Appendix 1

Microelectronics Technology and the Electronics Sector

I. INTRODUCTION

1.1 The application of microelectronics and information technologies is well advanced, and industries incorporating these technologies are expected to become the world's largest and most rapidly expanding economic sector during the second half of the 1980s.

1.2 The world electronics equipment market has expanded dramatically over the past fifteen years, from sales of some $50 billion in 1970 to an estimated $380 billion in 1985 (current values in each case). Although semiconductors are critical components, they usually constitute only a small fraction of total electronics equipment systems and costs. The demand for semiconductors has been expanding more rapidly, though at a lower level, than that for electronics equipment, rising in current values from $2.2 billion to approximately $35 billion over the same period; this trend is expected to continue in the long run, despite some cyclical fluctuations as, for instance, the one being experienced in 1985.

1.3 The use of semiconductors in the developing countries is very limited, and that in the centrally-planned economies is not very marked. Together their consumption was less than 10 per cent of the world total in 1983, while they produced only 2 per cent of the world supply. The most important developing country producers of semiconductors are the Asian newly industrialising countries (NICs). For example, of the $4 billion of semiconductors imported by the United States in 1982, $3 billion came from US offshore facilities in four Asian countries: Malaysia, Philippines, Singapore and South Korea.

1.4 The United States and Japan are net exporters of semiconductors: the United States produces nearly two-thirds and consumes about one-half of world production; and Japan produces more than one-quarter and consumes rather less. Western Europe, on the other hand, is a net importer, consuming about one-fifth of world production of semiconductors and producing less than half that proportion.

1.5 Consumption of different types of electronics equipment in the major industrial countries in 1984, given in Table 1.1 below, shows the dominance of data processing and office equipment and of the importance of the industrial and military sector usage in the United States. Similar information is not available for developing countries, but the approximate order of importance is likely to be industrial and military applications, data processing (computers), and consumer products.

Table 1.1

Consumption of Electronics Equipment by Major Industrial Countries, 1984

(US$ billion)

	USA		*Western Europe*	*Japan*
Data processing and office equipment	79.0	Data processing and office equipment	60.5	41.8
Software	15.0			
Consumer products	21.3	Consumer products	15.8	11.2
Communications	11.5	Communications	12.8	3.0
Industrial and military	57.1	Industrial and others	15.8	21.6
Total	184.0	Total	104.9	77.6

Source: Lalor (1984) p. 9.

1.6 Statistics on the product and sector use of microelectronics are also available only for industrial countries, and in any case are not always internationally comparable. However, Table 1.2, which indicates orders of magnitude, shows that whereas computers were the dominant end-user of integrated circuits (ICs) in the United States, consumer products were pre-eminent in Japan. In Western Europe, computers, consumer products, communications and other industrial uses were all of approximately equal importance.

Table 1.2

End-use Distribution of Integrated Circuits, 1982
(Percentages of sales)

<table>
<tr><th></th><th>USA</th><th>Japan</th><th>Western Europe</th></tr>
<tr><td>Industrial</td><td>72</td><td>49</td><td>70</td></tr>
<tr><td>Computer</td><td>40</td><td>13</td><td>25</td></tr>
<tr><td>Communications</td><td>21</td><td>10</td><td>20</td></tr>
<tr><td>Office automation equipment</td><td>5</td><td>19</td><td rowspan="2">25</td></tr>
<tr><td>Other industrial</td><td>6</td><td>7</td></tr>
<tr><td>Consumer</td><td>11</td><td>51</td><td>25</td></tr>
<tr><td>TV/VCR</td><td></td><td>22</td><td></td></tr>
<tr><td>Audio</td><td></td><td>14</td><td></td></tr>
<tr><td>Other consumer</td><td></td><td>15</td><td></td></tr>
<tr><td>Government/Military</td><td>17</td><td>0</td><td>5</td></tr>
<tr><td>Total</td><td>100</td><td>100</td><td>100</td></tr>
<tr><td>($ million)</td><td>(7,269)</td><td>(2,580)</td><td>(1,988)</td></tr>
</table>

Source: OECD (1985) p. 20.

