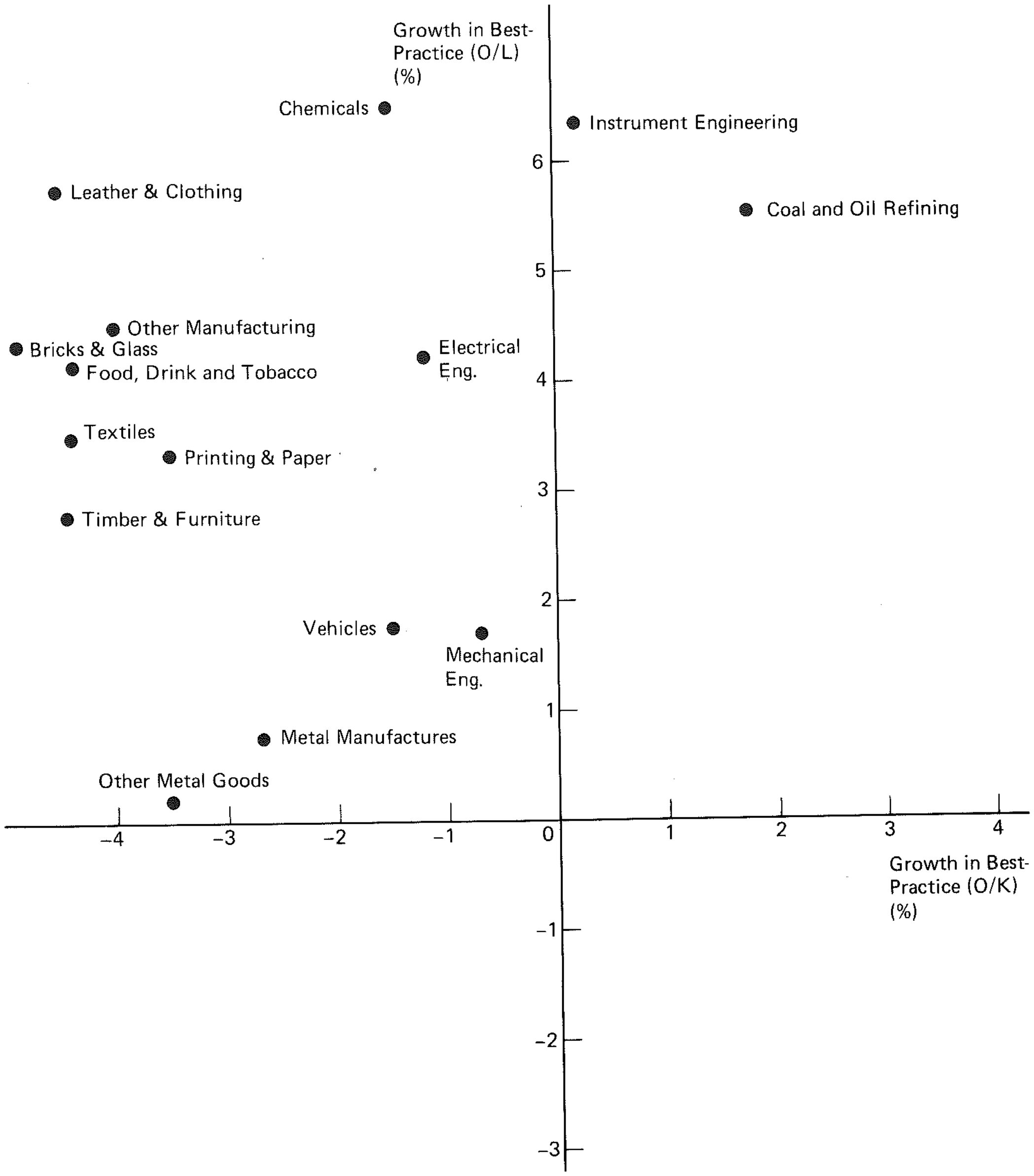


Figure 15: 1960–70 growth in best-practice labour and capital productivity in the UK manufacturing sectors (Orders III to XIX)

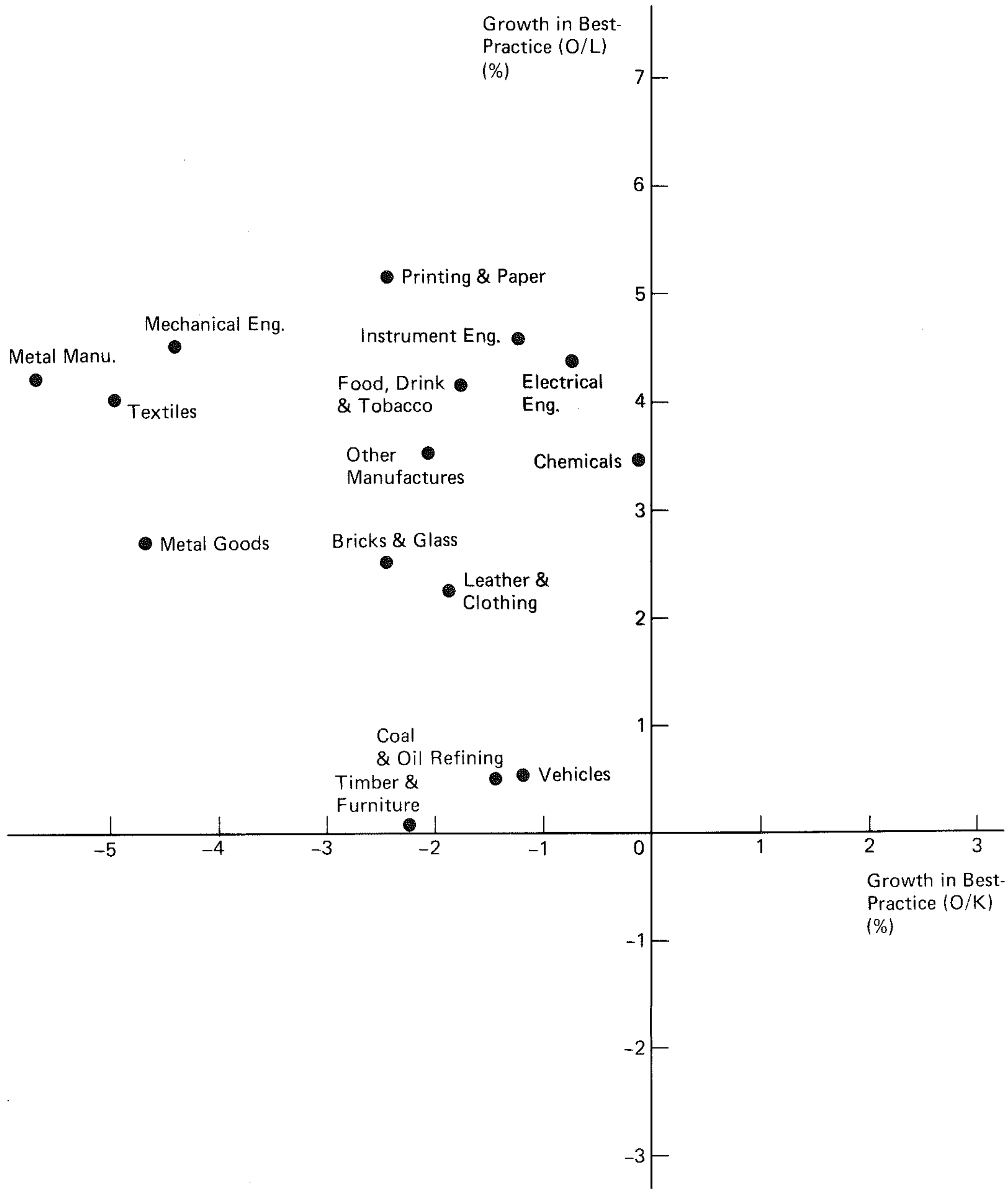


Figure 16: 1970–80 growth in best-practice labour and capital productivity in the UK manufacturing sectors (Orders III to XIX)

capital-productivity have grown simultaneously. As Figure 17 already hints, the debate about the employment impact of *electronics*, and particularly microelectronics, centres on two propositions which are quite distinct from the traditional arguments about 'technology-induced' employment displacement in most manufacturing sectors. Firstly, that electronics technology is not so much *'labour-saving'* but leads to a dramatic increase in both labour and capital productivity (see, for example, the evidence presented in Section I in Figures 2–4), and is thus in the 'modified' Harrodian sense suggested above, 'capital-saving'.

Secondly, that as a consequence it will lead on the one hand to a more rapid substitution of capital for labour, affecting in particular those sectors that have witnessed little labour displacement so far (e.g. services) and relatively labour-intensive sectors (e.g. clothing), while on the other hand it will lead to substitution of 'electronics' (sometimes also referred to as 'intelligent capital') for older, electromechanical capital (including some first or even second generation electronic capital equipment such as computers, robots etc.). This will be particularly the case in those highly capital-intensive sectors where investment costs are one of the major growth inhibiting factors, and where the economies of scale linked to large-scale investment (vintage plants) are a major factor in preventing firms from acquiring the required flexibility in periods of low output growth and uncertainty, leading to either large-scale under-utilisation of capital or significant 'scrapping' of productive capital.

