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THE IMPACT OF MICROELECTRONICS ON EMPLOYMENT AND INDIGENOUS TECHNOLOGICAL CAPACITY IN THE REPUBLIC OF KOREA

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Preface

This study by Dr. Hak K. Pyo of Seoul National University is the second in a series of studies on the employment and income effects of new technologies on Third World countries which are prepared within the framework of the World Employment Programme and financed by the Swedish Government (SAREC).

The main objectives of this study are (1) to study the motivation for introducing microelectronic machinery as well as the current pattern of its application, and (2) to assess its impact on employment and technological capacity in the Republic of Korea. The microelectronic equipment covered includes industrial machinery such as NC and CNC machines including machining centres, robots and CAD/CAM, and office automation equipment such as microcomputers, word processors, facsimile and photocopy machines. The study utilised both second-hand industry-level data and first-hand information obtained through a survey of about 40 users of microelectronic equipment.

Even though the use of microelectronic machinery in the Republic of Korea hsa a relatively short history, domestic demand for it has been quite strong, especially since 1981 when the Korean Government designated the electronics and information industry as a strategic industry for development.

Findings in the field survey suggest that the major motivation for introducing microelectronic factory automation (FA) equipment is to upgrade the quality standard and to meet the product requirements imposed by both domestic and foreign buyers. The recent boom in the automobile industry seems to have been playing a key role since the industry requires precision parts and components. The rising labour cost is another important influencing factor. This is a major explanation for the active demand for microelectronic office automation equipment.

Regarding the employment impact of the new technology, employment continues to increase despite microelectronic innovation. This may be explained by two factors. First, FA and OA equipment in most cases is rather new. Second, the strong demand for user industries offsets the potential labour saving effect.

Import of microelectronic technology has produced a positive impact on indigenous technological development in the Republic of Korea. Fourteen cases of significant local development in NC machine production have been identified which were encouraged by imported technology. The development of the NC-unit and that of robots are the most lively examples.

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List of Abbreviations

FA:	Factory Automation
OA:	Office Automation
NC:	Numerical Control
CNC:	Computerised Numerical Control
CAD/CAM:	Computer Aided Design/Computer Aided Manufacturing
FAX:	Facsimile
AIS:	Administration Information System
EIAK:	Electronic Industries Association of Korea
KAIST:	Korea Academy and Institute of Science and Technology
KIET:	Korea Institute for Economics and Technology
KIIA:	Korea Information Industries Association
KIRI:	Korea Industrial Research Institutes
KOMMA:	Korea Machine Tool Manufacturers Association
MOST:	The Ministry of Science and Technology
MTI:	The Ministry of Trade and Industry
SMIPC:	Small and Medium Industry Production Corporation

THE IMPACT OF MICROELECTRONICS ON EMPLOYMENT AND INDIGENOUS TECHNOLOGICAL CAPACITY IN THE REPUBLIC OF KOREA

The main objectives of this study are (1) to study the motivation for introducing microelectronic machinery as well as the current pattern of its application, and (2) to assess its impact on employment and technological capacity in Korea. The microelectronic equipment to be studied includes factory automation (FA) equipment such as NC and CNC machines including machining centers, robots and CAD/CAM, and office automation (OA) equipment such as micro computers, word processors, facsimile (FAX) and photocopy machines. The study will be based on second-hand industry-level data and on micro level information obtained through a field survey of about 40 users of micro-electronic equipment.

After the start of the first Five-Year Economic Development Plan in 1962, the Korean economy experienced an unprecedented rapid growth. The average annual growth rate of GNP in real terms was 6.6 per cent between 1960 and 1982, which was the third highest among all developing countries after Singapore (7.4 per cent) and Hong Kong (7 per cent).[1] Economic development in Korea can be divided into two broad phases. The first is the period 1962-74 when the first oil crisis occurred and the second is the post-1974 period. During the first phase, there were two prime targets. One was to build social infrastructure and basic industries such as electricity, steel and cement, and the other was to promote labour-intensive export industries such as textile, plywood and footwear. The first unit of computer was installed in 1967, but it was during the second phase that FA and OA equipment started to be introduced via imports. Therefore, the use of microelectronics in Korea has a relatively short history. Section I below discusses the current extent and pattern of application of microelectronic equipment in Korea. In section II, we analyse macro level data and micro information from our field study. Sections III and IV deal with the impacts of microelectronics on employment and on indigenous technological capacity, respectively. The last section contains a summary and conclusions, which include prospects for the use of microelectronics and policy implications of our findings.

I. The Use of Microelectronic Equipment

1. An overview

Most microelectronic FA and OA machines have been introduced in Korea through imports from Japan and the United States, and their diffusion gained momentum after 1981. Contrary to the common view that the demand for such equipment is very sensitive to business conditions, the demand increased during the recent business recession in Korea. As a result of the world-wide recession and the political disruption in 1979, the Korean economy recorded a negative growth (-5.2 per cent) in 1980 for the first time since 1962. Although the economy resumed its positive trend in the next year, the average annual growth rate of GNP in real terms in 1980-84 was only 4.2 per cent, as compared with 10.2 per cent in 1973-79. The growth rate of the mining and manufacturing sector slowed down from 17.5 per cent in 1973-79 to 7.0 per cent in 1980-84.

i) The factory automation equipment

Table 1 shows some trends concerning NC machines which are the major microelectronic FA equipment used in Korea. During the period of twelve years since its first introduction in 1973, the domestic demand has grown considerably, although not quite smoothly. The large demand for cheap NC machines in 1974 is attributable to the establishment of the Chang-Won complex and, in particular, the defense industry. As of 1983, a total of 1,656 units of NC machine tools are estimated to have been owned by the Korean machinery industry which corresponds to about 1.2 per cent of total metal cutting machines (135,000 units) owned by the industry.[2] The steady and rapid increase in domestic production of NC machines is in sharp contrast with significant fluctuations in imports, which have been very sensitive to domestic business conditions (Table 1). Imported NC machines are more expensive and larger than domestically produced ones, and their main users are large firms. These firms' investment programmes influence not only the overall level of imports but also its composition. For example, the purchase of machining centres by the Hyundai Motor Co. and Daewoo Heavy Industries is clearly reflected in domestic demand in 1983, while in 1984, most of the NC machine imports were for subcontractors of the two automobile companies and subcontractors to Japanese NC machine manufacturers. In 1984, Japan accounted for 66 per cent of NC machine tools and 60 per cent of conventional metal cutting machine tools imported by Korea, in terms of value. The second largest supplier was the Federal Republic of Germany which accounted for 30.9 per cent and 20.3 per cent respectively.