1.7 Data on trends in microelectronics technology applications in developing countries are scarce, usually imprecise and often inconsistent. An examination of the major categories of computers (including software), industrial applications, and telecommunications shows that their diffusion is very limited. Developing countries therefore consume only a very small fraction of the world's semiconductors, perhaps only one per cent of ICs and two per cent of microprocessors.[1]

1.8 On the other hand, computer imports into the more industrially advanced developing countries have been quite dynamic in recent years, registering annual growth of between 30 and 40 per cent in some cases. The main importers (Asian and Latin American NICs) tend to demand the same kind of highly complex devices and electronic capital goods as the developed countries. Aggregate data are not available on the sectoral use of computers in developing countries but the most rapid growth has probably been in the public sector, followed by services and then industry. Typically the first computers used in developing countries were mainframes, often imported by subsidiaries of foreign companies for routine clerical work. Government purchases soon followed and the public sector remains the dominant user of mainframes. With the emergence of mini- and then micro-computers the situation changed significantly, and the use of mini-computers increased markedly during the 1970s. Data on micro-computers are more difficult to obtain but it seems that their use is increasing even in the poorer countries (in Bangladesh, for instance, only six micros were known to be in use in 1980 but by 1984 there were more than 150).

1.9 With the proliferation and declining cost of computing systems, demand for computer services[2] has grown exceedingly fast—much quicker than for most categories of computers. Although global estimates vary, the OECD Secretariat has assessed computer service revenues at $30.5 billion in the United States in 1982, $3.5 billion in Japan in the same year, and $16.2 billion in Western Europe in 1985. Figures for software production and use in developing countries are virtually non-existent. However, it is relevant to note that since the early 1970s, the value of software imports has exceeded that of hardware, and with the increasing, albeit still low, levels of computerisation in the developing countries, this generally constitutes an area of growing technological dependence. The only exceptions are those countries, such as South Korea, Singapore, India and Argentina, which are building up their own computer capabilities.

II. IMPACTS OF NEW TECHNOLOGIES ON THE ELECTRONICS SECTOR

Overview

1.10 The electronics sector encompasses a range of related industries. These can be categorised in various ways but here we divide the sector into: electronic components; consumer electronics; telecommunications;[3] computers; and software peripherals. These groups can of course be further subdivided; for example, within the components industry the main focus has been on semiconductor products.[4]

1.11 The variety of products emanating from the electronics sector, and their increasing application to the processes and products of other sectors, has caused microelectronics to be considered an essential element in the economic development of the modern state. The emergence of what has been called a 'new technological paradigm based on semiconductor developments'[5] has been at the heart of the microelectronics revolution which is currently affecting all industry groups within the electronics sector as well as a whole range of other economic sectors.

Electronic components

1.12 While it may be difficult to separate out the wide variety of what might be classified as electronic components, there is no doubt that the impact of semiconductor technology is at the core of the microelectronics revolution. It is on semiconductors that this section therefore focuses. The products of the semiconductor industry can be classified in a number of ways—in terms of their function (discrete devices/integrated circuits/special purpose devices); by the technology involved in their fabrication (bipolar or metal oxide); or by their scale of integration on a chip (from small-scale integration (SSI), with 30–80 transistors, to very large-scale integration (VLSI), with about one million transistors). The main and fastest growing product of the industry is the integrated circuit, and this is the area in which there is the greatest R & D effort, the greatest product innovation and the most significant impact on end-users.

1.13 The evolution of the semiconductor industry reflects a process of continuous technological change. This has increased the degree of product integration, improved product performance and reliability, enlarged the number of products, and caused a massive reduction in costs per device and per unit (bit) of processed information.

1.14 The semiconductor industry also possesses a number of features which distinguish it from other electronic sub-sectors. These include the high levels of capital intensity; high dependence on sophisticated and specialised scientific and engineering skills; high degrees of inter-relationship between the industry, its suppliers and end-users; and the dominance of US know-how and markets. Perhaps the most important of these characteristics is the pervasiveness of its technologies in end-user sectors: the impact of techological change in the semiconductor industry cannot be dissociated from that in end-user industries such as computers, industrial applications, military equipment. This has led both to closer linkages between semiconductor producers and end-users, and to backward linkages by end-users into semiconductor design and production. Another aspect of the interdependence of the semiconductor industry is its reliance on a range of specialist suppliers, with the high rate of product innovation requiring greater than usual dialogue between suppliers (whether of materials or knowledge inputs) and producers.