Both propositions pinpoint the significant *output growth* implications of (micro)

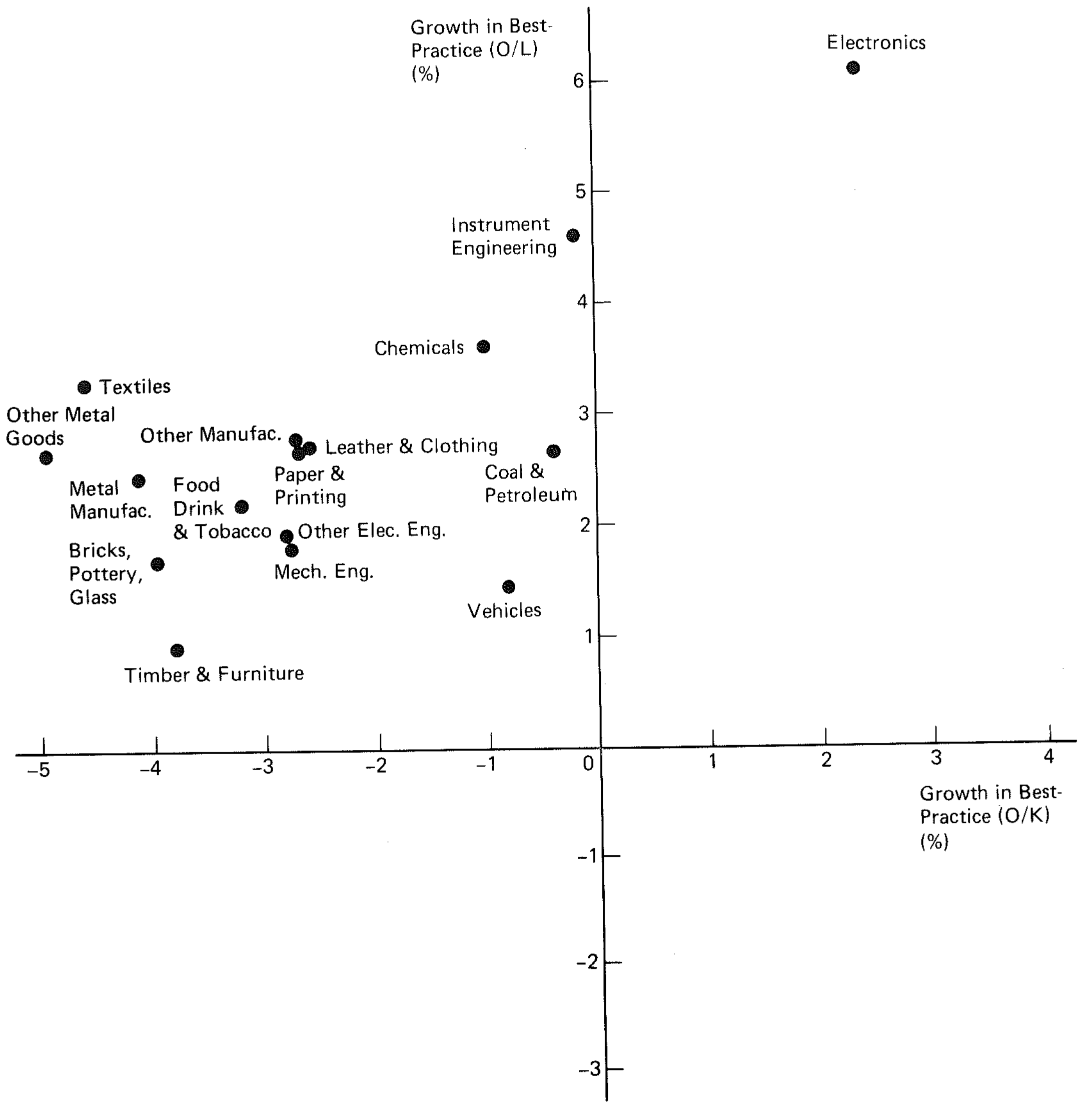


Figure 17: Post-war growth in best-practice labour and capital productivity in the UK manufacturing sectors (Order III to XIX; 1954–80)

electronics. On the one hand, the dramatically increased capital productivity alleviates possible fears for a 'capital shortage' output constraint, new electronics technology allowing output to be produced with a relatively small amount of capital; on the other hand, productivity growth occurs in *both* labour *and* 'physical' capital and not just in one (or at the expense of the other, as in the 'classical' process of mechanisation of production). An overall possible effect in terms of output growth is thus likely, in the first instance because of the reduction in the relative prices for electronics output (see, amongst others, Section I, Table 2) which will reinforce further the substitution of electronics capital goods for labour and existing capital; in the second instance because of the increase in consumer demand for electronics goods, and cheaper 'electronically-produced' manufactures and services.

In Figure 18 the evolution over the post-war period in best-practice labour and capital productivity of the electronics and electrical engineering industries is graphically represented. The specific labour-saving bias of technical change in the *electrical* industry is most clearly illustrated by the decline in best-practice capital productivity since the early

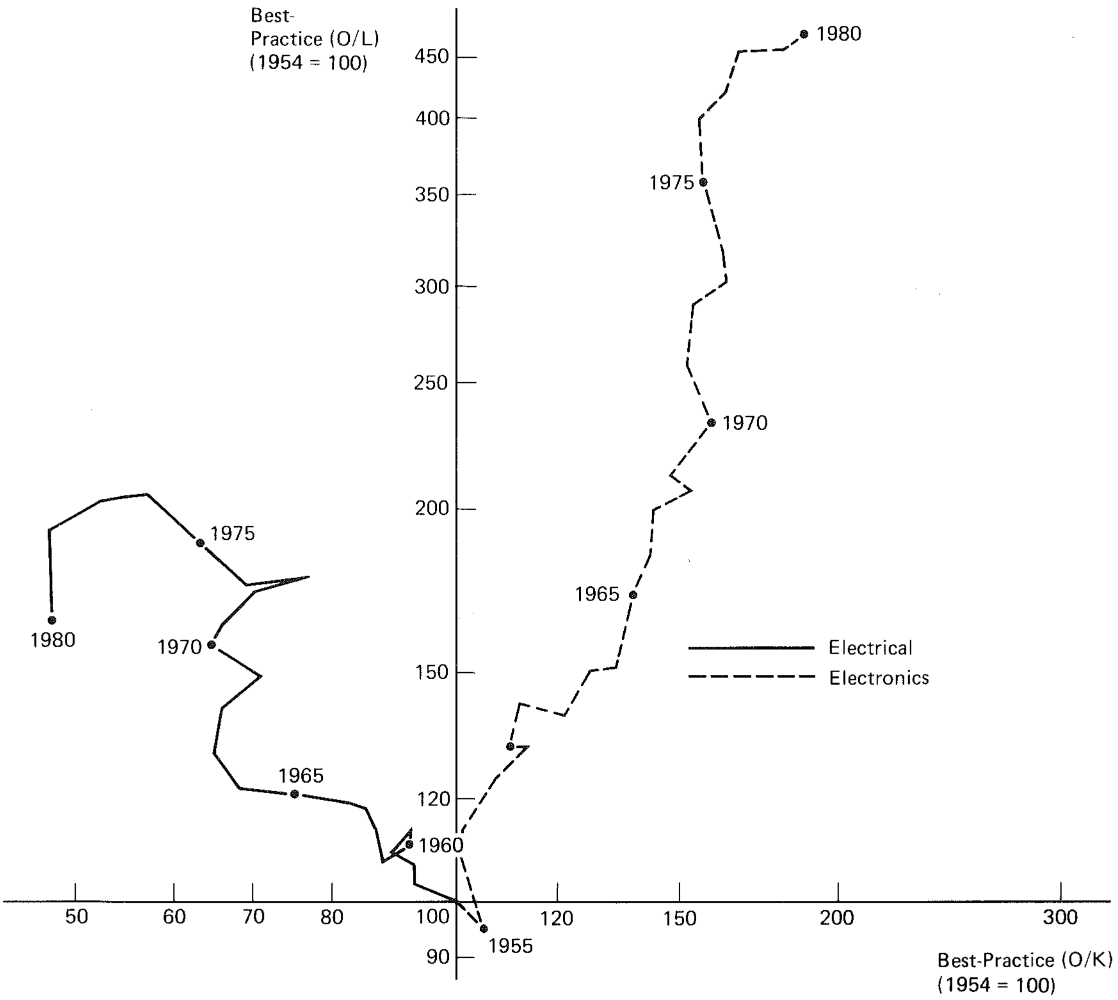


Figure 18: Trends in best-practice labour and capital productivity: electrical and electronics (1954–80; 1954 = 100)

1960s and the rapid increase in best-practice labour productivity. Whereas the most recent very low capital productivity figures point undoubtedly to very low utilisation rates of capital in the electrical sector, the overall long-term trend in the best-practice output/capital ratio is clearly decreasing. In sharp contrast, the *electronics* industry displays a pattern of growth in best-practice labour and capital-productivity, pointing from a Harrodian perspective towards a possible 'capital-saving' bias of technical change. In terms of employment, however, best-practice labour productivity growth is still higher than capital productivity growth (in Hick's terminology, technical change is still labour-saving), so that the amount of capital per employee continues to rise.

Figure 19 indicates for the various electronics subgroups the average annual growth rate in labour and capital-productivity for the period 1970–80, whereas Figure 20 presents the trend in best-practice labour and capital-productivity for the period 1959–80.