Table 1. Trends related to machine tools in Korea***

(values in million US dollars)

Year	(1) Production						(2) Exports						(3) Imports						(4) Domestic demand** for NC machines (1)-(2)+(3)	
	Total		NC		NC (%)		Total		NC		NC (%)		Total		NC		NC (%)			
	Units	Value	Units	Value	Units	Value	Units	Value	Units	Value	Units	Value	Units	Value	Units	Value	Units	Value	Units	Value
1974	13,034	7.0	-	-	-	-	8,836	0.5	-	-	-	-	5,980	34.2	273	3.8	(4.6)	(11.7)	273	3.8
1975	29,536	6.2	-	-	-	-	4,076	0.1	-	-	-	-	14,569	57.8	12	1.4	(0.1)	(2.5)	12	1.4
1976	11,055	13.9	-	-	-	-	1,245	0.2	-	-	-	-	5,091	76.7	30	0.7	(0.6)	(0.8)	30	0.7
1977	32,995	31.5	5*	0.2*	(0.0)	(0.6)	1,166	0.7	-	-	-	-	6,395	104.9	21	1.3	(19.6)	(1.1)	26	1.5
1978	24,980	75.0	20*	0.9*	(0.1)	(0.0)	10,743	3.6	-	-	-	-	16,149	156.1	70	3.5	(0.4)	(2.2)	90	4.4
1979	33,916	58.8	40*	1.8*	(0.1)	(3.1)	4,978	12.5	-	-	-	-	7,704	200.0	144	26.7	(1.9)	(13.3)	184	28.5
1980	31,742	54.8	22*	1.1*	(0.1)	(2.0)	6,811	20.9	4	0.2	(0.1)	(0.8)	8,206	91.5	52	3.8	(0.6)	(4.1)	70	4.7
1981	16,904	63.2	100*	4.6*	(0.6)	(7.3)	10,824	28.7	51	2.1	(0.1)	(7.5)	20,724	101.2	39	11.7	(0.2)	(11.6)	88	14.2
1982	10,917	76.1	295	15.3	(2.7)	(20.1)	19,851	30.9	186	10.1	(0.9)	(32.6)	2,400	48.0	39	4.0	(1.6)	(8.3)	148	9.2
1983	12,348	97.0	371	21.7	(3.0)	(22.4)	7,430	19.7	128	5.7	(1.7)	(28.8)	8,172	103.9	118	9.7	(1.4)	(9.3)	361	25.7
1984	15,159	118.4	459	24.2	(3.0)	(20.4)	6,748	20.3	195	7.6	(2.9)	(37.5)	3,176	92.6	169	32.7	(5.3)	(35.3)	433	49.3
1985	17,628	141.5	578	38.0	(3.3)	(26.9)	6,324	19.8	177	7.2	(2.8)	(36.4)	8,368	150.6	192	25.7	(2.3)	(17.1)	593	56.5

Sources: KIET and Korea Machine Tool Manufacturers' Association (KOMMA): Machine Tool Statistics Handbook, 1985 and Machine Tool Industry Korea, 1986.

Notes: * Estimates by KIET
** Includes Inventory
*** Metal Cutting Machine Tools

The use of industrial robots and CAD/CAM started around 1979, but spread mainly after 1983. As shown in Table 2, the production of industrial robots began in 1982 but the domestic demand is still met mostly by imports. Most users of industrial robots are large companies with over 1,000 employees in the automobile, machinery, shipbuilding, or electronics industry. The demand for industrial robots from the automobile and electronics industries is growing fast, especially for assembly and welding. Although key components such as the controller, sensor and actuator have to be imported, a number of companies are currently planning large-scale production.

As of mid-1985, 24 CAD/CAM units were installed in Korea, according to a KAIST report: electronics and electrical machinery industry (11), automobile industry (4), shipbuilding industry (4), and others (5). All the systems were imported and the main hardware systems were Computervision and IBM. Here again their users are mostly large firms. However, an interesting application of CAD/CAM has recently been made in the textile and garment industry, where about four large garment manufacturers and about six small firms have introduced CAD systems, mainly for designing garments, adjusting the designs to various standards, and optimising the use of fabrics and clothes. A few of these companies have plans to introduce a CAM system for automatic cutting and grading. According to their experiences, CAD could reduce the time required for designing a suit jacket from 420 minutes to 142 minutes. Waste of fabrics could be reduced by 2-5 per cent so that at least 91 per cent of the fabrics could be utilised. A company expects to save about 430 million Won in 1986 by means of CAD.

There have been several factors contributing to the recent growth in the demand for microelectronic FA equipment. First, after the shocking experience of negative growth in 1980, the Koreans began to emphasise the need for consolidating investments already made rather than new investments, in the light of excessive capacities in many industries which arose as a result of unchecked government-sponsored expansion during the late 1970s, as well as the world-wide recession. At the same time, stagnant exports induced a general shift in the emphasis from capacity expansion to productivity increase, and from quantity to quality, and many firms turned to productivity- and quality-oriented machines. Second, the recession did not hit all the industries. The automobile industry and the electronics industry expanded their production and exports remarkably while the other industries had a very sluggish demand: the production indice jumped from 100 in 1980 to 265.4 in the first industry and to 235.0 in the second industry in 1984, while the average index of all manufacturing rose to 160.6 only. The production capacity index in metal products, machinery, and equipment industries

Table 2. Production and imports of robots and CAD/CAM

(1,000 dollars (units))

Year	1979-81	1982	1983	1984	1985
1. Industrial robots*					
Production	0 (0)	21 (1)	388 (10)	322 (10)	630 (16)
Imports	1,502 (13)	240 (7)	316 (8)	1,308 (40)	12,020 (324)
Domestic demand	1,502 (13)	261 (8)	704 (18)	1,630 (50)	12,592 (338)
Exports	-	-	-	-	58 (2)
2. CAD/CAM					
Units installed	(2)**	(1)	(8)	(4)	(9)

Notes: * "Robots" are defined to be general purpose, programmable machines possessing certain anthropomorphic characteristics.