1.15 The results of the increased application of, and demand for, semiconductors are reflected in the increase in production, from a world-wide value of $400 million in 1959, to $1.7 billion in 1969, $15.4 billion in 1979, and an estimated $35 billion in 1985. Given that the reductions in unit cost have significantly exceeded the rise in values caused by inflation, these figures obviously underestimate the volume of growth in semiconductor production. But the increase has not been a steady one, and despite the close relationship of semiconductor suppliers and end-users, there have been marked swings in demand. For example, there was recession during 1974–75 and a slump in 1983;

though there was some recovery in 1984, demand in 1985 has been disappointingly sluggish and considerable excess capacity has reappeared in the industry.

1.16 The geographical concentration of the industry is such that in 1983 the United States, Japan and Western Europe together accounted for 98 per cent of world production of semiconductors and a slightly higher share of that of ICs. The United States alone accounted for 73 per cent of IC production in 1980 but, like that of Europe, its proportion has since decreased, whereas that of Japan has increased.

1.17 This expansion in world production has been accompanied by considerable changes in the nature of the semiconductor industry. Until the 1960s it had been characterised by low barriers to entry and expansion. Many of the small firms that entered at that time (particularly in the United States) grew substantially both in size and in market share. But even by the mid-1960s, firms in Western Europe and Japan began to face considerably greater difficulties in entry, because of the increasing complexity of semiconductor products, the technological lead of earlier entrants and the higher R & D costs necessary to be competitive. Despite this 'classical maturation' process, the continuing product and process innovation in the semiconductor industry emphasised its increasing capital intensity and reliance on a high degree of specialisation by skilled workers. The requirement for higher capital expenditures reflects the increased complexity of the products, with consequently more sophisticated production processes and a need for more sophisticated quality control. One estimate[6] of the minimum investment for semiconductor production suggests an increase from $100,000 in 1954 to $60 million in 1982 (see Table 1.3 on facing page).

1.18 These increases in capital costs have been paralleled by increases in R & D costs. The industry is characterised by high technical and commercial risks, which are magnified by its rapid product innovation and obsolescence. In order to maintain a competitive position, firms must devote considerable resources to R & D, especially since the increased competition caused by the rise of production in Japan. But though R & D expenditures have risen markedly, their size as a proportion of sales has tended to remain fairly steady, ranging from around 8–10 per cent in the United States to 13–15 per cent in Japan.

1.19 The complexity and dynamism of semiconductor technologies have also had impacts on the pricing policies of major companies. Learning-curve economies, together with economies of scale and predatory pricing to establish market shares, have reduced the ability of new producers to enter the market and favoured larger companies over smaller ones.

Table 1.3

Estimated Minimum Investment for Semiconductor Production

Year	*$ Required*
1954	100,000
1958	300,000
1967	500,000 (a)
1972	2,000,000 (a)
1976	5,000,000 (a)
1978	10,000,000 (a)
1982	60,000,000 (b)

(a) Wafer fabrication only.
(b) Total wafer-assembly cost.
Source: Truel (1980).

1.20 All these elements have combined to alter the minimum efficient scale of semiconductor production. Larger companies are in a much better position than smaller ones in terms of their ability to obtain capital and skilled labour, and thus in their capacity to undertake R & D and maximise scale economies in production, and hence to follow aggressive pricing policies. While there are differences within the industry (for example in degrees of integration, or production of standardised compared with customised products), there is no doubt that size has become a very important barrier to entry into the semiconductor industry. Its effectiveness is evident from the recent intensification of efforts at national or supra-national cooperation, particularly in R & D, as in the case of the EEC Esprit programme. The quest to achieve larger scale has also contributed to the increasing trend for large companies (including transnational corporations (TNCs) and national or international consortia) to acquire smaller companies. There are two inter-related issues. First, many large companies are seeking rapid access to 'frontier' technologies which may sometimes be developed in smaller firms. Secondly, smaller companies are recognising a growing need for collaboration if they are to increase their access to the capital necessary to produce effectively in an increasingly competitive international market.

1.21 The impact of new technologies in the semiconductor industry has also been significant in terms of changing skill requirements. Evidence shows a continuing decrease in production workers as a proportion of the industry's labour force. Skilled workers (such as technologists, engineers and technicians) now predominate in all sections of the semiconductor industry, as can be seen from the data in Table 1.4.