The dramatic growth in both best-practice labour and capital-productivity in electronic

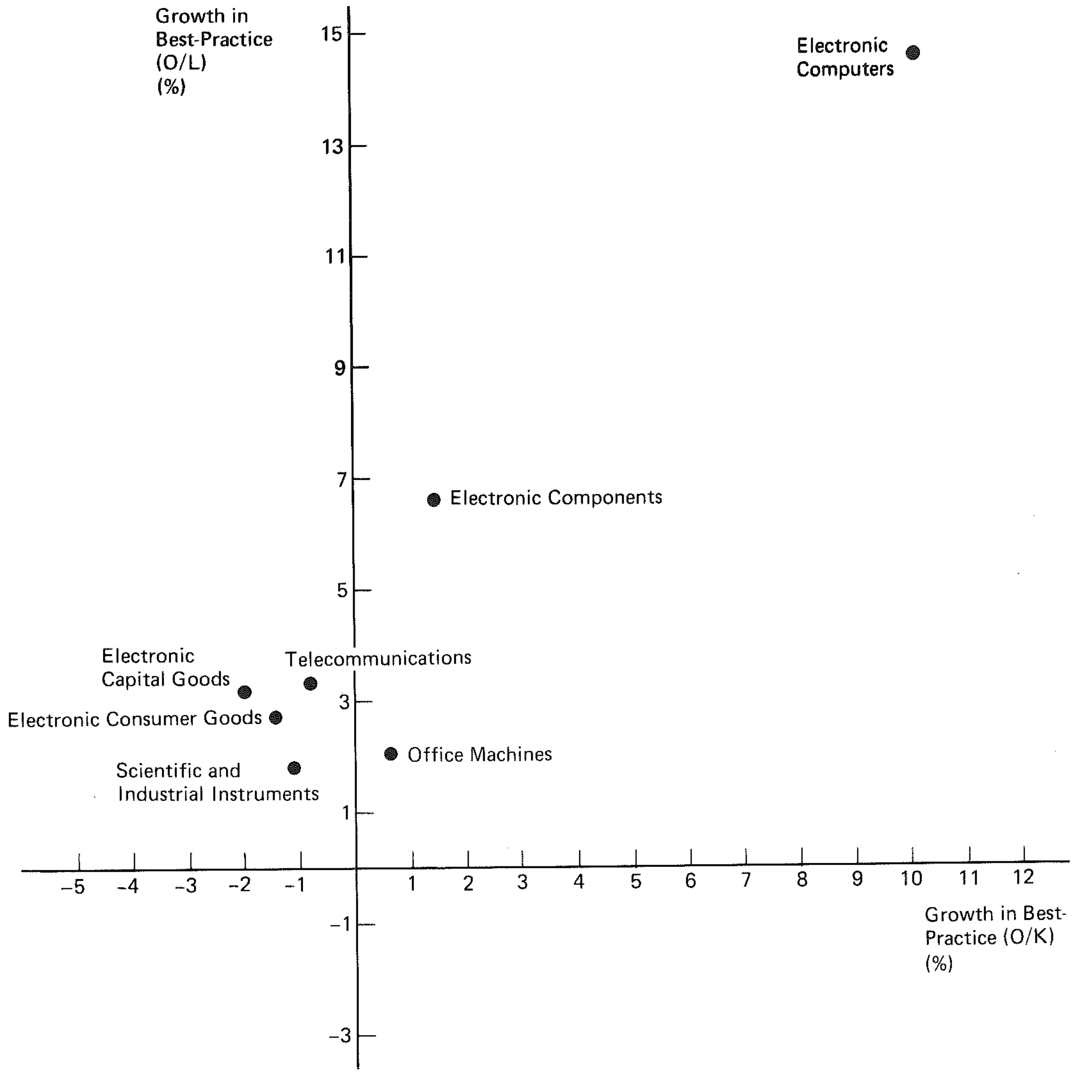


Figure 19: Growth in best-practice labour and capital productivity in the electronics subsectors—1970–80 (by MLH)

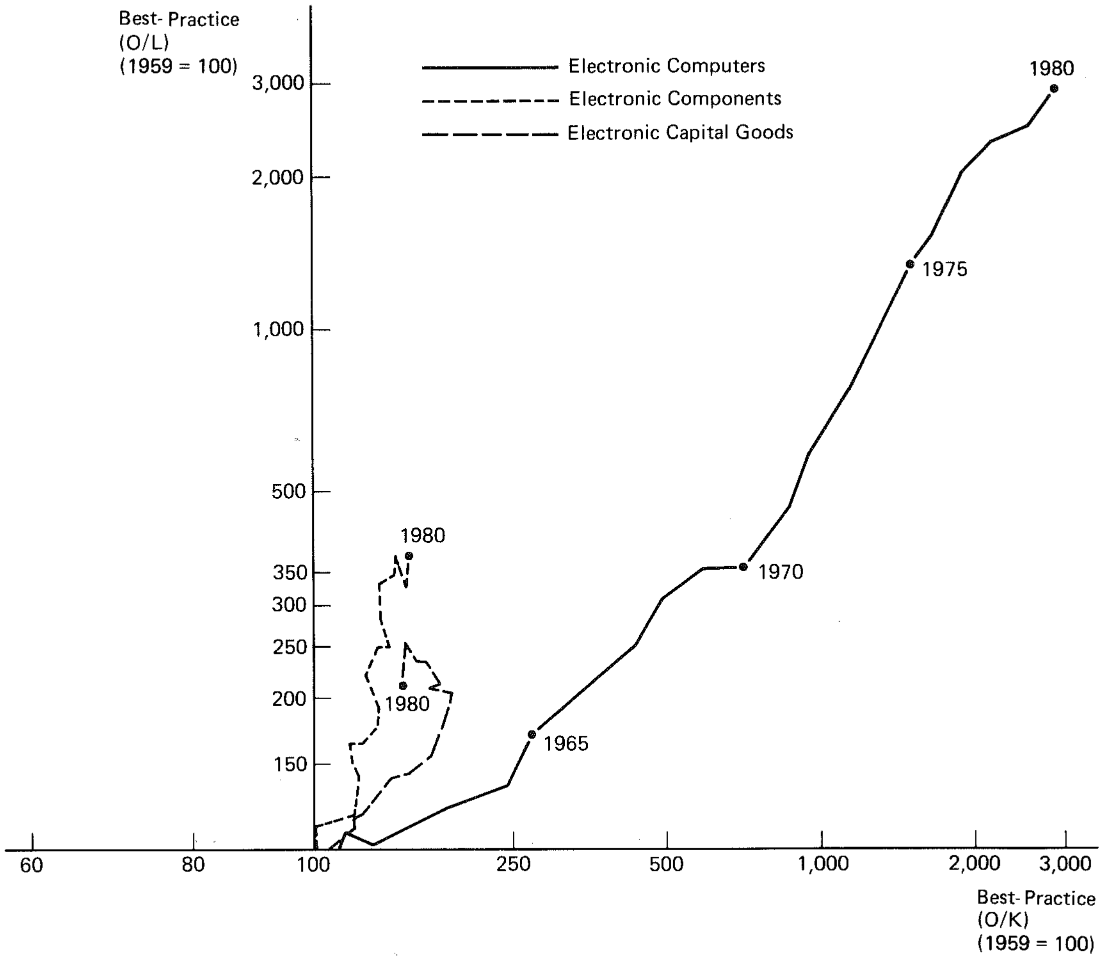


Figure 20: Trends in labour and capital best-practice productivity: electronic subsectors (1959–80; 1959 = 100)

computers is most striking (in 1980, thirty times higher than in 1959). There are some peculiarities of the UK computer industry which require further investigation, but the electronic computer industry seems also to display a pattern of technical change of near 'Hicks-neutrality', the best-practice K/L-ratio remaining practically constant. By contrast, the other 'electronic subsectors', with the exception of electronic components (and particularly for the most recent period, see Figure 19), display a more traditional pattern of 'labour-saving' technical change.

To summarise this relatively lengthy argument about the possible biases of technical change in manufacturing and electronics in particular, Figures 14–20 point towards the dual impact on employment of (micro) electronics technology. On the one hand, and as a first round effect, significant job losses will occur as a direct consequence of the rapid 'electronification' of a number of mechanical and consumer goods sectors: in particular in office machinery (e.g. cash registers); in telecommunications (switching equipment); in radio, TV and hi-fi equipment (replacement of hard wiring and discrete components, automatic insertion); and in other non-electronic consumer and capital goods (as in the automotive and domestic electrical appliances industry). The potential for *further* employment displacement is particularly significant in services and other, so far largely unaffected, industries where wage costs remain the most significant (single) cost item. The output growth of these sectors is to some extent limited because of low income elasticities of demand and international competitiveness based on absolute cost advantages.

On the other hand, however, the replacement of 'intelligent' capital for 'non-intelligent' capital should in principle lead to a significant output growth impact and, possibly, employment growth. The growth of both labour and capital productivity could lead to an improvement in profitability and/or international competitiveness, with a positive effect, other things being equal, on employment growth in manufacturing. At present the further diffusion of (micro) electronics capital equipment is in many ways hampered by the rapid rate of technical change in microelectronics itself; firms expecting prices to fall in a not-too-distant future for more sophisticated equipment (3rd and 4th generation robots for example are expected to cost by 1990 less than 50 per cent of the present 1st and 2nd generation ones) adopting a typical 'wait and see' attitude, described in detail in much of the diffusion literature, and part of the so-called 'retardation' hypothesis.

The diffusion of a major technological paradigm such as microelectronics is indeed a long-term phenomenon. Its rapid diffusion is as much hampered by institutional factors, an inability or unwillingness to adapt, as by the rapid rate of technical change within the paradigm itself.