** For 1980-81.

Sources: The Ministry of Trade and Industry, and KAIST.

increased to 140.6 as compared with 127.1 for all manufacturing in the same year. The Government's promotion policy for these industries as key export industries played an important role.[3] While total exports increased by 67 per cent during 1980-84, the machinery and transport equipment exports almost tripled during the same period. The export drive has given rise to a strong demand for microelectronic FA machinery, especially in relation to the precision work for parts and components. It is interesting to note that, even though the pattern of diffusion of NC machine tools in Korea is somewhat different from that observed in Japan, as will be discussed later, the basic drive for the technology diffusion came from the same industries in both countries.[4] The third factor which seems to have encouraged factory automation is the rising labour costs in Korea. The hourly wage rate in Korea is still quite low compared with some other countries, but it grew fastest during the period 1975-80 among the six major competitors/trade partners.[5] This must have made Korean firms more conscious of the need to reduce labour costs to remain competitive in international markets, even though it is not the primary reason for the application of microelectronic machinery as we will see later.

ii) The office automation equipment

In 1967, three units of IBM 1401 were installed by the Economic Planning Board to conduct a population census. Since then, the demand for computers has continued to increase. According to KAIST, a total of 1,114 units are estimated to have been operating in Korea in 1983 (Table 3). KAIST maintains that the figure will rise to about 2,000 if special-purpose micro computers (excluding personal computers) are included. The use of computers has been growing fastest among business firms other than banking and insurance, while educational institutions remain the second largest users (Table 3). According to KAIST, over 50 per cent of the computers installed before 1980 were rented or leased, but more recently about 60 per cent were purchased. This may indicate that more users of computers are becoming confident in the selection and the use of their computers.

Table 3. Installation of computers by size and by user group

(in no. of units (million dollars))

	1976	1978	1980	1982	1983	Annual growth rate (1980-83)
By size						
Total	126	255	522	766	1,114	28.7
	(43.9)	n.a.	(141.0)	(376.7)	(469.0)	(49.3)
Super	7	n.a.	31	60	76	34.8
Large	20	n.a.	46	84	114	35.3
Medium	43	n.a.	111	174	214	24.5
Mini	24	n.a.	143	210	318	30.5
Super mini	32	n.a.	191	238	392	27.1
By user group						
Government	30	39	56	68	81	15.2
Educational institutions	35	60	103	178	247	32.2
Banking and insurance	30	36	67	94	135	24.0
Business firms	31	120	296	426	651	54.5

Sources: KAIST and MTI.

Table 4. Trend in microelectronic OA equipment market in Korea

(in 1,000 U.S. dollars (units))

	1981	1982	1983	1984	1985
1. Computers*					
Production	-	5,261	58,973	135,159	200,391
Imports	-	58,709	92,392	124,552	284,000
Exports	-	517	35,121	82,102	158,110
Domestic demand	-	63,453	116,244	117,609	326,291
2. Word processors					
Production	295	1,810	5,757	2,652	1,004
Imports	4,341	13,576	15,177	-	-
Exports	-	-	461	2,153	508
Domestic demand	4,636	15,386	21,082	499	536
3. Copy machines					
Production	19,360	23,847	32,784	35,653	40,578
Imports	7,839	6,775	6,659	10,393	-
Exports	-	600	1,279	3,932	4,945
Domestic demand	27,197	30,022	38,164	42,116	35,633
4. Facsimile machines					
Production	-	212	3,158	9,820	15,716
	(72)	(440)	(1,450)	(2,501)	(4,000)
Imports	(134)	(70)	-	-	-
Exports	-	-	6	-	-
Domestic demand	(206)	(510)	(1,456)	(2,501)	(4,000)

Notes: * Includes mainframe components.
Sources: The Ministry of Trade and Industry, and the Electronic Industries Association of Korea.

The expansion in the microelectronic OA market since 1981 is remarkable (Table 4). As will be discussed later in Section II, the Government designated the electronics and information industry as a strategic industry for development in 1981. Various government policies such as those encouraging the Administration Information System (AIS) and the improvement of the communication network also played an important role. The wage factor seems to have greater bearings on the demand for OA equipment than the demand for FA equipment, as will be discussed in sub-section 2(ii) below.

2. Survey findings

In this section, we will discuss briefly the characteristics of sample firms, the motivations for introducing microelectronic equipment, the sources of microelectronics information, and the rate of capacity utilisation of such equipment, on the basis of our field survey of 30 FA and 10 OA equipment user

firms.[6] Some additional information will be presented from similar surveys conducted recently by different institutes.

i) The sample firms

Table 5 shows the industrial distribution of our sample firms and the microelectronic machines owned by them. The heavy weights of the automobile and general machinery industries in the FA sample, and that of the service industries in the OA sample reflect the leadership of these industries in the respective area of automation. As we selected only FA and OA equipment users and as the use of such equipment is still rare among small enterprises,[7] our sample is also biased towards large firms: only five FA users and four OA users in our sample employed fewer than 300 workers, and only five and three had capital of below 100 million Won.

A total of 237 NC machines were owned by the 30 FA user firms. Of this total, 112 (47.2 per cent) were NC lathes, followed by milling machines and boring machines. Locally-built machines accounted for about 75 per cent of NC lathes and about 60 per cent of milling and boring machines. About 40 per cent of the NC machines and more than 80 per cent of machining centres, CAD/CAM and robots were purchased after 1983. The sample firms owned several host computers. Compared to the size and the number of host computers, the number of other OA machines was quite limited. These findings indicate that the office automation has not yet been well established in Korea. In fact, many executives interviewed were not sure of the applicability of micro computers and personal computers because the management information system was still at an infant stage. The limited use of other OA equipment is due to the lack of delegation of power and responsibility to lower echelons. However, many OA user firms expressed their intention to acquire more OA machines in the near future because they had become aware of the crucial effect of OA on the productivity of office work.

ii) Motivations for microelectronics application

Table 6 gives the main reasons for introducing microelectronic equipment as reported by our sample firms. FA machinery had been introduced mainly for three reasons: 'for better quality control', 'to compete in export market' and 'due to the product standard imposed by domestic buyers'. The first and third reasons are obviously inter-related. Since Korean manufacturers are very much export-oriented they feel that to meet with international quality standards, factory automation was imperative. Most firms (27 out of 32) reported that the introduction of microelectronics helped them save both time and expense in quality control work. Some of them even stated that the

