

## **Appendix 2**

# **Industrial Applications of Microelectronics: the Textiles, Clothing and Engineering Industries**

### **I. INTRODUCTION**

2.1 Besides their use in computers and consumer electronics, microelectronics have several major industrial applications in the form of computer-aided design (CAD), computer-aided manufacturing (CAM) and robots, while there is extensive incorporation of microprocessor control systems into equipment specific to each industry, for example numerically controlled machine tools (NCMTs) in engineering and electronic sewing machines in clothing. Overall, in the developed countries, investments in NCMTs are much larger than in CAD systems, or robots. In the United States, for example, of the \$2.9 billion invested in industrial applications in 1981, 65 per cent was in NCMTs, 30 per cent in CAD and only 5 per cent in robots. In Japan, in the same year, investments in NCMTs were three times higher than in robots. For the developing countries, NCMTs probably account for the largest proportion of investments in this area, followed by CAD/CAM, and robots (the latter being almost negligible).

2.2 Very few of the existing 10,000 CAD systems are in developing countries, and those which are have been used mainly for mapping. However, the use of CAD systems in the engineering industry seems to have been growing in these countries, albeit from a very small base. The technology is still mainly restricted to large users, due to the relatively high price of the equipment. Similarly, developing countries, with the exception of a few newly industrialising countries (NICs) (notably Argentina), have made little use of robots. By contrast, some 31,000 robots had been installed in the industrial countries by 1982,

about 42 per cent in Japan, 20 per cent in the United States and 11 per cent in Germany (F.R.).

2.3 In this appendix we examine the growing use being made, particularly in developed countries, of microelectronics-based equipment in three industries of importance to developing countries—textiles, clothing and engineering. The implications for productivity, employment and international trade were examined in Volume I, Part II, Chapter 1 of this Report.

## II. TEXTILES AND CLOTHING

2.4 The textiles and clothing industries have traditionally been associated with the early stages of industrial development. Thus since the 1950s and 1960s production capacity has been set up and steadily expanded in many developing countries, while falling in most developed countries. This has tended to endorse the view that both industries are based on mature, labour-intensive technologies. However, a large number of innovations have occurred in the last 20 years in both industries, especially textiles, culminating in the introduction of microprocessor-based techniques. The following paragraphs briefly review the nature of these technological changes, focusing on the latest generation, and discuss their implications for the textiles and clothing industries of developing countries.

### **The new technologies<sup>1</sup>**

2.5 Essentially the processes involved in producing textiles are designing, fibre preparation, spinning, weaving or knitting, and finishing (including dyeing); making clothes involves designing and pattern making, followed by cutting, sewing and finishing. The new technologies have affected all of these processes, though to differing degrees, as they have the general management of the textile and clothing industries. Much, however, has depended on the extent to which the new techniques have been diffused.

### *Designing*

2.6 CAD techniques offer extensive opportunities for both textile and clothing production. Textile manufacturers have traditionally had to prepare several samples of cloth for their potential customers, which can be a time-consuming task. Now hundreds of examples can be presented to a customer on a computer screen, and only a few are then woven into samples before a final choice is made. Moreover, the

computer has all the information ready for setting the loom for production. There appear to be greater problems in using CAD to depict the drape and fall of material, as is required in clothes designing, though a prototype is reported to have been developed and may be on the market soon. However, once a basic design has been drawn up manually, minor adaptations can be made with the help of a computer, and CAD systems have become important in grading and marker-making activities.

### *Fibre preparation*

2.7 The blending, carding and drawing out of fibres in preparation for spinning have undergone various degrees of mechanisation. Latest equipment is highly automated and can be operated with the use of computers. At the same time, there have been changes in the processing of chemical-based fibres which are not spun before being woven. For example, crimplene can now be textured at a rate of 800 metres a minute—compared to the 50 metres achieved in the 1950s.

### *Spinning*

2.8 The ring-frame spinning machine which was first introduced in the United States in 1830 is still widely used today, though in a much improved form; between 1950 and 1975 the speed of output doubled, while the quality of yarn and reliability of operation also increased. As limits on this equipment were approached, open-ended spinning machines were developed which operate at speeds four times as fast as ring-frame spinners, partly because they allow the integration of three previously separate processes (roving, spinning and winding). Although fabrics woven from open-end spun yarns are reported to be inferior to those from ring-spun yarns, this technique now accounts for more than 15 per cent of all yarns produced in the United States, compared to only 3 per cent in 1975.