Notes

[1] The reader should note that on the x-axis best-practice output/capital ratios are at *constant* prices, thus expressing the 'physical' productivity per unit of constant-price capital—this differs from Harrod's definition in that the latter is at *current* prices. From a purely economic point of view Harrod's definition is the relevant one in the sense that microeconomic profitability calculations are generally related to capital investment at current prices—moreover, a current-price approach avoids the complex issues related to the measurement of capital and the nature of price deflators. On the other hand, an approximate measure of 'physical' output 'per machine' highlights the trends in equipment-related technical progress (i.e. the rates of product-innovation in capital goods) jointly with (different degrees of) mechanisation of production (as expressed by changes in the capital/labour ratios, which can be easily seen by dividing the values on the x- and y- axis). As a shorthand, we shall use expressions such as 'Harrod's neutrality', etc. in the modified sense described above, i.e. in terms of constant prices. This might, however, slightly overestimate the extent of the 'biases' of technical change.

[2] The growth rates have been calculated in Figures 15 and 16 for the peak levels of best-practice labour productivity, in order to eliminate some of the effects of the 1980 recessive year.

8

EXPORT PERFORMANCE AND IMPORT PENETRATION IN THE UK ELECTRICAL AND ELECTRONICS INDUSTRIES

Little has been said so far about the effects of international trade on output, productivity growth, employment growth and employment displacement in the electrical and electronics industries. Yet there is little doubt that exports have become an overriding factor both for output and for employment growth in many sectors of the electrical engineering industry and that imports have emerged as a major factor of 'competitive pressure' on the industry. Table 21 summarizes the available evidence on the trade balance, export performance and import penetration for a number of years over the period 1963–82 for the various MLH-industries included in the electrical and electronics industries.

In terms of the trade balance, Table 21 lends further support to the worries expressed on various occasions about the international competitiveness of the UK electronics industry (see, amongst other sources, NEDO, 1982). The trend in electronics exports and imports, where a trade surplus of £106m in 1963 has been wiped out and replaced by a deficit of £876m, is indeed disturbing. In terms of the more narrow definition of electronics (MLHs 364 to 367) used earlier on, this pattern is even more worrying; apart from electronic capital goods, where the trade surplus reflects in the first instance the strong UK position in military electronic equipment, all sectors are now characterised by a growing trade deficit. However, the electrical industry, apart from electrical consumer goods, appears to continue to display a healthy trade surplus. This, however, might be more the result of the relative 'closeness' of the major UK electrical markets, as exemplified in the order policy for power stations or wires and cables. In the latter case this emerges quite clearly from the very low import penetration ratios.

In terms of export performance, the export sales ratios have risen significantly in most MLH sectors over the period considered, more rapidly than for manufacturing as a whole. The same can be said, however, for import penetration. The exceptions relate primarily to by and large 'protected' sectors (such as telecommunications and insulated wires and cables) and sectors heavily dependent on public military procurement (such as electronic capital goods).

Table 22 provides a different picture of the export performance of the UK electrical and electronics industries at the individual product level, in terms of so-called Revealed Comparative Advantage Indices (a traditional specialisation proxy), which compares the performance of the industry with its major competitors, in terms of the UK world (OECD) export share, weighted by the overall UK manufacturing world (OECD) export share. Table 22 points towards the relatively limited comparative advantage (indices above 1) of the United Kingdom in (only) a number of electronic products, particularly other tubes and electronic valves, electronic computers, and, at the limit, microcircuits. The industry's major weaknesses relate in the first instance to the electronic consumer sector (including office machinery and related components). In the electrical industry, areas of comparative advantage include batteries and accumulators, distribution and transmission electrical equipment and industrial electrical apparatus. As in electronics

Table 21: Trade balance—export performance and import penetration in the UK electrical engineering sector by MLH—1963-82

Industry Group	TRADE BALANCE (Exports-Imports) (£ millions)							EXPORTS/SALES RATIO (%)							IMPORTS/HOME DEMAND RATIO (%)						
Industry MLH	1963	1968	1970	1973	1976	1979	1982	1963	1968	1970	1973	1976	1979	1982	1963	1968	1970	1973	1976	1979	1982
ELECTRONICS:																					
Broad definition (363, 367, 338, 354)	105.7	47.5	11.1	−253.6	35.0	−402.9	−876							n.a.							n.a.
364 Electronic components	20.7	1.5	−11.3	−89.8	−13.7	−52.7	−314	26.5	25	28	32	49	52	64	17	25	30	41	50	53	71
365 Electronic consumer goods	−3.5	−7.9	−16.5	−218.4	−108.7	−383.8	−922	6	7	9	8	25	25	24	8	11	15	35	37	51	71
366 Electronic computers	0.5	−17.9	−55.3	−50.6	−145.3	−189.3	−554	23	36.5	41	61	72	92	104	22	44.5	51	66	78	93	103
367 Electronic capital goods	26.7	36.2	43.2	37.4	193.0	138.4	227	24	25.5	27	28	41	30	37	9	12	15	20	23	22	29
338 Office machinery	9.8	−9.6	−5.5	−6.7	−16.6	−37.7	−38	51	67	49	64	92	100	131	41	71	51	66	84	100	124
354 Scientific instruments	23.7	18.6	30.4	37.3	77.0	79.9	78	30	35	37	40	48	45	53	20	30	29	34	42	42	50
363 Telecommunications	27.8	26.6	26.1	37.2	49.3	49.3	19	29	17	15	13	22	16	12	3	4	5	6	14	10	10
ELECTRICAL: (361–369)	152.5	135.8	189.4	156.7	485.7	450.7															
361 Electrical machinery	55.5	50.7	82.4	105.4	311.4	410.5	623	19	17	24	32	41	47	56	4	8	10	18	20	29	36
362 Insulated wires and cables	32.5	41.1	41.2	44.2	124.4	94.2	134	23	19	16	15	27	20	25	1	2	2	3	6	8	12
368 Electrical consumer goods	28.4	12.6	21.2	−28.3	−29.0	−124.7	−316	18	16	21	18	23	20	17	5	11	13	24	27	30	39
369 Other electrical equipment	36.1	31.4	44.6	35.4	78.9	70.7	103	18	16.5	20	21	26	26	30	6	9	11	5	19	22	25
ORDER IX ELECTRICAL ENGINEERING	224.7	174.3	175.6	−132.5	461.1	13.1	−1001	20	19	23	25	37	38	43	7	13	18	27	32	38	48
TOTAL MANUFACTURING	n.a.	148.3	664.2	−1178.5	n.a.	−2842	−1402	n.a.	17.5	18.1	19.6	23.7	24.3	26.6	n.a.	17.1	16.6	21.4	23.1	25.8	28.4

Source: Department of Industry, *Economic Trends* (Hewer, 1981), and *British Business*, July 1983

Table 22: Specialisation indices for a selected number of electrical and electronic products

PRODUCT	1978	1979	1980
Typewriters	0.55	0.52	0.56
Calculating machines	0.52	0.34	0.33
Electronic computers	1.57	1.61	1.31
Television receivers	0.37	0.38	0.40
of which - colour	0.45	0.46	0.50
- black and white	0.29	0.18	0.11
Radio, gramophones, sound reproducing, e.g.	0.50	0.42	0.31
Video equipment	0.42	0.38	0.26
Telecommunication equipment and electronic components	0.77	0.78	0.75
of which - cathodic tubes for televisions	0.24	0.28	0.40
- other tubes and electronic valves	1.89	1.58	1.66
- diodes, transistors	0.73	0.95	1.22
- microcircuits, etc.	1.09	1.01	1.02
- piezo-crystals, etc.	0.40	0.46	0.46
Distribution and transmission electrical equipment	1.07	1.02	1.07
Industrial electrical apparatus	1.10	.98	1.05
Electric motors and parts	1.11	.98	.99
Washing machines	0.78	0.67	0.58
Refrigerators	0.43	0.30	0.35
Dish-wash machines	0.04	0.02	0.02
Other electrical domestic appliances	0.82	0.75	0.75
Electric lighting equipment	1.15	1.02	.98
Electric medical equipment	0.77	0.62	0.48
Batteries and accumulators	1.60	1.23	1.36

Source: Calculated from OECD, Trade by Commodities, Series C

comparative advantage weaknesses relate in the first instance to the consumer sector, but also to electrical medical equipment.

The trade picture emerging out of Tables 21 and 22 reinforces the impression emerging from the previous Technology Section, that the UK electronics industry can only rely upon a limited number of 'strongholds', primarily related to electronic computers and electronic capital goods. Outside these particular areas the industry faces major competitive weaknesses. In the electrical industry, by contrast, the trade picture appears healthier than could be expected from both the technology analysis and the output/productivity growth pattern.

9

EMPLOYMENT TRENDS BY GENDER AND OCCUPATIONAL CATEGORY

The analysis of employment by gender and occupational category will be limited to the electronic sector. One of the reasons for doing so is that this is indeed one of the few sectors that did not see its employment fall so dramatically over the seventies. It will be interesting, particularly in view of the subsequent employment forecasting exercise in Section III, to compare the trends in male and female employment and the possible growth and declines in employment in specific occupational categories.