Table 5. Ownership of microelectronic equipment by the sample firms

Number of units

User industry (number of firms)		NC machines lathes	NC machines milling	NC machines boring	Machining centre	CAD/CAM	Robots
Shipbuilding	(4)	5	2	4	2	3	-
Automobile	(7)	12	19	8	8	2	15
General machinery	(10)	82	41	45	32	3	-
Electronics & electrical	(3)	4	-	-	-	1	-
Mould & tool	(4)	9	4	2	-	-	-
Engineering	(2)	-	-	-	-	-	-
Total	(30)	112	66	59	42	11	15

		Computer Main	Computer Micro	Word Processor	Copy Machine	Facsimile machine
Banking, insurance, security & investment	(4)	11	42	10	42	12
Trading	(3)	5	12	8	14	5
General machinery	(1)	3	5	2	4	1
Electronics	(2)	4	17	6	9	3
Total	(10)	23	76	26	69	20

Source: Our Survey.

improvement in quality control was the single most important result of using microelectronic equipment. Some firms in the machinery industry purchased machining centres recently for this very reason. Savings in the quality control staff has often permitted expansion of R and D efforts. The rising labour cost was not a significant reason for introducing FA equipment.

In contrast, the need for labour saving seems to be the primary motivation for OA, which underlies items 6 and 7 in Table 6. In Korea, the

Table 6. Motivation for microelectronics application

Motivation		FA users	OA users
1.	To compete in export markets	18	-
2.	Due to the product standard imposed by domestic buyers	15	-
3.	For efficient production	8	-
4.	For better quality control	22	-
5.	Because of rising labour costs	2	-
6.	To increase office productivity	-	10
7.	To save administration costs	-	15
8.	To improve corporate image	-	4
Total		66	29

Note: The total number of replies exceeds the total number of respondents since many firms gave more than one reason.
Source: Field survey.

office workers' average earnings are more than double that of the production workers', and the former increased almost as fast (28.4 per cent a year) as the latter (29.0 per cent) during 1974-81. Moreover, during 1970-80, the average annual rates of employment growth were 7.3 per cent for the clerical workers, 6.1 per cent for the professional and technical workers and 5.0 per cent for the production workers.[8] During the business recession of 1980-82, banking and trading firms were eager to cut the labour cost through office automation.

It is interesting to compare our findings on FA with those of a large-scale survey which KAIST conducted by mail in June 1985. Out of a total of 1,395 selected firms, 266 (19 per cent) responded.[9] The most important motivations for introducing (or planning to introduce) FA equipment were 'to increase productivity' (50.0 per cent), 'to reduce production costs' (21.0 per cent) and 'for quality control and upgrading' (18.0 per cent). Clearly, the productivity is stressed much more than in our survey. This difference may be explained by a number of factors: the difference in the size distribution of the sample firms; the way the question was asked (our question was an open-ended one); the difference between actual users and potential users; and our survey was based on interviews, not by mail, so that the replies were more specific.

Regarding OA, the KAIST survey report (1982) indicates that only 26.3 per cent of respondents appreciated the productivity and accuracy gain obtained through the use of the computer. The percentage of firms who mentioned such effect increased to 47.9 per cent in the KIIA survey (1983).

iii) Sources of information

Regarding the sources of information on FA equipment, foreign equipment manufacturers and their agents are the most important (14 and 12 cases), followed by domestic equipment manufacturers (12), foreign technology partners (8) and domestic parent firms/customers (6). International exhibitions and publications were cited by two firms each. For OA users, too, the most important sources of information were equipment manufacturers: ten firms mentioned foreign suppliers and six domestic ones. International exhibitions and publications were mentioned by eight and four firms, respectively.

iv) The rate of utilisation

Table 7 indicates that CAD/CAM and personal computers are not currently well utilised. NC machines among FA equipment and word processors and copy machines have the highest rate of utilisation. As the user firms confirmed repeatedly in our interview, the utilisation rate of FA and OA equipment depends crucially on the firm's capacity to utilise such equipment. It can be illustrated with reference to personal computers. Many companies had acquired personal computers with a view to diversifying the use of the computer among different divisions, motivating middle management, and reducing the burden on the host computer. In reality, however, we discovered that activities were not sufficiently delegated to lower echelons. As a result, the personal computers were not utilised adequately and the burden on the host computer did not decrease at all.

Although the rate of utilisation of machining centres was not so high as other NC machines, their owners anticipated it would pick up soon. Most machining centres had been acquired for specific projects such as production of components for a United States-based multinational producer of industrial transport and construction equipment and assembly of parts and components for American aerospace companies. Since these projects were at the initial stage, the rate of utilisation of the machines was low. Two automobile manufacturers were using their machining centres more fully. The case seems to be similar with the robots whose use is currently confined to relatively simple work such as painting and assembly. Our interviewees attributed the low rate of utilisation of CAD/CAM[10] to three factors: (a) the lack of necessary manpower, (b) a low level of factory automation in general which limited the

scope for CAD/CAM application, and (c) insufficient supplies of software and know-how. The low utilisation of CAD/CAM also indicates that many firms do not yet have the ability to develop their own design and manufacturing.

According to the KAIST survey (1985), 21.5 per cent and 16.9 per cent of the sample firms mentioned the high cost of the CAD/CAM system, and the lack of necessary manpower, as a major constraint on its application, while 32 per cent stated the productivity gain in design and manufacturing as the most beneficial effect, 15 per cent skill improvement effect and 13 per cent labour-saving effect. When asked whether or not they had developed their own application programme, only 24.4 per cent responded in the affirmative (6.8 per cent for NC machines and 5.3 per cent for drafting inputs). Major constraints on robotisation were found to be difficulty in selecting areas for robotisation and in economically justifying substitution for the existing equipment and labour. All this indicates that many firms find the introduction of CAD/CAM and robots premature.

Table 7. The average rate of utilisation by equipment

FA Equipment	Average rate of utilisation (%)	OA Equipment	Average rate of utilisation (%)
NC machines	82	Copy machines	90
Machining centres	68	Facsimile machines	80
Robots	60	Micro computers	65
CAD/CAM	54	Personal computers	40

Source: Field survey.

As shown in Table 7, we found relatively high rates of utilisation of OA equipment other than personal computers. In fact, many firms were planning to purchase more copy machines, word processors and facsimile machines since they found them quite useful in increasing office productivity. They felt no difficulty in training employees to handle this equipment.