### *Weaving*

2.9 In weaving, the major innovation since the mid-1950s has been the development of the shuttleless (flat) loom, of which there are four types—looms with gripper or dummy shuttles, looms with mechanically operated gripper arms, looms with water or air jets, and looms that mechanically propel the filling. Shuttleless looms are estimated to account for around half the looms now in use in Europe. They have the advantage of requiring less power and space and having lower sound levels than the automated conventional jacquard or dobby power looms, as well as being faster, particularly when multicolour fabrics are being produced. The more recent use of multiphase weaving has

allowed up to 600 picks per minute, as against 180 on high-speed conventional looms, with weft insertion rates rising from 400 metres per minute to 1,840 metres. Further improvements in productivity have been achieved, of up to 170 metres per man hour, with the use of microelectronics to control the looms and to monitor the quality of the cloth produced.

### *Knitting*

2.10 Since the 1960s changes in knitting technology have made it an increasingly popular way of producing cloth; labour requirements per unit of output are to 30 times lower than for weaving, while in a given time even a fast shuttleless loom produces only 12 per cent as much fabric as a modern circular weft knitting machine. Four other factors have been important. Costs have fallen as a result of declining prices of man-made fibres which are extensively used in high-speed knitting. There are also savings to be made for products where the fabric and garment stages can be combined in a single process (as in the production of hosiery or T-shirts). Knitting machines are very flexible, with most able to produce a wide range of products, which makes them particularly suitable for use in small units. Finally, the range of designs has been greatly extended (and down-time reduced) by the use of mini-computer control systems, integrating CAD with electronic selection of the needles. However, continued consumer demand for woven fabrics of natural fibres, which are less suitable for knitting, has restricted the substitution of knitting for weaving.

### *Finishing, dyeing and printing*

2.11 Textile finishing has become more automated, in the most advanced textile firms, than perhaps any other process, thanks largely to the incorporation of automatic control and computer systems, which have allowed continuous processing and quality improvements. Since the early 1970s computer controlled sensors have been developed for use in cloth dyeing. By monitoring and regulating the temperature and dye-bath strength, for example, they are able to improve the colour consistency of different pieces of cloth. More recent advances in colour physics combined with microelectronics have led to the use of computer-based spectrophotometers, which can define shades numerically, allowing colours to be repeated accurately, and also scan a piece of cloth (or garment) for colour consistency. They are being used primarily by manufacturers supplying high-quality fashions, for whom any colour mismatching can lead to large financial losses. Computers are also used to control continuous finishing, while computer-controlled lasers can be used to detect faults in cloth before it is finished, scanning an average of 270 metres per minute compared to the 50 metres achieved

with manual techniques. Further modifications are likely as manufacturers seek to reduce the hot water needed for dyeing, thereby cutting energy costs.

2.12 There have also been several changes in printing technology, with the development of roller, automated flat bed, and automatic rotary screen printing methods; in the latter case output has progressed from 500 to 2,000 metres per hour, while a large range of colour combinations is possible.

### *Pattern making and cutting*

2.13 Once a garment has been designed, CAD may be used to calculate different sizings and plan optimal lay-out (minimizing cloth wastage). This information can then be relayed directly to the cloth cutting equipment, which most recently includes CNC laser beams, water jets and steel knives that can be operated continuously, cutting up to 300 layers at one time. Together, these new techniques have helped to reduce the time to lay out and cut a suit, for example, from an hour to four minutes, and also to reduce the need for skilled workers.

### *Sewing*

2.14 In comparison with other processes there has been relatively little technological progress in the sewing stage of garment production, though there are signs that a revolution in production techniques is about to take place. While embroidery has been essentially automated, sewing machine speeds have increased by 50 per cent on average in the last 20 years. In particular, microelectronically-controlled dedicated machines, which perform all the tasks associated with one operation, for example collar assembly, have led to productivity increases in these tasks of up to 80 per cent, and operator-programmable multipurpose machines have raised productivity by up to 46 per cent. The use of synthetic fibres has led to some garments being fused together with high frequency sound waves (ultrasonic sewing) at a much faster rate than if they had been sewn with thread. But the impact on overall labour productivity has been restricted by the large amount of time which has to be spent loading and unloading material (about 75 per cent of a machine operator's time), arising from the numerous operations involved in the construction of a garment (for example 40 for a pair of trousers and 80 for a jacket). Other technological changes have been made in an attempt to cut down the time involved in these operations. One is the introduction of a microprocessor-controlled arm that can grasp cloth and move it through the sewing machine, repeating operations after they have been performed once by hand, though so far this technique has been restricted to fairly simple tasks. Another is