(a) Employment trends by gender

The most significant feature of the trend in female employment over the seventies is the decline in the *share* of female employment in electronics and in each of the electronic subsectors. Underlying this trend one can observe that female employment has, in every sector, either declined faster than male employment or grown more slowly than male employment. Table 23 illustrates some of these trends. It is interesting to note that the overall employment fall in the industry of some 41,787 is for 96 per cent the result of a fall in female employment, male employment having remained virtually constant. Over the most 'recessive' period 1975–81 this picture is even more striking, with a growth in male employment of some 3,500, compared with a loss of some 31,700 female jobs.

Underlying these specific male/female trends one finds no doubt significant changes in the employment growth/decline of the various occupational categories within each of the electronics industries.

(b) Employment by occupational structure

The electronics industry has a number of specific occupational characteristics which distinguish it quite clearly from the rest of engineering. As Figure 21 illustrates, these include a significantly higher proportion of scientists and technologists (10.2 per cent of total employment, as compared with 3 per cent for overall engineering), and technicians (13.6 per cent as compared with 8.3 per cent) and a significantly lower proportion of craftsmen (7.9 per cent as compared with 19.1 per cent). The most skilled occupational categories from managerial staff to professional and administrative staff represent no less than 39 per cent of total employment in the electronics industry as compared with 23 per cent in overall engineering.

Within the electronics subsectors the occupational structure is, however, also significantly different, with both electronic computers and electronic capital goods employing a far higher proportion of scientists and technologists (respectively 9 per cent and 15 per cent) and technicians (respectively 11 per cent and 19 per cent) than the other electronic

Table 23: Changes in the number of employees within the electronics MLH-industries by sex—1970–81

MLH	Industry	Male Share in Total Employment (%)			Female Share in total Employment (%)			Change in Male Employment (000s)		Change in Female Employment (000s)		Average Annual Growth 1970–81 (%)	
		1970	1975	1981	1970	1975	1981	1970–75	1975–81	1970–75	1975–81	male	female
354	Scientific and industrial instruments	68	67	71	32	33	29	−7.2	−4.0	−1.5	−4.8	0.7	−2.0
363	Telecommunications	57	59	62	43	41	38	−3.8	−15.6	−7.0	−13.5	−3.9	−5.9
338	Office machinery												
364	Electronic components	52	52	58	48	48	42	−14.8	−10.2	−15.2	−19.1	−3.6	−6.0
365	Electronic consumer goods	44	39	48	56	61	52	0.9	−5.6	6.7	−16.0	−2.3	−3.9
366	Electronic computers	73	74	75	27	26	25	−3.1	9.7	−1.3	2.1	1.4	0.5
367	Electronic capital goods	70	73	75	30	27	25	10.5	11.6	−1.5	1.2	3.1	1.0
364–367	*ELECTRONICS*	58	59	66	42	41	34	−5.2	3.5	−8.4	−31.7	−0.09	−3.2

Source: Engineering Industry Training Board

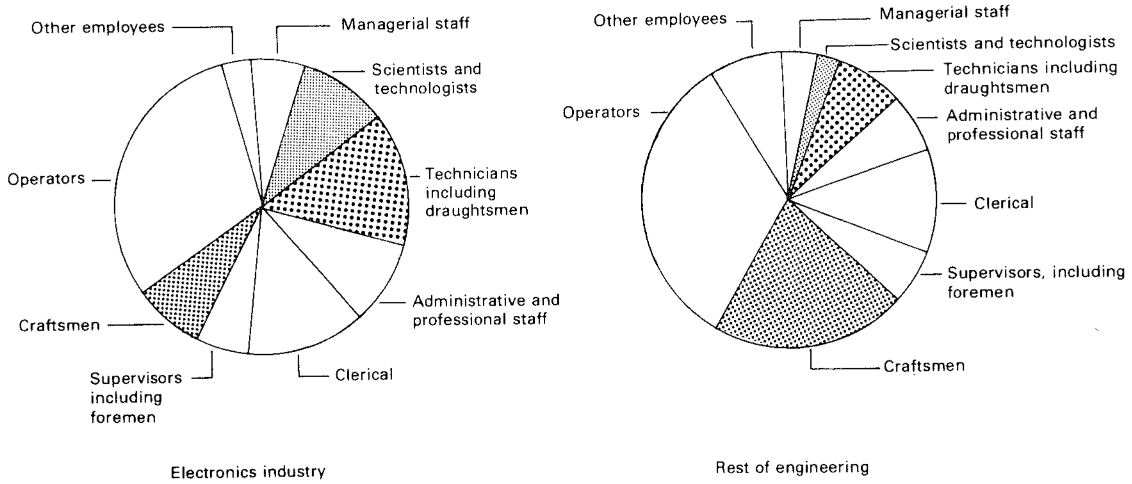


Figure 21: Employment by occupational category in the electronics industry and in the rest of engineering—April 1981. *Source*: EITB statutory returns (EITB, Brayshaw and Lawson, 1982, p. 12)

subsectors. Figure 22 provides more information about the occupational categories in the various electronics MLH-sectors. The very heavy reliance on a highly-skilled labour force in the electronic computers and electronic capital goods industries is illustrated by the fact that the most skilled occupational categories, 1–4, account for around 50 per cent of total employment. In electronic components and consumer goods these categories amount to only 25 per cent of total employment. In electronic components and consumer goods these categories amount to only 25 per cent of total employment. The importance of the skill factor emerges, however, even more clearly from the *change* in the individual occupational categories for each of the electronics subsectors and electronics as a whole.

In Table 24 the change in employment, both in absolute numbers and in annual growth rates in each of the nine major occupational categories is indicated (for the relatively short period of 1978–81) for the various MLH industries related and included in electronics. Table 24 illustrates the crucial importance of structural changes in employment growth and decline. Overall, despite the significant fall in employment in electronics over the period considered (−2.7 per cent a year), a number of occupational categories, particularly the most skilled ones such as scientists and technologists and administrative and professional staff, saw their employment grow at no less than 8.6 per cent and 4.7 per cent respectively. At the MLH level, sectors that witnessed a more significant fall in overall employment such as electronic consumer goods (−12 per cent a year) or electronic components (−7 per cent a year) *increased* their employment of specific occupational categories such as scientists and technicians and in consumer goods particularly of administrative and professional staff (+9.7 per cent a year).

At the other end of the scale, those industries such as electronic computers and electronic capital goods that increased their overall employment by 3.3 per cent and 2.3 per cent respectively nevertheless witnessed a significant decline in the employment of operators (−3.2 per cent and −2.7 per cent a year). *All* industries increased their demand for scientists and technologists over this period, despite the recession and despite the significant fall in overall employment in the majority of industries; and all industries saw a fall in the number of operators employed. Underlying these relatively dramatic changes in the occupational structure of the electronics industry and its various sub-sectors, over such a short period, one witnesses the significant *structural* employment impact of technical change.

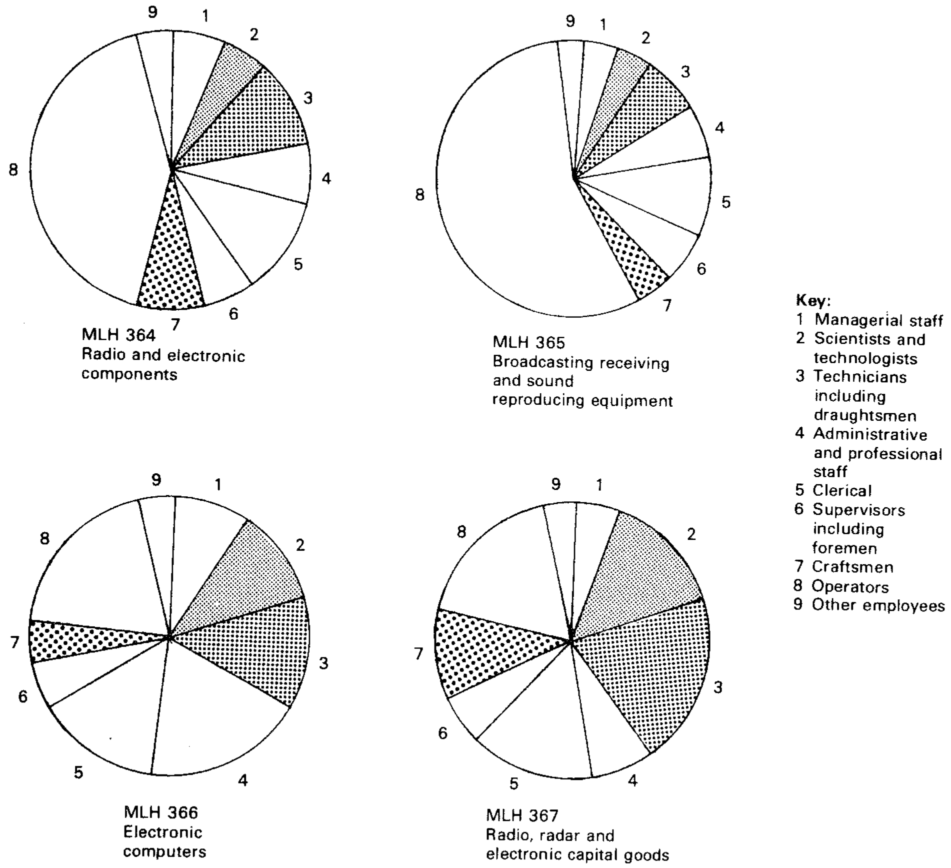


Figure 22: Employment by occupational category in the electronics industry by sector—1981.
Source: EITB statutory returns (EITB, Brayshaw and Lawson, 1982, p. 13)