Table 1.4

Effect of Changes in Technology on the Composition of the Labour Force

(Percentages)

	Electromechanical components	*Integrated Circuits*	*Large-scale integrated circuits*
Engineers and technicians	5	10	30
Qualified workers	60	70	35
Non-qualified workers	15	20	35

Source: H. Correa de Mattos, *Technology and Developing Countries,* International Telecommunication Union, Third World Telecommunication Forum, Geneva: ITU, 1979.

1.22 The highly specialised requirements of the industry have combined with the rapid changes in products and processes to create a demand for teams of scientists, engineers and designers. While increasing use is being made of automatic systems, this has been mainly concentrated on circuit verification and testing; designing elements have remained relatively labour-intensive. The limited supply of design engineers has had two effects: first, to act as a potential brake on the growth of custom products and in favour of standardised products; secondly, to cause very high levels of mobility within the industry, on both a national and an international basis.

1.23 At the national level until the 1970s, this mobility of technical personnel was considered a very significant factor in the creation of most new semiconductor firms, particularly in the United States. It resulted in increased transfers of technology and greater innovation. Subsequently mobility has come to be seen as a constraint on the development of the US industry, as it entered a more mature stage. Japan has seen little such mobility and may consider its relative stability in personnel to be an asset, particularly in R & D.

1.24 At the international level, the increase in demand for skilled personnel has had impacts in both developed and developing countries. The high salaries, mobility and career prospects in the United States have resulted in an important inflow of personnel from Western Europe (particularly Britain), with consequent problems for the development of this industry in Europe. There has been a similar brain-drain in respect of developing country personnel. As semiconductor industry technology has become more knowledge-intensive, this mobility of labour among firms and countries has also become more important, and its impacts are reflected in the location of production.

1.25 Technology has been a significant determinant of the location of the semiconductor industry. During the 1960s and 1970s US, West European and Japanese producers had set up some 120 plants in almost a score of other countries. Over two-thirds of these facilities belonged to US producers, whose offshore capacity was at one stage estimated at 37 per cent of the American total.[7] In the early years this move to offshore plants was caused by the desire for cost reduction, especially through the use of cheaper labour, and was made possible by the nature of the production processes. The assembly of semiconductors is labour intensive and in the earlier phases of the industry's expansion, assembly represented a significant part of total costs. While much of the move to offshore locations by US firms was related to the expansion of capacity, the motivation of the European and Japanese companies may have been influenced more by the desire to acquire new technology, be closer to end-users and, in Japan's case, to avoid trade frictions. These differing emphases were reflected initially in the tendency for US companies to expand production in developing countries and for European and Japanese companies to locate in other developed countries.

1.26 The changes in technology in semiconductors have, however, resulted in a decrease in the proportion of value added by offshore plants, and a fall in their share of production of the more sophisticated products. The increasing complexity both of products and of processes, and the expansion in vertical integration and inter-firm cooperation, suggest this trend will continue. As the industry has become more dependent on R & D, there has been an increasing trend to locate entire manufacturing processes in the parent country. Production offshore has in general focused increasingly on older-type devices, rather than keeping up with the technical developments of the industry.

1.27 This tendency to concentrate the new processes and products in firms' parent countries has been reinforced by the significant role which governments have played in the industry through procurement, R & D, and investment. Both government procurement and involvement in R & D have been major contributors to technological change.

1.28 Offshore production, particularly in its initial stages, has bestowed substantial economic benefits on some developing countries, contributing to increased exports and job-creation. However, almost all the semiconductor technologies have characteristics which cause most developing countries difficulty in gaining access to the industry. Particularly important are the high start-up costs; the need for specialist equipment, suppliers and skilled labour; the rapid innovation of technologies; and the possibilities for substitution between production processes. Even the technologically more advanced developing countries (notably the NICs) may have considerable difficulty in keeping abreast of the industry's rapidly moving technological frontier.

Consumer electronics

1.29 The consumer electronics industry includes a wide variety of products of differing degrees of sophistication. It does however exhibit a number of common trends resulting from the application of new technologies. First, there has been a proliferation of new products, based on microelectronics. The rapidly increasing demand for these products has stimulated the renovation and resurgence of what had largely become a mature industry. Secondly, the new technologies have significantly altered the unit cost, content and function of many consumer electronic products. While functions have greatly increased, unit costs/prices have sharply decreased (for example, in business calculators, the price per unit of function decreased from $170 in 1965 to around $5 in 1980).[8] Thirdly, there has been a process of transforming products from discrete devices to components in integrated systems; for example, cash registers have changed from adding machines to interactive data terminals.