the use of robots in automatic transfer lines, to pick up pieces of cloth from a bundle, lay them ready to be sewn in a correct sequence, remove the finished work, and take it on to the next machinist for further processing. With more developments along these lines already underway, it is possible to envisage a fully automated clothing factory emerging in the near future; indeed the Japanese plan to produce prototypes of such a flexible manufacturing system by 1987 and to start commercial production of the technology by 1989, while the EEC is spending some \$26 million in similar research.

### *Finishing*

2.15 This is still one of the more labour-intensive stages of garments production, with the continued extensive use of electric irons and steam presses. First generation innovations have included the continuous pressing of separate parts of a garment using a steaming balloon, and equipment incorporating microprocessor-controlled pressing variables (steam, temperature, etc) which remove a high proportion of the skill previously involved in pressing, at a capital cost of \$30,000–\$200,000.

### *General management*

2.16 Many textiles and clothing firms have also sought to raise their production and productivity by using computers to monitor and improve the organisation of their work processes and to operate automated materials handling and inventory control systems.

### **Technology diffusion**

2.17 The impact of these new technologies on the world's textiles and clothing industries will depend on their rate of diffusion. The limited evidence available suggests that diffusion of microelectronics-based technologies has been fairly slow (probably more so than in most other industries), being restricted for the most part to large firms in developed countries, though there are exceptions such as leading firms in Hong Kong, South Korea and Singapore. A recent survey of the industries in Germany (FR), France and the United Kingdom, for example, found that between 20 and 40 per cent of textiles and clothing factories used microelectronics, a lower proportion than for any other manufacturing industry.<sup>2</sup> While this may partly reflect the technological problems of automating garment-making processes (and the fact that there is no scope for incorporating microelectronics in textiles or clothing as products), it also reflects the relatively low levels of investment in both industries. This has meant that the technologies most commonly used in developed countries' textiles and clothing industries are well behind the 'state of the art' technologies, let alone the frontier,

microelectronics-based innovations. According to one estimate average productivity could be improved by as much as 33 per cent if all firms used the former, while even greater gains would be made with the latter.<sup>3</sup>

2.18 The newer technologies are expensive and usually require long production runs (and low down-times) for any productivity gains to be realised. A major barrier to their uptake has been the fragmented structure of the textiles and clothing industries, and even in the United States two-thirds of the output comes from firms with less than 50 workers. In the clothing industry, CAD systems which cost \$0.3 million to \$0.6 million in the United States (and much more in Europe) are calculated to require an annual company turnover of at least \$20 million to be viable.<sup>4</sup> About half the firms of this size are reported to have invested in CAD, but they account for barely one-fifth of the clothing output in developed countries. The cost of automated cutters is somewhat higher (\$0.5 million, or \$1 million if combined with CAD), in addition to which there are associated costs arising from the need to reorganise production to allow centralised cutting on a 24 hour basis, and this has restricted their use to the larger firms. Nevertheless, by the end of 1982 there were at least 700 CAD systems and 300 automated cutters in use worldwide. With increasing competition between CAD suppliers lowering prices, and the establishment of time-sharing bureaux making CAD equipment accessible to firms with sales of less than \$50 million, the number of systems is likely to grow fairly rapidly. Similarly, dedicated items of equipment costing \$15,000 to \$40,000, such as automatic belt-looping machines or pocket hemmers, need new parts costing some \$4,000 to be installed every time a style is changed, and this can only be justified for long production runs. Programmable sewing machines, on the other hand, which cost \$5,000 to \$8,000, are more suited to small firms, being both less expensive and more flexible, though most managers of small family-run enterprises are still likely to prefer conventional machines costing some \$600 as long as market conditions remain uncertain. On average, however, even in larger firms a survey found that only 5 per cent of sewing machines used had microelectronic controls.<sup>5</sup> But in the medium term the pace of technological change may increase if more technologies appropriate to the smaller firms are developed, or if the structure of the two industries becomes more concentrated, or if competition from developing countries grows following relaxation of the Multifibre Arrangement (MFA) which governs their exports of textiles and clothing.