Table 24: Changes in the occupational structure of the electronics industries—1978–81

Occupational Category	354 1978–81		363 1978–81		338 1978–81		364 1978–81		365 1978–81		366 1978–81		367 1978–81		364–367 1978–81	
	in Nos.	Growth p.a. (%)	in Nos.	Growth p.a. (%)	in Nos.	Growth p.a. (%)	in Nos.	Growth p.a. (%)	in Nos.	Growth p.a. (%)	in Nos.	Growth p.a. (%)	in Nos.	Growth p.a. (%)	in Nos.	Growth p.a. (%)
Managerial staff	+582	3.67	+191	2.83	+48	1.08	–350	–2.13	+126	3.23	+393	2.70	+592	4.13	+761	1.54
Scientists & technologists	+1,502	11.72	+2,250	24.25	+6	0.32	+312	1.90	+250	7.73	+2,180	14.11	+3,676	9.20	+6,416	8.56
Technicians & draughtsmen	+690	2.03	–1,145	–4.99	–197	–4.18	–522	–1.97	+415	5.99	+693	3.29	+1,010	1.80	+1,596	1.44
Administration & professional staff	+1,193	6.78	+951	8.62	–217	–2.80	–950	–4.92	+507	9.66	+1,774	6.61	+2,050	10.15	+3,381	4.71
Clerical	–1,338	–3.54	–294	–1.40	–633	–7.52	–1,916	–8.88	–565	–5.34	+406	1.66	–470	–0.96	–3,549	–3.03
Supervisors & foremen	+33	0.24	–1,390	–11.96	–58	–1.61	–895	–5.89	–545	–8.90	+169	2.09	+458	3.40	–817	–1.90
Craftsmen	–794	–2.17	+551	4.36	–355	–13.03	–961	–4.39	–640	–12.98	+506	7.02	+778	2.42	–317	–0.48
Operators	–5,006	–5.56	–3,010	–3.83	–2,962	–13.81	–12,985	–9.67	–13,230	–17.60	–1,153	–3.18	–1,505	–2.67	–28,873	–9.54
Other employees	–1,240	–10.71	–155	–2.62	–400	–8.83	–1,708	–15.49	–1,062	–24.00	+259	6.82	+225	2.05	–2,286	–7.49
Total	–4,378	–1.62	–2,051	–1.14	–4,768	–8.00	–20,977	–7.14	–14,752	–12.15	+5,230	3.31	+6,814	2.33	–23,688	–2.73

Source: EITB

KEY:
354 - Instrumentation
363 - Telecommunications
338 - Office equipment
364 - Electronic components
365 - Electronic consumer goods
366 - Electronic computers
367 - Electronic capital goods

Section III
Employment Prospects in the Electrical and Electronics Industries

This last section attempts to 'forecast' for the eighties and nineties the likely employment levels in the electronics and electrical industries, using a vintage capital-simulation model, developed by Clark (1980). Such a model 'simulates' the temporal development of the output and employment potential associated with successive 'vintages' of fixed capital. It will be used here as a sector-specific model, i.e. it will not take into account possible employment 'creating' inter-industry effects, which admittedly might be important in the electronics industry with the further diffusion of microelectronics to other industrial and service sectors. These inter-industry effects will only be captured in a 'full-blown' 'macro-economic' input/output forecasting exercise which does not fall within the scope of this book. The major advantage of using a vintage model as a forecasting device lies in the fact that it allows one to take into account technical change embodied in the existing capital stock and thus provides probably the most informative industry-specific forecast (assuming no major discontinuities in trend). Furthermore, for a fast-growing industry such as electronics, very much characterised by rapid, expanding investment (the so-called process of 'capital widening'), it will be interesting to compare the performance in terms of 'reasonable' employment forecasts of such a vintage model, designed in the first instance to take into account the effects of rationalisation and 'capital deepening' investment. After a brief description of the model[1] the results, both in terms of employment forecasts for the electronics and electrical industries and the various electronic subsectors, are presented in Chapter 11. In Chapter 12, an attempt is made to specify the occupational structure of the employment forecasts obtained in Chapter 11.

10

A CAPITAL VINTAGE SIMULATION MODEL AS EMPLOYMENT FORECASTING DEVICE

As mentioned above, the model used here is a simulation of the temporal development of the output and employment potential associated with successive 'vintages' of fixed capital. At each step, the quantity of capital scrapped during the preceding year is estimated,[2] and from this the 'lost' production and employment potential calculated. From these quantities and the available data on output and employment it is possible to work out the notional increments of labour and output associated with plant and equipment coming onstream in the year in question. For example, let us assume that L^s is the estimate of labour shed through plant scrapping, and L_1 and L_2 are the total numbers employed in the previous and current years respectively; a first approximation to the number of workers associated with 'new' plant and equipment is taken to be $\Delta L = L_2 - L_1 + L^s$, and the corresponding 'marginal best-practice intensity' (marginal capital/labour ratio) of this vintage of equipment is assumed to be $I/\Delta L$, where I is the magnitude of gross investment expenditure.

It is obvious that by no means all the variation in this marginal ratio is caused by year-to-year changes in the nature of the technology embodied in the newly-installed capital equipment. 'Labour-hoarding', 'shake-outs' and numerous other phenomena can have a significant, often dominant effect on the marginal ratio calculated as above. The assumption used here is that the larger the change in the marginal coefficient from the value in the previous year, the higher the *proportion* of the change ascribed to short-term factors. The marginal or best-practice ratio finally associated with equipment installed in the current year is, therefore, not allowed to vary from that of the previous year by more than a given percentage.[3] The remainder of the 'apparent' change in the marginal ratio—that ascribed to short-term factors—shows up as a change in the utilisation rate of labour. For example, a 'shake-out' of year-to-year employment figures without a corresponding large decline in production would show up in the model mainly as an increase in the utilisation of labour variable rather than as a dramatic reduction in the labour/capital ratio associated with that year's 'vintage' of equipment.

A similar procedure is used to split 'apparent' changes in the incremental capital/output ratio between the technological characteristics of the latest vintage of equipment and the utilisation of capital equipment. Having obtained these two ratios notionally associated with the latest generation of investment goods, the third—the marginal or 'best-practice' output-labour ratio (labour productivity)—follows by definition.

In defence of these apparently arbitrary distinctions, it can be argued that the main purpose of this analysis is only to capture major trends in rates of technical advantage over several years, rather than striving for precise year-to-year estimates. It also turns out that in many cases the qualitative results obtained are insensitive to the detailed assumptions regarding the 'allowable' change in the technological ratios. Further checks with other estimates of utilisation rates are unfortunately not available separately for the electronics and electrical industries. However, in general one would not expect these rates which, by assumption, are due to variations in short-term factors, to show any long-term secular trend. Beyond this, except in those rare cases where direct measures of best-practice ratios are available, appeal must be made to plausibility and readiness of interpretation by individuals familiar with detailed sectoral developments.

Notes

[1] For more detail we refer the interested reader to Clark (1983).

[2] As a first approximation, official statistics using the so-called 'perpetual inventory method' of estimating the capital stock are used in this procedure. That this method is frequently of dubious reliability is readily acknowledged; it is, however, easy to test alternative methods of estimating scrapping and to test the sensitivity of the model to the assumptions regarding scrapping.

[3] The procedure is as follows: the ratio $R^{(1)}$ of the first approximation to this period's technical coefficient to last year's coefficient is found and the 'embodied' part $R^{(2)}$ is calculated using an S-Curve: $R^{(2)} = \alpha/(1 + \beta_{\epsilon}\gamma R^{(1)}) + \theta$. This ensures that the ratio cannot exceed $(\alpha + \theta)$ nor be less than θ. The coefficients are chosen such that if $R^{(1)} = 1$, $R^{(2)} = 1$ also, i.e. there is no amendment to the 'apparent' coefficient.

11

EMPLOYMENT FORECASTS FOR THE UK ELECTRICAL AND ELECTRONIC INDUSTRIES

Having at our disposal both the official UK capital stock estimates (at more or less Order level) and the more disaggregated MLH capital stock estimates made for the Office of Fair Trading by Dick Allard (Queen Mary College), it is possible to present results for the broad electronics and electrical industries and the various electronic subsectors.

(a) The broad electronics and electrical industries

The model allows one to forecast employment levels assuming particular rates of output, investment and best-practice productivity growth. To avoid the difficulty of choosing a set of particular growth rates we will simply present results for a set of 'historical' output and investment and best-practice productivity growth scenarios.

In Scenario I we assume the same set of output, investment and best-practice productivity growth rates as those which the industry witnessed over the period 1954–80.

In Scenario II we assume the same output and investment growth rates as those which the industry witnessed over the seventies (1970–80), with the same best-practice productivity growth levels as in Scenario I.

Finally, in Scenario III we assume the same output and investment growth rates as in Scenario II, i.e. as those which the industry witnessed over the seventies (1970–80), whereas best-practice labour productivity growth is, in typical 'vintage' tradition, assumed to grow at 5 per cent a year, and the capital/output ratio assumed to remain constant.

Table 25 presents the employment forecasts obtained for the electronic and the electrical industries.

The forecasts given in Table 25 suggest that there is still a significant employment creation 'potential' in the electronics industry despite the recent fall in employment in the industry. Even in the case of the more recent pessimistic Scenario II employment recovers over the eighties and increases over the nineties, though only slightly—at a rate of 0.95 per cent a year. In the case of the broader, historical Scenario I which, it could be argued, is more realistic in view of the potential for further diffusion of electronic equipment throughout a large number of industries and services, employment will have increased by 1995, by an additional 100,000 jobs.