According to the KIIA report (1983) mentioned earlier, the average rate of computer operation increased from 288 hours per month in 1982 to 305 hours in 1983. The average rate of CPU operation also rose from 190 hours in 1982 to 224 hours in 1983. If we assume the standard operating hours of computers to be 200 hours (= 8 hours per day x 25 days), the average hours (305 hours)

found by the KIIA survey indicates significant overloads on the main system. In this survey 157 out of 234 institutions surveyed answered that they were using computers effectively. However, the long operating hours do not necessarily mean adequate utilisation of the computer system. Most computers are used in simple repetitive work such as accounting, personnel, purchasing, and inventory control. Applications to areas such as decision-making, production management, technology design and architecture, and advertising are rare.

II. Microelectronic Equipment Industry in Korea

After a steady period of growth during 1970-81 the total production and exports of the electronics industry more than doubled between 1981 and 1985 (Table 8). In 1985, the total production approached 7,285 million dollars, of which 59.7 per cent (4,352 million dollars) was exported. The electronics industry is now one of the largest industries in terms of both value-added and export ratio in Korea. In recent years, the growth of the industrial electronics and parts and components subsectors has exceeded that of the consumer electronics subsector which indicates that not only has the industry's output grown but the industrial structure of this industry has also been deepening. Diagram 1 depicts the dates of commencement of import and local production of different microelectronic machines.

The influence of Japanese firms both as exporters and as technological suppliers has been predominant. For example, in the case of NC machines which are the main microelectronic FA equipment currently used in Korea, imports from Japan accounted for 78.4 per cent in terms of number of units and 91.6 per cent in terms of value of total imports in 1983. Eight out of 11 cases of NC-related technological licensing agreements were with Japanese firms in the same year. The same is true with the microelectronic OA equipment. In general, domestic production begins when there is a reasonably high level of domestic demand for the product and when the government promotes it by means of import restrictions.

Since Korea is a technology follower to the United States and Japan, the life-cycle of the technology tends to be shorter than in these countries. In Japan, the first unit of the NC milling machine (so-called "hard-wired NC") was produced in 1958, the computerised NC (CNC: so called "soft-wired NC") became commercialised in 1970 and the age of the one-chip micro-processor CNC began in 1974.[11] Therefore, there was almost 16 years' time lag between "hard-wired NC" production and "micro computer NC" production. In Korea, the

Table 8. Growth of electronics industry in Korea: 1970-85
(US$ million)

Year	Production				Exports			
	Consumer electronics	Industrial electronics	Parts & components	Total	Consumer electronics	Industrial electronics	Parts & components	Total
1970	30	17	59	106	9	0.3	46	106
1971	33	19	86	138	11	0.4	77	88
1972	55	25	128	208	35	4	103	142
1973	135	42	285	462	104	18	247	369
1974	259	76	479	814	171	27	320	518
1975	270	94	496	860	199	35	348	582
1976	551	126	745	1,422	390	56	591	1,037
1977	679	185	894	1,758	436	103	568	1,107
1978	927	210	1,134	2,271	654	103	602	1,359
1979	1,374	320	1,586	3,280	915	111	819	1,845
1980	1,148	364	1,340	2,852	985	115	904	2,004
1981	1,574	494	1,723	3,791	1,123	125	969	2,218
1982	1,549	639	1,818	4,006	898	223	1,079	2,200
1983	2,189	943	2,426	5,558	1,161	440	1,446	3,047
1984	2,426	1,213	3,531	7,170	1,523	552	2,129	4,204
1985	2,411	1,518	3,356	7,285	1,555	783	2,014	4,352
Growth rate (%)								
1970-75	65.4	43.2	57.8	57.0	103.7	272.6	55.9	51.4
1975-80	39.1	32.1	24.3	29.9	41.1	31.1	23.7	30.4
1980-85	17.4	33.3	21.6	21.6	11.3	50.3	18.9	18.0

Source: Electronic Industries Association of Korea

Diagram 1. Time profile of microelectronics in Korea: Imports and domestic production

		1973	1977	1978	1979	1980	1981	1982	1983	1984	1985
FA machinery											
NC machines		I	P								
CNC machines			I			P					
Machining centres					I		P				
NC units				I							P
Robots					I			P			
CAD/CAM						I				P	
OA equipment											
Computers	I 1967							P			
Word processors							P I				
Copy machines		I					P				
Facsimile machines				I			P				

Notes: I the first year of import
P the first year of production

first unit of NC imported was "soft-wired NC" and the domestic production of NC began in 1977, followed by the production of CNC in 1980 and the machining centre in 1981. In other words, there was only 3 to 4 years' lag between NC and CNC production in Korea.

The phenomenon of this short life-cycle is by and large due to the rapid technological advancement in the Japanese NC machine industry rather than to the fast indigenous technological capacity building on the part of the Korean machinery industry. Since the Korean industry skipped almost 10 years of "hard-wired NC" development experience, their indigenous technological capacity is quite weak. While the Japanese industry pursued domestic development of such technologies, the Korean relied on Japanese technology so that major parts of CNC machines are still imported. According to the Ministry of Trade and Industry (MTI), the localisation rate in 1984 was still 60 per cent for the NC lathe and the milling machine, and 55 per cent for the machining centre. The production of robots is at the development stage and CAD/CAM is at the experimental stage.

Regarding the OA equipment, the localisation rate of the photocopy machines is reported to have been 70 per cent, and that of the facsimile machines around 40 per cent as of 1984. The production of micro computers, personal computers, and word processors started in 1983 when the Government designated the information industry for special developmental support during the 1980s. Micro and personal computers and peripheral systems, including word processors, are imported in semi-knocked-down (SKD) forms mostly from firms in the United States such as IBM and HP. The production of such OA equipment is promoted by the Government which is setting up an administration information system and which has introduced import restrictions on single-user micro and personal computers and other peripheral devices.