2.19 In developing countries the introduction of 'state of the art' technologies, let alone 'frontier' microelectronics-based technologies, faces even greater barriers. These operate at several levels. First, there are a number of technical barriers. For example, local yarn supplies

may not be of sufficiently high quality or energy supplies sufficiently reliable to use automatic looms. Secondly, there are often trade barriers restricting imports of new equipment—the result of balance of payments constraints, or even imposed by developing country governments to promote their own textile machinery industries. India has been one such example, though recently the Government relaxed its controls on loom imports in order to boost the competitiveness of exports.

2.20 Thirdly, and most important, there are economic barriers. Many new technologies are less appropriate for the textiles and clothing industries in developing countries, which are highly fragmented and where wages are comparatively low, than for those in developed countries. Even where these technologies appear to individual entrepreneurs to be economically efficient, they may not be for society as a whole. Thus some governments have deterred investment in new equipment, either directly by restricting modernisation in order to protect employment, or indirectly by limiting the capacity of firms in the organised sector in order to protect small producers in the informal sector. For example, in India the restriction on the size of spinning mills has meant that the economies of scale needed to justify some of the newer technologies have not been present. Weaving mills have not only had their capacity controlled but also the speed at which they could replace their plain looms with automatic ones. Thus over half of the spinning and weaving equipment in India is estimated to be over 20 years old and much of it over 40 years. Only 20 per cent of looms in the organised sector are automated and most of these are first generation conventional automatic shuttle looms—less than one per cent are shuttleless. Amongst other major developing country textile exporters the share of automated looms varies considerably, from 45 per cent in Brazil (though only 3 per cent are shuttleless), 78 per cent in Egypt, and 81 per cent in Pakistan, to 100 per cent in Hong Kong—reflecting major differences in economic factors and government policies.

2.21 The Hong Kong textiles and clothing industries are probably the most technologically advanced of all developing countries. Restriction of its exports under the MFA and increased competition from lower wage producers have forced it to move into high value, high quality goods which invariably has involved greater use of high-tech equipment. Thus most mill machinery now consists of open-end rotors and shuttleless looms, and there has been investment in computer-controlled cutters in a number of garment factories. In South Korea the government has subsidised the modernisation of the country's textile sector in a bid to increase automated weaving from 35 to 50 per cent and to replace 30 per cent of its weaving and spinning equipment estimated to be obsolete. Finally, a similar policy of promoting automation is being followed in

Singapore, as a means of boosting garment-makers' reliability and quality control.

2.22 In general the limited data available suggest that there has been little use of microelectronics-based technology in developing country clothing industries. Major suppliers have sold less than a dozen CAD units to the NICs, though in the medium term their volume of output would appear to justify an additional 30 to 40 units in Asia alone. Similarly there has been little diffusion as yet of automated sewing machines, with only a few of the larger Asian exporters and the Latin American producers for the domestic market buying dedicated units, and perhaps a larger number (20-30 units) of programmable machines being sold each year.<sup>6</sup>

## II. ENGINEERING

2.23 In the last twenty years the engineering industry in developed countries has been affected by the introduction of new, essentially microelectronics-based, technologies perhaps more than any industry. Whereas for others the predominant use of microelectronics has been to alter processes, for engineering it has altered both products and processes.<sup>7</sup> Within engineering some branches, notably electrical and instrument making, have experienced more product innovations than others, such as mechanical engineering, vehicles and other metal goods; the latter have, however, been involved in extensive process innovations. Changes in some branches have also affected others. For example the substitution of electronic for electromechanical components in electrical engineering has reduced its purchases from the mechanical engineering branch.

2.24 At the same time there have been substantial, though fundamentally different, developments in the engineering industry in developing countries. Here the emphasis has been on expanding the range of products as well as updating the processes used, predominantly through the use of imported and relatively mature technologies with some indigenous modifications. As a result, total engineering output has increased and a number of the technologically more advanced countries have emerged as large exporters of engineering goods. One of the main concerns of many developing countries is whether the new technologies offer them further opportunities to expand their engineering output, and if so, what the relative costs and benefits are, taking into account the impact on other industries. We deal with this next.