Interestingly, the employment prospects for the *electrical* industry are not as negative as could be expected from the significant employment losses which have characterised the industry since the mid-sixties. In the case of Scenario II, i.e. assuming a further fall in output of ±0.1 per cent a year, employment will further fall at a significant rate (−3.2 per cent a year). Following Scenario I, however, employment, after a further decline in the mid-eighties, will stabilise over the late eighties and nineties at about 350,000.

The extent to which these forecasts sound reasonable is of course very much open to debate. However, the assumptions about output, investment and best-practice productivity growth levels are of crucial importance in altering the 'predicted' employment levels.

Table 25: Employment forecasts for the electronics and electrical industries

	1982 Employm. (Actual Value) (1,000s)	Assumed		Employment Forecasts		
		Output Growth (p.a. %)	Best-Practice Labour Prod. Growth (p.a. %)	Average Annual Growth 1982–90 (p.a. %)	1990 (1,000s)	1995 (1,000s)
Electronics						
Scenario I	297.7	7.9	6.1	2.30	357.8	400.1
Scenario II	297.7	6.3	6.1	0.95	321.2	337.5
Scenario III	297.7	6.3	5.0	1.38	342.5	362.9
Electrical						
Scenario I	347.7	3.3	3.4	0.10	350.4	358.1
Scenario II	347.7	−0.1	3.4	−3.17	269.8	235.1
Scenario III	347.7	−0.1	5.0	−3.52	262.4	220.5

Thus, as illustrated in Scenario III, an across-the-board assumption of a 5 per cent growth in best-practice labour productivity and a constant K/O ratio, while using the output and investment growth rates of Scenario II, produces more significant gains in employment for the electronics industry and more significant employment losses in the electrical industry.

(b) **The electronics subsectors**

Employment forecasts for the various electronic subsectors are given in Table 26 using the same three scenarios but with a different timescale, due to the availability of output data.

Scenario I assumes the same output, investment and best-practice productivity growth levels as the various electronic industries have witnessed over the period 1959–80.

Scenario II, the more recent one, assumes the same best-practice productivity rates as in Scenario I but output and investment are assumed to grow at the same rate as they did over the period 1974–80.

Scenario III assumes the same output and investment growth rates as in Scenario II, but with best-practice labour productivity growing in all sectors at 5 per cent a year, and a constant K/O ratio.

Interestingly, for both electronic computers (MLH 366) and electronic capital goods (MLH 337) significant employment gains are forecast *whatever the specific scenario*. Even in the case of the relatively pessimistic Scenario II, employment in the electronic computer sector will have increased by 50 per cent in 1995, while in the electronic capital goods sector it will have increased by nearly 20 per cent. In the two other electronic subsectors—electronic components and electronic consumer goods—Scenario II forecasts significant job losses. Overall though, in terms of the broad historical scenario (Scenario I), all four electronic subsectors witness gains in employment; in consumer goods, a practically insignificant gain to 22,800 by 1990, well below the 69,000 employ-

Table 26: Employment forecasts for the electronics subsectors

	1982 Employment (actual value) (1,000s)	Assumed		Employment Forecasts		
		Output Growth (p.a. %)	Best-Practice Labour Prod. Growth (p.a. %)	Average Growth 1980–90 (p.a. %)	Employment levels 1990 (1,000s)	Employment levels 1995 (1,000s)
Electronic Components						
Scenario I	108.2	8.1	7.1	2.71	134.4	150.0
Scenario II	108.2	2.3	7.1	−1.91	92.9	85.8
Scenario III	108.2	2.3	5.0	−1.49	96.0	91.7
Electronic Consumer Goods						
Scenario I	22.6	2.0	2.6	0.09	22.8	22.8
Scenario II	22.6	−2.8	2.6	−4.43	15.9	12.8
Scenario III	22.6	−2.8	5.0	−4.73	15.5	12.2
Electronic Computers						
Scenario I	58.9	21.3	15.7	6.49	99.0	128.5
Scenario II	58.9	18.8	15.7	3.34	76.9	84.5
Scenario III	58.9	18.8	5.0	9.07	121.7	210.5
Electronic Capital Goods						
Scenario I	108.0	5.7	4.5	1.70	123.7	134.7
Scenario II	108.0	4.5	4.5	0.82	115.3	121.3
Scenario III	108.0	4.5	5.0	0.81	115.2	121.0

ment peak of 1973; in components a significant gain to 150,000 by 1995; in capital goods a similar gain to 134,700 by 1995; and a dramatic gain to 128,500 by 1995 in computers.

In Scenario III the 5 per cent best-practice labour productivity growth assumption, compared to the actual 15.7 per cent growth rate in electronic computers, and combined with an 18.8 per cent output growth rate, leads quite naturally to a very high employment forecast in electronic computers which is clearly a significant overestimation. In the other sectors the forecasts obtained with Scenario III are more or less in line with the forecasts using Scenario II.

The forecasts given in both sections (a) and (b) all point to the relatively important future employment potential of the electronics industry, despite the present stagnation and actual fall in employment in the industry. An important assumption behind these forecasts is that the UK industry will be capable of fighting off foreign competition; the model used here is indeed a 'closed' economy model. The extent to which import penetration or more fierce competition on the UK export markets might both reduce the growth potential of the UK industry, and put pressure on a more rapid introduction of labour-saving rationalisation investment, remains a question open to debate. The forecasts given in Tables 25 and 26, particularly those related to Scenario I, might consequently depict a too optimistic picture of future employment trends in both the electrical and electronics industries.

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EMPLOYMENT FORECASTS BY OCCUPATIONAL CATEGORY

We conclude this section by presenting some forecasts for the various broad occupational categories of the electronics industry. In view of the significant employment *growth* forecast—between 25,000 and 60,000 additional jobs by 1990—such an exercise seems particularly worthwhile. Skill bottlenecks might indeed become a significant growth-inhibiting factor and specific training provisions a most obvious and relatively easily implementable policy. If anything, it becomes essential to utilise fully the employment growth potential of the electronics industry.

Table 27 presents for each of the nine broad occupational categories the employment levels and employment gains and losses predicted for 1990 and 1995 in the electronics industry, based on the overall employment forecast using a combination of Scenario II and Scenario III given earlier, and considered here as probably the most reasonable ones.

Table 27: Employment forecasts in the electronics industry (MLH 364–367) by occupational category

Occupational Categories	1980 Employment Level	Employment Forecasts			
		1990 Employment Level	Gains/ Losses	1995 Employment Level	Gains/ Losses
Managerial staff	16,917	26,609	12,692	34,721	17,804
Scientists and technologists	25,658	47,185	21,527	53,606	27,948
Technicians, inc. draughtsmen	38,697	48,096	9,399	47,122	8,425
Administrative and professional staff	26,176	43,603	17,427	72,632	46,456
Clerical	40,578	39,583	−995	35,076	−5,502
Supervisors, inc. foremen	15,101	19,383	4,282	19,841	4,740
Craftsmen	22,822	21,237	−1,585	17,715	−5,107
Operators	104,525	82,559	−21,966	68,734	−35,791
Other employees	10,934	6,660	−4,274	4,960	−5,974
TOTAL	301,408	337,900	36,492	354,300	52,892

As Table 27 illustrates, the employment gains are particularly concentrated in the highly-skilled categories: managerial staff; scientists and technologists; and administrative and professional staff. By contrast, significant employment losses are forecast in operators, and to a lesser extent in other employees, clerical and craftsmen.

As indicated in Table 27, the overall electronics employment growth of 52,892 (by 1995) is accompanied by an increase of around 100,000 in the four most skilled categories, with a decline of about 50,000 in the lowest skilled categories. Such a trend illustrates well the importance of the skill factor both for employment growth and employment displacement, and points directly to the crucial role of training and retraining policies in providing the necessary 'labour supply' conditions if the electronics industry is to take full advantage of its own rapid rate of technical change.

CONCLUSIONS

As we hope this book has illustrated, an analysis of the implications of technical change (and in particular microelectronics) for the future of the electrical engineering industry needs to separate out the electronics industry from the other, primarily electrical industry. How this can be done in a more or less acceptable way has been discussed in more detail in the Introduction to this book, and much of what followed was an attempt to do so. Suffice it to say here that, as much in terms of the speed and the nature of technical change itself as in terms of economic performance, such a distinction is essential in order to understand some of the complex interactions between technical change in the electrical engineering industry and the employment growth and displacement in which it has resulted both within the industry and in the economy at large.

Electronics is of course the sector that has witnessed very rapid technical change. Nearly a third of total R & D spent in the United Kingdom in the business enterprise sector relates at present to electronics technology. The latter, from the emergence in the fifties of 'semiconductor' technology—vastly superior to the old valve and electro-mechanical-based technologies—to the recent 'microelectronics', corresponds indeed to a major new technological 'paradigm', with an overall economic impact that can be compared to that of the steam engine, railroads or electricity in the last century.