1.30 These developments are typical examples of the trend towards convergence in the electronics sector. This has several implications. First, components integration has resulted in a shift in value-added away from final products manufacture towards components and hence components manufacturers. In the case of calculators the cost of components and materials during the electromechanical era had been around one-fifth of the total, but with the introduction of electronics it increased to three-fifths. On the other hand, the cost of labour was reduced from 23 to 5 per cent.[9] Secondly, integration into systems has led producers to move from components production into supplying total systems (with similar implications in costs of entry as those in semiconductors noted above). Thirdly, the need has arisen for communications networks to enable 'systems' to interact. Fourthly, the dynamics of new technologies have drastically reduced the product cycle duration, with a consequential need for increased flexibility of both management and production workers.

1.31 In contrast to the semiconductor industry, consumer electronics has until recently involved a relatively high amount of labour-intensive assembly work. It therefore offered a relatively easy point of entry for developing countries; the export of consumer products by Asian countries in the 1960s and 1970s expanded at more than 20 per cent annually. While the involvement of TNCs in local assembly was crucial in the early expansion of the industry, a number of developing countries were able to develop a strong local industry in some of the more mature products.

1.32 The emergence of Asian countries as the dominant source of consumer electronics products was the principal feature of the industry during the 1960s and 1970s. Reflecting a competitive advantage based on low labour costs, many other developing countries attempted to follow the same path. Indeed, in certain product categories, new entrants in developing countries may still be able to retrace earlier steps, and by concentrating first on satisfying the domestic market, they can probably do so without external involvement. However, where the intended objective is to export more sophisticated products, a whole new set of difficulties has arisen.

1.33 Again, the situation of Asian developing countries is instructive. Despite a growing local industry, most of the consumer electronics producers in these countries have been heavily dependent on Japanese multinational companies either for know-how or for components. On average the countries imported more than 70 per cent of their ICs, precision component parts and colour TV components from Japan.[10] Such dependence has proved a problem for the producers in these countries as they try to upgrade their product capabilities.

1.34 The changing technologies in consumer electronics have many impacts which are similar to those in the semiconductor industry. The speed of technological development, inadequate technology transfers and increased international competition have all made entry much more expensive and difficult. The introduction of improved products and process automation have tended to erode the developing countries' labour cost advantage. A comparison of the costs of manufacturing electronic devices in Hong Kong and the United States shows that the difference is very much less with semi-automated processes than with manual ones, and is almost negligible with automatic processes[11] (see Table 1.5 overleaf).

1.35 There has been increasing evidence in consumer electronics of the greater use of scale economies to achieve market dominance and of significantly altered investment patterns. Both have accentuated the development of newer consumer electronics products in the major industrial countries. The experience of the NICs, however, suggests that flexibility to exploit changes in demand may enable some developing

Table 1.5

Manufacturing Cost per Electronic Device
(US dollars)

Process	*Hong Kong*	*United States*
Manual	.0248	.0753
Semi-automatic	.0183	.0293
Automatic	.0163	.0178

Source: Rada (1984).

countries to fill a variety of product niches. For example, Hong Kong has moved out of those lines for which demand is sluggish, including table calculators, dictating machines and tape recorders, into those where it is more buoyant, such as portable colour televisions and electronic watches. The decreasing unit prices of semiconductor devices also offer possibilities for introducing new technologies into other consumer products such as toys.

1.36 In general, however, the developing countries' shortages of skilled labour have reinforced the trend for their output of consumer electronic products to be focused on those items whose production processes are technologically mature, rather than on those dependent on the latest technologies.

Computers

1.37 The computer industry also shows a wide range of products with different production structures. These products range from large, very expensive and highly sophisticated mainframes produced by a small number of TNCs, to very small and often simple computers produced by hundreds of small manufacturers. The evolution of the industry reflects its continuing response to the availability of new technology.

1.38 The impact of new technologies, particularly those emanating from the semiconductor industry, has largely affected computers in terms of their speed and cost per unit of operation, and memory capacity. The evolution of the first four 'generations' of computers reflects these changes: first generation, discrete components and hard valve technology; second, discrete components and separate transistors; third, based on integrated circuits; fourth, evolving into large-scale chip integration. The consequential gains in performance and reductions in cost have resulted in a very rapid expansion in world demand, although there have been considerable fluctuations in growth.