### **The new technologies**

2.25 By far the most extensive types of new technology in engineering are those based on microelectronics, though changes arising from

**Table 2.1****Applications of Information Technology in Engineering Processes**

<i>Activity</i>	<i>Application</i>
<b>Information processing and handling</b>	
Administration: i.e. accounting, customer order handling	Computers for record keeping, analysing information
R & D	Computers for model building, complex calculations
Design and draughting	CAD
Production planning, inventory control	Computers for scheduling
<b>Materials processing and handling</b>	
Processing	Computer controlled conveyors and other machines, robots
Testing	Automated testing equipment
Output	Automatic packaging, computer controlled warehousing and distribution
<b>Combined information and materials processing and handling</b>	
Manufacturing	Linking computer controlled machines with a common data base—known as direct numerical control or flexible machining/engineering systems
Inventory/distribution	Automated warehousing—linking computer controlled machinery with computerised information on inventory and distribution
Manufacturing/design	Integrated manufacturing system or CAD/CAM—linking CAD and computer controlled machinery with a common data base
Fully integrated control of materials and information	Integrated business system—CAD/CAM linked to all systems for controlling marketing, buying, production planning, administration

*Source:* Adapted from Wilson (1984) p. 17.

**Table 2.2**

**Recent Technological Changes in the Japanese Automobile Industry**

<i>Product technology</i>	<i>Parts or processes replaced</i>
—New vehicle design, e.g. shift to front wheel drive	Propeller shaft, differential gear
—New parts, e.g. digital display meters, disc-brakes, electronic accessories	Analogue display meters, drum-brakes
<i>Production technology</i>	
—New materials, e.g. plastics, ceramics	Steel stamped parts
—Processing of more complex shapes and/or higher quality parts, e.g. with moulding, NC machine tools	Smaller stamped or machined parts, hand-operated or automatic machines
—Improvement of work environment, need for more flexible equipment, e.g. with robots	Manual work, mechanical automation
<i>Organisation technology</i>	
—Includes use of automatic loaders/unloaders, transfer machine lines, CAD/CAM, and office automation, and also the ‘just-in-time’ system	Manual work, inventory control and management

*Source:* Adapted from Watanabe (1984) p. 11.

technologies for producing new materials and renewable energy sources are also taking place. The wide range of applications of computers and microprocessors, from the processing and handling of information (including design) to the control of materials processing, and even fully integrated business systems, is shown in Table 2.1 above; Table 2.2 lists the numerous technological changes in the Japanese car industry. CAD is the principal automation technology in the design phase of the production process; besides applications in engineering, it is used widely in other industries (as discussed above in Appendix 1 on microelectronics). So, too, is CNC technology, which is extensively used in manufacturing although originally developed for machine tools.

2.26 CAD has had a profound impact on engineering designs. It was first used in the late 1950s by the aerospace and defence industries, only being introduced to the electronics sector in the early 1970s and mechanical engineering after 1975. Its interactive graphics capacity

means that all features of a product or part can be graphically represented in three dimensions, allowing the effect of a change in any parameter to be calculated instantly and a multicomponent product to be 'exploded' to see how the parts fit together. Not only are design times drastically reduced, but working drawings can be produced and parts lists prepared more quickly and accurately than before. CAD also encourages the automation of subsequent manufacturing stages (whether by CAM or some other form) as the reduction of all design information to electronic signals, which occurs in CAD, means that downstream machinery equipped to receive electronically transmitted instructions can be directed and controlled with minimum human intervention.

2.27 The diversity of CAD technology has led to a rapid growth in its use, with global sales rising from \$80 million in 1976 to \$1 billion in 1980 and \$5 billion forecast for 1985; a 40 per cent annual growth is projected during the 1980s for the OECD market alone. Global installations of CAD, of 10,000 in 1982, are expected to grow to 27,000 by 1986; about 50 per cent of them will be in the United States, 35 per cent in Western Europe and less than 0.5 per cent in developing countries. In the developed countries, CAD is predominantly used in the electronics, aerospace and automotive industries,<sup>8</sup> but it is increasingly being found in mechanical engineering, architecture, clothing and construction. The limited data available for developing countries suggest CAD is being used primarily in the engineering sector, for example in component and automobile manufacturing, metal works, and consultant engineering, as well as in shipbuilding.