Yet apart from its own dramatic technological performance, it is primarily the so-called 'pervasiveness' of microelectronics which 'promotes' it to the concept of a radical new technological system or technological paradigm. It is the extent to which it affects virtually all sectors of the economy, both manufacturing and services, that is one of its most striking and crucial features.[1] As with other major technological paradigms, the 'diffusing' process is a relatively slow and gradual one. It is, however, also a highly diversified process, the technology diffusing rather rapidly through some sectors and very slowly in other sectors of the economy. McLean and Rush (1978) and Freeman (1982), have tried to classify the various sectors of the economy in terms of the speed by which 'electronification' would take place. Both studies point towards the electronic sectors themselves as being, quite logically, the first to be affected by the rapid diffusion of microelectronic technology over the sixties and seventies. In most other sectors the diffusion process, now more than twenty years after the first major semiconductor innovation, is still in its infancy and can be expected to accelerate in the future.

Some of the economic evidence presented in Section II of this paper lends support to this argument. The specific nature of technical change in electronics, affecting both labour and capital best-practice productivity, emerged quite strongly out of the analysis in Section II.2. Underlying the dramatic growth in best-practice capital productivity in electronics and in electronic computers in particular, one observes, we would argue, the rapid diffusion in that sector of, in the first instance, semiconductor technology, the impact of which can be compared to a process of more or less continuous material-saving technical change. Some of the implications of such diffusion for the 'technological performance' of the computer industry were illustrated in Tables 3 and 4 in Section I.

Semiconductor technology, as indicated in Table 2, Section I, has indeed led to a dramatic absolute and relative fall in the price of semiconductor output.

This process, we would claim, has in many ways been responsible for the specific capital-saving nature of technical change in the electronics industry, and particularly in electronic computers, the most important user of semiconductor output. The evidence on this issue remains, however, speculative, and might to some extent be the result itself of measurement problems. At the same time though, the extent of the 'capital-saving' bias or more precisely of the simultaneous growth in best-practice labour and capital productivity, as illustrated in Figures 19 and 20, and the underlying dramatic growth in 'technological' performance presented in Figures 3 and 4, is quite striking. It certainly provides support for the argument that the further diffusion of electronic equipment and electronic computers in particular, which could be referred to as 'intelligent' capital, must have a significant overall growth impact on the economy. That growth impact will be most significant in those sectors of application of microelectronics where productivity growth has been the hampering factor behind output growth; one can think immediately of a large number of services. Furthermore, there could be significant growth potential for those areas of application of microelectronics where the significantly increased productivity growth might improve the international competitiveness of the sector.

But more interestingly, there are straightforward growth implications in the replacement of electromechanical, or first- (and possibly second-) generation electronic capital equipment by new, third-generation electronic capital equipment which should lead to significant savings in terms of capital expenditure and thus in principle to higher profits. The result might well be the restoration of the profit rate in a large number of capital-intensive sectors which have been suffering from low profits. More straightforwardly, if these gains from technical change and from capital-saving technical change in particular are translated into lower prices, this should again lead to increasing demand for that sector's output. What the implications of such a capital-saving diffusion pattern are for *employment* remains, however, an open question. On the one hand one can expect a rather dramatic employment displacement effect in those areas of application of microelectronics where straightforward 'substitution' of capital for labour will occur and will not be fully 'compensated' for by output growth (one can think in particular of those sectors which have limited output growth because of possible saturation effects—see Freeman *et al.* 1982, Chap. 7). On the other hand, there is at least potential for employment growth in those areas where the diffusion of microelectronics has led to significant output growth. Here one would expect that the possibilities for employment growth depend very much on the existing output/employment growth relationship.

It must be emphasised, however, that the overall employment implications of microelectronics can only be analysed within a macroeconomic model. In microelectronics itself we forecast in Section III a continuous growth in employment primarily based on successive vintages of computers, moving from large main-frame to mini- and now to micro-computers (in which the United Kingdom seems to have captured a significant market share), to even further developments of other and newer vintages of computers. Whereas the employment forecast for the electronics sector and the electronic capital sector itself are positive and indicate further employment growth in these sectors, the overall economy-wide employment implications of the application of microelectronics cannot be judged from this paper. They depend in the first instance on the relationship between output and employment growth in each sector and on the overall impact of the productivity gains of microelectronics, both in terms of labour productivity and in terms of capital productivity, on output growth. Both these relationships can only be analysed through the use of a macro-economic model. We therefore need to say far more about, and need to analyse in far more detail, the process of the diffusion of microelectronics, which we would like to refer to as 'intelligent capital'. Information on the number of computers in use in various sectors (as illustrated by the mini-computers in use in the Japanese industry, see Table 23) provides a first indication of such diffusion. Ideally though, one needs to distinguish between investment data in 'electro-mechanical' and 'electronic', intelligent machinery, if one is to understand fully the specific features and implications of the diffusion and penetration of microelectronics for employment growth and displacement in the economy at large. This then becomes, in our view, one of the most important issues for further research.

Notes

[1] To quote Freeman *et al.* (1982), 'It is indeed difficult to think of an industry or occupation which will *not* be affected by micro-electronics. The former Conservative Party spokesman on technology, Ian Lloyd, could think of only a few; among them were the makers of top hats, handloom weavers in the Outer Hebrides and psychoanalysts. He may well have been wrong about at least two of these.'

Table 28: Number of mini-computers in use in Japan by industry—1969–76

Industry breakdown \ Term	1969		1970		1971		1972		1973		1974		1975		1976	
	Q'ty	Value	Q'ty	Value	Q'ty	Value	Q'ty	Value	Q'ty	Value	Q'ty	Value	Q'ty	Value	Q'ty	Value
Agriculture, forestry															1	10
Marine ind.									1	5	1	5	2	27	3	38
Mining ind.							1	61	6	245	11	331	17	379	19	508
Construction	1	9	5	41	17	181	26	328	45	604	71	838	88	1,101	100	1,253
Foodstuffs	2	16	3	34	7	66	13	138	23	328	61	807	77	1,005	93	1,194
Textiles	1	9	7	49	10	134	21	223	38	422	66	774	127	1,539	176	2,116
Paper-pulp	1	8	2	13	4	30	4	30	10	95	21	256	42	486	59	668
Publishing, printing			1	12	16	257	25	300	34	376	64	748	80	963	102	1,275
Chemicals, oil	24	552	54	990	85	1,552	116	2,179	195	3,019	293	5,126	499	9,123	596	11,059
Glass, cement			1	12	5	65	8	79	14	133	36	220	57	883	77	1,044
Iron & steel	29	526	40	743	95	1,868	117	2,186	145	2,541	214	3,837	356	6,608	467	9,338
Non-ferrous metals	3	26	9	75	24	256	27	300	36	441	49	610	92	1,449	104	1,626
Machinery	2	14	13	72	32	191	58	416	107	760	211	1,428	278	2,147	354	3,285
Electric machinery	12	63	129	752	380	2,556	676	4,769	862	6,148	1,486	11,617	2,063	18,652	2,432	22,720
(minicomputer mfrs.)	(3)	(9)	(85)	(409)	(248)	(1,480)	(442)	(2,796)	(513)	(3,299)	(839)	(6,286)	(1,258)	(10,914)	(1,420)	(13,058)
Other mfrs.	(9)	(54)	(44)	(343)	(132)	(1,076)	(234)	(1,972)	(349)	(2,849)	(647)	(5,331)	(805)	(7,738)	(1,012)	(9,661)
Transportation machinery	5	64	20	289	63	781	113	1,293	184	2,164	322	4,096	446	6,088	420	6,678
Precision machinery	2	13	13	88	28	175	52	343	79	579	127	848	149	1,043	206	1,571
Other mfrs.					6	45	10	96	15	153	36	381	88	883	177	2,305
Retailing trades	2	15	15	97	57	508	85	924	164	1,717	287	3,248	370	4,231	480	5,556
Insurance, finance			1	6	4	30	16	158	72	813	126	2,068	178	3,167	217	331
Real estate			1	5	1	5	3	17	9	112	13	193	16	240	20	4,005
Transportation			7	50	26	287	70	753	120	1,531	180	2,377	256	3,549	324	4,575
Electricity, gas			4	19	19	113	30	322	57	804	143	2,126	207	3,467	248	4,313
Services			5	36	30	295	99	796	214	1,927	356	3,871	480	5,376	715	7,976
Hospitals			2	13	3	32	17	152	32	339	39	469	81	1,120	136	2,156
Universities	51	321	115	802	256	1,804	402	2,912	594	4,355	872	6,485	1,081	8,626	1,314	11,025
High schools	3	11	6	24	34	185	80	571	165	1,067	248	1,649	293	1,984	321	2,251
Other schools			4	24	7	44	10	69	13	91	18	127	20	146	20	116
Local cooperatives	3	25	7	63	23	210	59	1,035	122	2,023	206	4,240	321	7,485	407	9,445
Governments	17	131	42	299	80	605	113	1,075	179	1,989	260	2,964	317	4,027	368	4,981
Government related	3	83	25	335	40	534	97	927	212	1,774	297	3,194	435	5,821	648	9,529
Agricultural cooperatives			9	82	23	276	37	539	59	801	107	1,662	138	2,223	175	2,660
Religious corp.					1	5	2	8	2	8	4	13	8	105	9	114
Private lab	4	16	9	59	15	94	33	246	38	423	44	453	55	592	83	805
Misc.	7	76	76	446	279	1,715	548	3,149	1,005	5,681	1,614	9,192	2,377	12,649	3,129	16,113
Total	172	1,929	625	5,530	1,670	14,897	2,965	26,395	4,851	43,457	7,873	76,253	11,094	117,176	14,060	152,671

Source: Japan Fact Book (1979)

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