1. <u>FA Equipment Industry</u>

According to Groover (1980), historically, factory automation has evolved through six different stages: (1) hand work, (2) mechanisation, (3) partial automation of unit machinery, (4) full automation of unit machinery, (5) automation of a production line, and (6) full factory automation. The current state of factory automation in Korea is mainly at stages (3) and (4). Some companies in the automobile industry are heading to stage (5), but they are rather exceptional.[12] The main product of the FA equipment industry in Korea is NC machines. Some companies have started producing machining centres and robots. Most CAD/CAM units and robots are still imported and no installation of a full-scale FMS (Flexible Manufacturing System) is reported

yet. However, according to the KAIST report (1985), a number of companies are considering installing FMC (Flexible Manufacturing Cell) or FTL (Flexible Transfer Line).

i) NC machine tools

The production of conventional machine tools started in 1960 in Korea when NC machine tools began to be commercialised in the United States. Local production of such machine tools started in 1977. However, the official record of NC machine tool production dates back to only 1982 when the Korea Machine Tool Manufacturers' Association (KOMMA) began collecting member firms' data. The pre-1982 data are estimates by the Korea Institute for Industrial Economics and Technology (KIET) and the Ministry of Trade and Industry (MTI), as indicated in Table 1 above.

From the same table one can see that the NC-ratios of machine tool production, exports and imports have been rising. Lathes accounted for 49 per cent and 66.1 per cent of total NC machine tool production and exports (in value) during 1982-85, and machining centres (MC) for 43.5 per cent of production and 31.4 per cent of exports. During the same period, 49.9 per cent of total NC machine tool imports was lathes and 17.1 per cent milling machines (in value) (Table 9). The United States has been the biggest export market for Korean machine tools, both the conventional and NC, and Europe has also been an important market for NC machine tools. It is interesting to note that while NC lathes accounted for 84.3 and 77.8 per cent of total NC machine exports to Europe (50 out of 57 units) and the United States (73 out of 85 units) in 1984, respectively, only 4.4 per cent of total NC exports to Japan were lathes. Surprisingly the bulk (92.9 per cent) of NC machine exports to Japan consisted of 42 units of machining centres.[13] As we discovered in our field study, two of the largest local NC machine manufacturers had international subcontracting arrangements with their Japanese technology partners, who supplied some key parts and components of machining centres for assembly in Korea to be re-exported back to Japan. No international subcontracting is yet reported in manufacturing other types of NC machines, even though all the NC machine manufacturers had technological licensing agreements with the Japanese firms. This may imply that the technological and quality standard of Korean NC machines is not acceptable to Japanese firms and/or that they are regarded as potential competitors in export markets.

In Korea, there is no systematic statistical information on the shipments of NC machines by type of users. However, our preliminary survey by mail and field study of 30 FA user firms, indicate that at least 60 per cent of domestic shipments were directed to large firms and the rest to small and

Table 9. NC machine tool production, exports and imports by type of machine

	PRODUCTION								EXPORTS								IMPORTS							
	Total		Lathe		Milling machine		MC		Total		Lathe		Milling machine		MC		Total		Lathe		Milling machine		MC	
Year	Units	Value	Units	Value	Units	Value	Units	Value	Units	Value	Units	Value	Units	Value	Units	Value	Units	Value	Units	Value	Units	Value	Units	Value
1974	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	273	3,841	258	3,705	15	1,380	-	-
1975	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	1,447	2	67	10	1,380	-	-
1976	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	655	23	412	7	243	-	-
1977	5*	200*	5*	200*	-	-	-	-	-	-	-	-	-	-	-	-	21	1,253	16	1,054	5	199	-	-
1978	20*	850*	20*	850*	-	-	-	-	-	-	-	-	-	-	-	-	70	3,498	51	2,575	19	923	-	-
1979	40*	1,800*	35*	1,600*	5*	200*	-	-	-	-	-	-	-	-	-	-	144	26,677	115	12,654	29	14,023	-	-
1980	22*	1,090*	19*	940*	3*	150*	-	-	4	169	4	169	-	-	-	-	52	3,792	45	2,889	7	903	-	-
1981	100*	4,624*	80*	3,800*	19*	760*	1*	64*	51	2,143	46	1,823	-	-	5	320	39	11,684	26	10,707	5	603	8	374
1982	295	15,312	220	10,130	-	-	75	5,182	186	10,085	138	7,106	14	625	34	2,354	39	3,987	18	1,886	16	1,106	5	995
1983	371	21,728	223	10,982	20	875	118	9,871	128	5,682	65	2,509	-	-	63	3,173	118	9,668	49	3,386	51	3,006	18	3,176
1984	459	24,195	268	11,622	76	3,512	115	9,061	195	7,606	127	4,506	8	69	60	3,031	169	32,667	107	22,599	44	7,934	18	2,134
1985	578	38,007	360	15,874	62	3,064	156	19,069	177	7,172	155	6,083	3	41	19	1,048	192	25,655	89	8,025	78	11,736	27	5,894

Notes: (*) Estimates by KIET

Sources: Korea Machine Tool Manufacturers' Association, Machine Tool Statistics Handbook, 1985 and Machine Tool Industry Korea, 1986.

Table 10. Major NC machine tool manufacturer in Korea (1984)

(Thousand dollars)

Company	Main Items	Total machine tool production	NC machine production	Share of NC in production (%)	Exports (all machine tools)	Capital	Number of Employees Total
1. Daewoo Heavy Industries Co.	NC lathes, NC milling and machining centre	18,971	10,510	55.4	4,535	58,504	1,260 (8,419)
2. Whacheon Machinery Works Co. Ltd.	"	24,934	5,660	22.7	2,498	3,016	630
3. Kia Machine Tool Ltd.	NC lathes milling machines	24,673	5,428	22.0	118	8,444	700 (986)
4. Tong Il Co. Ltd.	"	11,371	3,313	29.1	7,375	45,838	1,200 (3,983)
5. Korea Heavy Machinery In., Ltd.	NC lathes NC milling	6,113	379	6.2	713	21,110	250 (2,212)
6. Daegu Industrial	NC lathes	4,429	31	0.7	1,773	60	220
7. Hyundai Motor Co.	Machining centre	5,344	326	6.1	0	113,800	270 (9,147)
8. Namsun Machinery Works	NC milling	3,029	521	17.2	198	133	182
9. Kiheung Machinery Works Ltd.	"	1,949	115	5.9	591	121	161

Source: The Ministry of Trade and Industry

Table 11. Motivations for NC machine production

Respondent / Motivation	Automobile business group			Large independent firms			Small independent firms			Total number of respondents
	A	B	C	D	E	F	G	H	I	
1. Extension and diversification of our business	2	-	-	-	3	1	1	1	1	6
2. Customer's request or advice	-	-	-	-	-	-	3	-	-	1
3. Technology partners' advice	-	-	-	-	-	2	2	3	-	3
4. To help other business operation (e.g., automobile manufacturing)	3	1	2	-	-	-	-	-	-	3
5. To become a main exporter	1	3	3	2	3	-	-	-	-	5
6. To become a main domestic supplier	-	2	1	1	2	3	1	2	2	8
7. To take international subcontracting work	-	-	-	-	-	-	-	-	3	1

Note: The numbers indicate the order of importance, "1" being the most important.
Source: Field survey.

medium-sized firms (i.e., firms with fewer than 300 employees or less than 300 million Won (362 thousand dollars at 1984 exchange rate)) and vocational training institutions. On this basis, we estimate the shares of exports, domestic shipments to large firms, and those to small and medium-sized firms at 31.4 per cent, 41.2 per cent and 27.4 per cent, respectively.