2.28 NCMTs, which drill, grind, etc according to instructions numerically recorded on magnetic or perforated tapes or cards, were introduced in the early 1950s. The control hardware was expensive and bulky, which limited its use and ensured the continued dominance of conventional machine tools. The incorporation of computers in NCMTs to produce CNC machine tools has challenged conventional tools by creating an increasingly versatile, accurate and cheap piece of equipment, which can combine previously discrete operations into one machine. This has radical implications for the organisation of production. CNC tools may be linked directly to CAD systems, leading to the integration of design and manufacturing, while the use of a central computer to control simultaneously a number of CNC machines allows a continuous production process instead of batch production. In some cases up to 100 machine tools incorporating micro-computers have been directly controlled by a single mainframe computer. This allows a two way flow of information, with the mainframe transmitting instructions to the individual tools via their micro-computers, which in turn transmit back information on the status, volume and quality of production to

the mainframe, providing managers with an instant overall picture of the production process. There are also important implications for producers of conventional equipment—as outlined in Volume I, Part II, Chapter 1. For example CNC lathes have been substituted for the engine lathes which form the bulk of NIC lathe exports, rather than for other types of conventional lathes.

2.29 These factors have led to a rapid growth in the use of CNC equipment, and their share in the production of all metal cutting machine tools in six OECD countries (United States, Japan, Germany (FR), France, Italy and United Kingdom) rose from 25 per cent in 1976 to 41 per cent in 1982. The bulk of CNC tools in Japan and the United States are used in the general machinery sector, after which transport equipment and electrical machinery are the most important. In comparison the demand for CNC machine tools in developing countries is still small although it is growing, particularly in the NICs, as Table 2.3 shows. Capital goods firms appear to be the leading users, with CNC tools helping to produce turbines, pumps, valves, oil equipment, agricultural machinery, hydroelectric equipment, automobile components and so on.

**Table 2.3**  
**Production of and Demand for CNC Lathes in Selected Countries**

<i>Country</i>	<i>Production (units)</i>	<i>Demand (units)</i>	<i>CNC lathes as % of total lathe investment</i>
Argentina	10–15 (1981)	60–65 (1981)	38 of all imported lathes (1978–82)
Brazil	36 (1980)	85 (1980)	—
India	4 (1981)	33 (1980)	—
South Korea	222 (1982)	100–125 (1981)	2.4 (1977–78) 34 (1981–82)
China (Taiwan)	174 (1981)	123 (1981)	7 (1977–78) 20 (1981–82)

*Sources:* Jacobsson, 'Technical Change and Industrial Policy: The Case of CNC Lathes in Argentina, Korea, and Taiwan', in Hoffman, ed. (1985) and Chudnovsky, *The Diffusion of Electronics Technology in Developing Countries' Capital Goods Sector: The Argentinian Case* (CET/IPAL Report, 1984).

2.30 The use of robots, which began in the late 1960s, accelerated in the late 1970s as a result of major technical improvements (Table 2.4). In absolute terms the largest user is Japan followed by the United States, Germany (FR) and Sweden, though as a proportion of manufacturing employees the ranking is somewhat different as the table shows. The main area of application is vehicle production, where there are four major robot types: 'intelligent' robots (mainly used for assembly), numerically controlled robots (assembly and machining), play-back robots (arc- and spot-welding) and fixed sequence robots (loading and unloading). While expansion in the range of activities of robots is likely to increase their number in other industries, particularly in electrical and mechanical engineering, the rate of installation is expected to grow more slowly than in the vehicle industry.

2.31 Linking CNC tools with some form of materials handling system (for example a robot which can transfer workpieces between tools) leads to the formation of an automated manufacturing cell, while the linking of cells via an automated transfer line controlled by a computer hierarchy leads to what is known as a *flexible manufacturing system* (FMS). The considerable costs and difficulties involved in FMS have restricted their number in the OECD to about 150, incorporating some 1,200 CNC machine tools, primarily in factories producing vehicles, machine tools and construction machinery (see Table 2.5 on page 33).