1.39 There are two major developments currently working through the computer industry, which further reflect its dependence on new technologies. The first is the blurring of the traditional lines and roles of computers. The emergence and phenomenal growth of demand for micro-computers has resulted from their cost and performance (with 16 and 32 bit processing capacity, the latter is approaching many mainframe computers). The second (at the opposite end of the scale) is the development of fifth generation machines. These can be divided into two sub-groups, viz. computers involving artificial 'intellegence', and 'super-computers' applying vast processing power to classic number-crunching tasks. It is expected that, in future, super-computers will start to move along a similar price-performance curve to that already taken by other types of computers.

1.40 The key characteristics of the computer industry are the intensifying competition in most product lines and a consequent increasing resort to alliances and partnerships. The latter has, in turn, led to a rapid convergence of component, computer and other information technologies.

1.41 Many producers have been concerned not only with the growing cost of R & D in computer technologies but also with the increasing penetration of the industry by Japanese companies and the entry of the world's dominant computer company—IBM—into new segments of the market, particularly personal computers.[12] Other companies have responded by increased collaboration through what has been described as 'strategic partnering alliances'.[13] In the past a manufacturer usually supplied only one segment of the computer industry, such as software, mainframe or mini-computers. Now these products are converging and customers want to buy entire systems from one supplier. Manufacturers have therefore had to broaden their product lines very rapidly and most have either invested in other companies or bought technology and products from them.

1.42 But if these relatively large (second-tier) companies are now facing problems in maintaining their place in the changing industrial structure resulting largely from responses to new technologies, then the position of smaller companies (and of developing countries) is even more difficult. First, they have to face high capital investments in both R & D and production facilities. Secondly, they are very vulnerable to competition, not least because of their lack of product diversification.

1.43 The full implications of the impact of new technologies on developing countries' computer industries are, however, not yet fully clear. The vast increase in the range of applications of computers has led to a similar expansion of developing countries' demand (particularly for micros), but doubts remain as to their ability to satisfy this demand. While some local suppliers may be assured of advantageous positions in filling niches left by international suppliers, and may be able to build complete systems from off-the-shelf components, the apparent failure of the Brazilian experiment raises significant doubts. The problems faced in Brazil included the high cost and questionable quality of the locally produced units; the difficulties of Brazilian firms in keeping up with advances in technology and achieving self-sustaining growth, stimulated by indigenous innovation and supported by the expansion of domestic components production; and the aggressive responses of foreign firms barred from what they saw as an extremely lucrative market.

1.44 Another issue is the impact of technology on the developing countries' role as exporters of computers. Developed country manufacturers have turned increasingly to developing countries as a source of low-cost labour for assembling computers (primarily micros) and manufacturing competitively-priced components and peripherals. These initiatives have been undertaken to supply both developed country and local markets, and in the case of the NICs, such as Mexico, Brazil, Singapore and and South Korea, to serve regional markets as well.

1.45 This entry of foreign firms has been accompanied by the emergence of domestic producers of computers, particularly in the NICs. The same is true of production of computer parts and peripherals. For example, the Asian NICs have been able to exploit niches left by some of the major developed country suppliers of parts and peripherals; whereas none of the four biggest developing country producers, viz. Singapore, Hong Kong, South Korea and China (Taiwan), were exporting more than $300 million of these products in 1982, all expect to be exporting more than $1 billion worth in a few years time. China (Taiwan) and South Korea hope to become major suppliers of terminals, monitors and printers. South Korea already has 18 CRT terminal manufacturers with annual production of 306,700 units and nine printer manufacturers producing 23,000 units annually.[14] Singapore aims to become a major supplier of disk drives, while other developing countries, such as Malaysia, have entered the components market.

1.46 It is therefore possible that the combination of sourcing by foreign firms and exporting by domestic firms will lead some developing countries to become significant suppliers in particular segments of the computer industry.

1.47 Yet while there is scope for developing countries to design and produce computers, components and peripherals, by exploiting product niches, there is also evidence that the rapidity of change in technology may be increasing the barriers to entry in a similar manner to that we have observed in the semiconductor industry.

Software

1.48 The impacts of new technologies on the software industry are perhaps less marked than those on other parts of the electronics sector; those which are apparent, however, have a number of characteristics in common.