In a number of aspects it is interesting to compare the above findings with the Japanese experience. According to Watanabe (1983), the corresponding figures in Japan were 2.2 per cent, 68.5 per cent and 27.4 per cent in 1970, but they were 46.8 per cent, 19.7 per cent and 32.8 per cent by 1981. He notes that, "for some time after the introduction of the new equipment which embodies a new technology and requires a sizable capital investment, and also certain technical expertise to master the equipment, well established large companies alone can afford to take the risk and adopt it".[14] A similar proposition applies to Korea, but there are also a couple of important differences. For one thing, the share of small and medium-sized firms still

Table 12. Average prices of locally-built machine tools by type of machine (thousand US dollars)

	Conventional lathes	NC lathes	Conventional milling	NC milling	Machining centre	Wholesale price index
1977	4.5	40*	3.9	-	-	54.3
1978	5.5	42.5*	4.1	-	-	60.6
1979	6.6	45.7*	2.0	40.0*	-	72.0
1980	5.3	49.5*	5.1	50.0*	-	100.0
1981	8.6	47.5*	6.5	40.0*	64*	120.4
1982	6.7	46.0	8.7	-	69.1	126.0
1983	6.9	47.1	9.6	43.8	83.7	126.3
1984	7.2	43.4	9.2	46.2	78.8	127.2

Note: (*) Estimates by KIET
Source: KOMMA: Machine Tool Statistics Handbook, 1985 (Seoul).

remains very small in Korea. This is at least partially explained by the underdevelopment of the subcontracting system: the Korean automobile industry and the shipbuilding industries rely much less on subcontractors than these industries in Japan. An even more striking contrast is related to the ratio of export demand. In Korea it was high from the beginning, while it increased very slowly in Japan until the mid-1970s. This may be explained as follows: the Korean NC machine manufacturers had to start with the assumption that the domestic demand would pick up very slowly, so they had to look to the export market from the beginning. This has been confirmed in our field study in which we discovered that one of the main reasons for their technical tie-up with Japanese NC manufacturers was to develop export markets. Another explanation is that during the period of 1981-84, Japanese NC manufacturers moved to higher cost machines including machining centres, permitting Koreans to penetrate into smaller and lower-cost NC machine markets.

Currently there are about nine major producers of NC machines in Korea as listed in Table 10. The biggest manufacturer and exporter of NC lathes is

Daewoo Heavy Machinery which produced 10.5 million dollars of NC machines and exported 4.5 million dollars in 1984. According to the recently released company data, it exported 7.3 million dollars of NC lathes, machining centres and other NC machines in 1985. The biggest manufacturer of machining centres is Hwacheon Machinery Works Co. Limited which produced 5.7 million dollars of NC machines and exported 2.5 million dollars in 1984. Its exports increased by 34.1 per cent to 3.4 million dollars in 1985. Another remarkable manufacturer is Tongil Co. Limited which recently developed a CNC unit. The company exported a total of 4.6 million dollars of NC machines and expects to double the export volume in 1986. A unique company is Hyundai Motor Co. Limited which started producing machining centres for its own use.[15] The other companies are much smaller, often working as a subcontractor for different companies. It is interesting to note that all three major automobile manufacturers (Hyundai, Daewoo and Kia) have an NC machine tool production division either within the company or as a subsidiary. The rest can be divided into two categories: large independent firms, and small and medium-sized firms with fewer than 300 employees. Whacheon Co., Tong Il Co., and Korea Heavy Machinery Industries Limited belong to the former, and the remaining three companies (Daegu, Namsun, and Kiheung Co.) to the latter.

According to the results of our field survey, the first group, namely major automobile manufacturers, has a relatively short history of both conventional (0 to 8 years) and NC machine tool production (2 to 4 years). The second group has the longest experience in NC machine production (5 to 7 years), with 12 to 14 years' experience in conventional machine production. The third group, i.e., conventional machine makers, started NC machine production quite recently (2 to 3 years ago), while they have the longest experience in conventional machine manufacturing (15 to 20 years).

All nine companies listed were included in our sample. To our inquiry about the motivation for NC machine tool production, they replied as shown in Table 11. Most of them anticipated that the domestic demand for such machines would increase as the need for factory automation became stronger, and wanted to become a major domestic supplier. The next important motivation was to extend and diversify their business as a producer of conventional machine tools. All the automobile manufacturers cited the need to help expanding automobile manufacturing facilities as another motivation.

Table 12 gives the average list prices of locally built machine tools. The average price of conventional lathes increased by 2.7 thousand dollars between 1977 and 1984 in nominal terms. When adjusted by WPI the wholesale price index (1980 = 100), however, it declined from 8.3 thousand to 5.7

thousand dollars during the same period. In the case of NC lathes, the average price in constant prices fell more than 54 per cent. This is quite remarkable when we consider the qualitative improvements made in both conventional and NC machines.

ii) CAD/CAM and robots

As indicated earlier, there has been no large-scale effort for localising CAD/CAM production. Most of the systems installed so far have been imported. However, there have been some attempts to develop smaller CAD systems utilising microcomputers. For example, an engineering company, which is a specialised plant design firm, has developed a small CAD system for graphic purposes. They felt the CAD systems on the market were too expensive for smaller firms who wanted to use them just for simple graphic designs and modifications, developed their own system and put it on the market at almost half the import price of comparable systems.