### **Diffusion in developing countries**

2.32 While there are several reasons for the adoption of these new engineering technologies—to improve the quality of products, to alter their nature, and to increase factor productivity (as discussed in Volume I, Part II, Chapter 1 of this Report)—their diffusion in developing countries has been relatively limited. One factor has been the initial cost of the equipment, which ranges from about \$20,000 for a robot to millions of dollars for a complete FMS. However, with advances in both electronics technology and the structure of the machines, the cost of some new types of engineering equipment has fallen to below the price of conventional equipment. For example, an FMS for the production of 50,000 tractor components annually may cost \$18 million compared to a dedicated transfer line costing \$28 million, while an FMS for truck axles may cost the same as a conventional system with a similar capacity but have the advantage of virtually eliminating set-up costs and occupying a quarter of the floor space.<sup>9</sup> In other instances, such as Japanese lathes, the price differential between CNC and conventional machine tools fell from 11:1 to 4:1 between 1970 and 1981,<sup>10</sup> while the price of the average CAD system in 1980, at \$300,000, was even in nominal terms a tenth of that of the first system developed in the 1960s.<sup>11</sup> Taking into account the shorter payback period, new

**Table 2.4**  
**Population of Robots<sup>a</sup>**

	1974	1978	1980	1981	1982	1985 <sup>b</sup>	1990 <sup>b</sup>	<i>Robots per 10,000 employed in manufacturing</i>	
								1971	1981
Japan	1,500	3,000	6,000	9,500	13,000	27,000	67,000	1.9	13.0
United States	1,200	2,500	3,500	4,500	6,250	15,000	56,000	0.8	4.0
Germany (FR)	130	450	1,200	2,300	3,500	8,800	27,000	0.4	4.6
Sweden	85	800	1,133	1,700	1,300 <sup>c</sup>	4,100	8,300	1.3	29.9
United Kingdom	50	125	371	713	1,152	2,700	10,000	0.1	1.2
France	30	—	580	790	950	2,100	6,500	0.1	1.9

Note: Data based on a narrow definition of robots.

<sup>a</sup> Accurate data on the world population are not available, but the following estimates are indicative: 1980—13,700; 1981-22,000; 1982-31,000.

<sup>b</sup> Forecast.

<sup>c</sup> Data revised downward as a result of definitional changes.

Sources: UN Economic Commission for Europe (1985) p. 42, and UNIDO, *Microelectronics Monitor*, No. 10/11, April-September 1984.

**Table 2.5****Final Products Incorporating Parts Manufactured by FMS in OECD Countries**

<i>Final product</i>	<i>Number of FMS</i>	<i>per cent</i>
Automobiles and trucks	27	21
Machine tools	22	17
Tractors and construction machinery	18	14
Aerospace	9	7
Diesel engines	6	5
Electric motors	6	5
Pumps, valves and compressors	6	5
Hand tools, electric tools, etc.	5	4
Railway equipment	4	3
Office machinery	4	3
Others	20	16
Total	127	100

*Source:* Edquist and Jacobsson (1984).

equipment now appears often cheaper than its conventional equivalent; for example it may take no more than two years to pay off a robotic unit operating two shifts, or two and a half years for an FMS. A British company producing aircraft components found that inventory savings alone were sufficient to pay off its £1 million investment in computer-controlled machinery centres.

2.33 As well as these direct costs, however, the cost of complementary investment in non-microelectronic advanced technologies needs to be included. Generally it seems that the large investments involved, coupled with considerable ignorance about their likely benefits and a reluctance to take risks (especially during a recession), have delayed their introduction in several enterprises, even in developed countries, let alone developing ones.

2.34 Besides cost, an important factor restricting the diffusion of new technologies is the higher (and increasing) minimum efficient scale of production of many of them compared with conventional equipment. Although the flexibility of CNC tools, CAD and, to a lesser extent, FMS, means that they can be used to produce small batches economically—for example, lots of 20 to 100 workpieces in Japan<sup>12</sup>—there are certain levels of aggregate output below which their use is not economical. For robots to be justified in Sweden it was found that

batch runs had to be of more than 10,000 pieces, whereas for CNC tools the batch could be less than 1,000 and annual production above 100,000.<sup>13</sup> Put another way, one CNC tool may substitute for between two and five non-CNC tools. There is, however, some variation between countries, reflecting the different types of new technology in use. Thus in Japan, where CNC tools tend to be smaller and simpler, two-thirds of those sold in 1981 were bought by small- and medium-sized firms—26 per cent by firms with less than 30 employees.<sup>14</sup> In contrast, in the United States two-thirds of CNC tools were being used by plants with more than 100 workers. In the case of CAD, systems based on mini-computers are most profitable if used by more than ten designers, while a mainframe computer can take more than twenty.