1.49 The high rate of growth of the software industry, developed through specialised computer service firms as well as hardware producers, has caused changes in operating practices. The increasing complexity of hardware and operating systems, the appearance of sophisticated new software engineering techniques, and the growing requirements of users, have all imposed more demanding conditions on software creators. Software houses now need more complex equipment and more highly-skilled personnel than in the 1970s; and these resources have become very scarce. Since the rate of innovation does not always allow time for employees to learn new skills, software houses are looking to external supplies of labour, while the qualifications they seek are becoming increasingly costly.

1.50 The likelihood of technology gaps emerging among computer service firms now seems greater than in the 1970s when software houses offering custom services had little competition and so were not obliged to keep abreast of the state of the art. But in the 1980s, the software-package phenomenon has compelled software houses to become much more competitive, both at home and abroad. Many houses have responded to the challenge by developing packages themselves. But apart from the technological prerequisites, this strategy implies undertaking substantial development investment for an uncertain return. Packages involve very different costs and risks from traditional custom-made software. They also require much more marketing activity than does custom software: for example, promotional campaigns should cover all potential markets.

1.51 All these factors considerably increase the financial costs of meeting competition in the computer services industry. For most software houses, these costs are a new constraint, prompting them to seek new financial and organisational arrangements. In the United States, where these trends have been taken furthest, there has been a very marked increase in mergers and acquisitions in the industry: there were 87 acquisitions, with a total value of $688 million, in 1980; 118, with a total value of $766 million, in 1981; and 146, with a total value of more than $1 billion, in 1983.[15] Many software houses which have grown rapidly and want to keep their independence have become public companies. But only those with established market positions can raise the necessary finance for this through merger or equity issue. New enterprises cannot do so, and neither can they hope to borrow from the banks, which are very cautious about financing such entities. The principal remaining source of funds for the entrepreneur is venture capital, which has become very important in some countries, especially the United States.

1.52 New technologies have also had some impact on software productivity (notoriously difficult to measure) through the application of automation to the coding, 'debugging' and testing/development stages. These have proved amenable to change brought about by the use of structural programming, programme generator software, and automated testing. Software production is also being influenced by the move to fifth generation (artificial 'intelligence') computers and by the development of 'firmware', although evidence of the scale of their impact is not yet readily available.

III. CONCLUSION

1.53 These brief reviews of industry groups within the electronics sector show the difficulties inherent in attempting generalisations at the sectoral level of the impacts of new technologies. As well as the rapidity of change in technologies being introduced both from outside the sector and from industries within it, the inter-related nature of the electronics complex makes isolating impacts difficult. However, the distinction which has been drawn between impacts on the semiconductor industry and those on the other parts of the electronics sector may be becoming less apparent. There appears to be some evidence that throughout the sector the impact of new technologies is increasing the advantages of scale, restrictions on access for new entrants, size of establishment costs, and capital needed to support both R & D and marketing. But whilst these characteristics appear to have generally adverse implications for developing countries, other evidence suggests that there are still niches in which producers in these countries may have advantages and through which they can continue to develop their electronics capacities.

NOTES*

1. Rada (1982).
2. These include data processing services; professional (consulting, engineering and custom) services; software products; and integrated turnkey systems.

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* In those cases where only abbreviated references are given here to the works cited, complete references will be found in Appendix 10, Selected Bibliography.

3. Telecommunications are considered in Appendix 3.
4. The somewhat arbitrary division of the electronics sector adopted here is reflected in the lack of any consistent identification in production and trade statistics either of the sector as a whole or of its component parts. There are but few and partial efforts at estimating output, employment, productivity or other indices of the electronics sector, even at the national level. Considerable confusion is also possible because of the changes over time of the 'electronics' components of various subsectors. In particular, there are few statistics on the impact of new technologies in the developing countries (except for the NICs' experience in consumer electronics), and most evidence relates to the results of innovation in the developed countries.
5. Soete and Dosi (1983).
6. Truel (1980).
7. Rada (1982).
8. Hoffman (forthcoming).
9. Rada (1984).
10. J. Clarke and V. Cable, 'The Asian Electronics Industry Looks to the Future', in R. Kaplinsky (ed.) *Comparative Advantage in an Automating World,* IDS Bulletin, March 1982.
11. *Global Economies Information Newsletter* No. 25, October 1982; Rada (1982) p. 10.
12. IBM already has about 70 per cent of the mainframe computer market and about 50 per cent of all computer systems, worldwide.
13. UNIDO, *Microelectronics Monitor,* No. 10/11, September 1984.
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