2.35 Another factor is the externalities to be gained from the use of several CNC machines as part of a system, compared to their use separately. As well as lower capital-output ratios, indirect costs may be reduced—between six and eight machines are needed to occupy fully a programmer and setter while a maintenance engineer can cope with as many as 15–30 such machines.<sup>15</sup>

2.36 These minimum efficient levels of production constitute an effective barrier to the use of newer technologies by smaller workshops in developing countries, unless they are subsidised, or are able to increase the volume of their output. This in turn will depend partly on the relation between the size of the domestic market and the minimum efficient scale; although exports are always possible, a large domestic market reduces the risk of upgrading production methods and allows products to be proven before export.

2.37 Finally, the need for a minimum level of infrastructure should be mentioned: not only for training design engineers and other skilled personnel, but also for guaranteeing stable electricity supplies. If the electricity voltage falls by 15 per cent or more, as is frequently the case in some developing countries, then CNC machine tools cease to function.

2.38 A major issue is the degree of substitutability between new and mature technologies, and how quickly the former are diffused at the expense of the latter. In the short term it seems that conventional equipment will continue to command an important (though shrinking) share of the market for engineering goods, with sales falling in absolute terms in the developed country markets but rising elsewhere. Developing country exports may be sustained, however, if developed country producers shift production of conventional equipment to developing countries, so that they themselves can specialise in high-tech tools, as major Japanese machine-tool builders have been doing.<sup>16</sup> The question

then arises as to whether developing countries will be able to produce and export high-tech equipment competitively. As suggested earlier, there are a number of barriers to the market which only some of the NICs are likely to overcome. One is the increasingly large scale of production needed to be competitive: in some cases scale may be more important than wage levels, as the share of labour in total costs is falling. Another is the need for domestic capability in electronics design and engineering, servo-techniques, and R & D. A third is the growing links between producers and users of sophisticated equipment which requires the support of an international marketing and after-sales network.

2.39 In conclusion it seems that the new engineering technologies have important implications for the organisation of production and employment in the developed countries' industries. In particular the use of computer-based design and machine tools has allowed continuous production processes to replace batch production in many cases. Associated with this has been increased labour productivity, and substantial capital savings (working and fixed), though initial capital outlays have risen with larger minimum efficient plant sizes. These changes appear, in the first instance, to have most relevance for the more technologically advanced developing countries. Those currently producing conventional machine tools will find their export markets are restricted unless they are able to incorporate some microelectronics into their products. Exporters of other engineering goods may also find their competitiveness eroded by the new production methods, though there is little evidence of this as yet. But some of the new equipment may help in the development of engineering industries in the less technologically advanced developing countries. For example, both CAD and CNC tools could help to reduce the skill constraint, and at an increasingly affordable price. However there is still a minimum level of skills needed for the operation of this equipment, and a minimum level of operation, which would seem to preclude its use spreading to the smaller developing countries in the near future.

#### NOTES\*

1. This section draws on: V. Cable and B. Baker, *World Textile Trade and Production Trends*, EIU Special Report No. 152, London, 1983; OECD, *Textile and Clothing Industries*, Paris, 1983; and K. Hoffman, 'Clothing, Chips and Competitive Advantage: The

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

- Impact of Microelectronics on Trade and Production in the Garment Industry', in Hoffman, ed. (1985).
2. Policy Studies Institute (1985).
  3. Hoffman and Rush (1980) p. 86.
  4. Hoffman, op. cit., in Hoffman, ed. (1985) p. 377.
  5. Ibid., p. 379.
  6. Ibid., p. 388.
  7. For example, Northcott and Rogers (1984) p. 6, show that 30 per cent of mechanical engineering factories in the United Kingdom and 50 per cent of electrical engineering factories use microelectronics in their products while in processes the respective figures are 45 per cent and 50 per cent.
  8. In the United Kingdom a third of all establishments using CAD in 1981 were in the electronics sector. (E. Arnold and P. Senker, *Designing the Future: The Implications of CAD Interactive Graphics for Employment and Skills in British Engineering Industry*, mimeo, SPRU, University of Sussex, UK, 1982).
  9. Hoffman (forthcoming).
  10. Watanabe (1983) p. 27.
  11. Kaplinsky (1982) p. 41.
  12. Watanabe (1983) p. 9.
  13. Jacobsson (1983) p. 153.
  14. Watanabe (1983) p. 22.
  15. Ibid., p. 67.
  16. Ibid., p. 73.