Such simple CAD systems appear to have a good market prospect. According to the Institute of Computer Training at Electronic Industries Association of Korea (EIAK) which started a CAD training programme in September 1985 in response to member firms' requests, a large number of smaller firms expressed an interest in introducing smaller-scale CAD systems (not CAM yet) and some large enterprises too wanted to experiment with smaller-scale systems at different branches of operation independently. The latter group was afraid of introducing a too expensive complex CAD/CAM system and ending up with under utilisation. The Institute installed 24 sets of 16 bit personal computers (SPC-3000) manufactured by a local firm and used software called Auto CAD for the training. So far they have offered the training programme to about 72 member firms of which about 60 per cent were from the electronics industry, about 30 per cent from the construction industry, and the remaining 10 per cent from other industries. To meet with increasing demand, the Institute is planning to expand the programme.

The development of robots has been much more systematic. KAIST started working on robots in 1979 and developed a control unit in 1981 jointly with Daewoo Heavy Machinery Co. In 1981, Kukje Co. and Samsung Precision Co. developed basic manipulator and playback robots respectively. Subsequently, Daewoo Heavy Machinery Co. developed loading and unloading playback robots in 1982. In the same year, Gold Star Communication Co. and Tong-Il Co. Limited developed a fixed sequence robot called Gold Finger 2000 and material transport robots respectively (KIET, 1983). Daewoo Heavy Machinery Co.

introduced a series of models for factory automation including welding robots in 1984. As shown in Table 2, the total demand for robots rose from 18 units (0.7 million dollars) in 1983 to 338 units (12.6 million dollars) in 1985 (MTI, 1986).

2. <u>OA equipment industry</u>

As shown in Table 4, the expansion of the microelectronic OA market since 1981 is truly remarkable. The Government designated the electronics and information industry as a strategic industry for development in 1981. Since then, various promotional policies have been combined with import restrictions on single user computers as well as other OA equipment as the domestic industry becomes prepared for production. The industry started basically as an assembly industry importing major parts and components. By 1985, the localisation rate had risen to almost 90 per cent for personal computers and to around 70 per cent and 60 per cent for the copy and facsimile machines, respectively.

The ratios of exports of computers and peripheral equipment have been extremely high: 73 per cent (158 out of 216 million dollars) and 80 per cent (242 million out of 303 million dollars) in 1985. The largest product items were personal computers (183 million dollars) and monitors (177 million dollars), and they accounted for 79 per cent of total exports. (All the monitors produced were exported.) At the same time, imports of computers, peripheral equipment and components have grown very rapidly: at an annual rate of 56.8 per cent, 27.4 per cent and 41.9 per cent respectively, between 1978 and 1984. The total amount of mainframe imports reached 62 million dollars in 1984 when the total amounts of mainframe production and exports were 147 million dollars and 82 million dollars. Since digital CPU and central storage units, which are regarded as part of mainframes, are entirely imported (63 million dollars) the trade deficit in computer mainframes amounted to 43 million dollars in 1984.

In 1985 there were about 68 firms in the computer industry, and some of them produced both mainframes and peripheral systems (Table 13). About five mainframe manufacturers employ over 500 workers and the rest are much smaller. The production capacity of the industry increased from 60 million dollars in 1982 to 649 million dollars in 1985, by more than ten times. The capacity utilisation rate was over 80 per cent during 1982-85 when other manufacturing industries were operating at much lower rates.

The production of facsimile machines requires fairly demanding technology as well as simultaneous development in related technology in the chemical and

Table 13. Number of firms in the computer industry

		Number of firms			
		1982	1983	1984	1985
Main-Frame	medium	-	1	2	2
	mini	2	3	4	7
	super mini	8	11	13	14
	personal	11	29	42	39
Peripheral system	FOD (Floppy disk drive)	-	11	15	14
	printer	9	13	17	20
	terminal	11	17	19	22
	banking terminal	1	2	3	6
	CRT (Cathode ray tube)	9	11	12	12
Communi-cation	modem	4	6	6	7
	multiplex	1	3	5	6
TOTAL		27	52	71	68

Note: Some firms produce more than one item.
Source: Ministry of Trade and Industry.

optical instrument industries. In addition, it requires an adequate communication network. The establishment of Korea Electrical Communication Corporation in 1982 and Korea Data Communication Corporation in 1983 helped increase the demand for facsimile machines. The total production in 1983 tripled and reached 4,000 units in 1985. The Ministry of Trade and Industry, forecasts 15,000 units to be produced in 1988 of which 4,000 units will be exported. Currently there are about seven facsimile manufacturers in Korea. Six of them, including three who are the only manufacturers of copy machines in the country, maintain licensing agreements with Japanese firms. The major components still being imported are optical parts such as lens and lamps, electronic components such as thermal heads, charge coupler devices and motors, and cutters.

The production of word processors does not show a stable trend. Our field survey discovered a number of software houses which built word processors combining, for example, IBM hardware with software in Korean. These products may not have been captured in EIAK statistics which rely on reports from hardware manufacturers.

III. The Impact of Microelectronics on Employment

1) An overview

The impact of microelectronic FA and OA on employment is very difficult to assess, even at a micro level because many other changes take place simultaneously. Another difficulty is related to the short history and limited diffusion of the new technology in Korea. With these difficulties in mind, however, we attempt here to assess the impact of microelectronics on employment by means of both macro-level data and micro-level field work.

Between 1975 and 1980, the index of industrial production doubled and that of metalworking industries grew even faster. Among five sub-industries, general machinery was the slowest in growth of production. During the same period, employment growth in the manufacturing and service sector was 59 per cent and 63 per cent, respectively (Table 14).

During the period of 1980-85, the production of the general machinery and transport equipment industry outpaced both the manufacturing and metalworking industries. Employment grew fastest in the transport equipment industry (65 per cent). In the case of the general machinery industry where most of the NC machines have been used, the increase in production workers (11 per cent) was far behind the increase in office workers (55 per cent). It may partly reflect the impact of FA, particularly in large machinery enterprises. The labour productivity index in the manufacturing sector rose from 36.4 (1970) to 100 (1980) and 158.6 (1984). The index in the metalworking industries shows the most drastic change: from 23.3 (1970) to 100 (1980) and 199.1 (1984).

The average monthly earnings in all industries increased from 185 to 292 thousand Won between 1980 and 1984, by about 58 per cent in nominal terms (Ministry of Labour). On the other hand, the wage differential between office workers (including administrative and technical workers) and production workers has decreased: the ratio of office workers' average earnings to production workers' fell from 2.0 to 1.79 in the manufacturing sector and 1.93 to 1.69 in the metalworking industries, between 1980 and 1984. However, the earnings differential between industries seems to be widening. The ratio of average earnings in the banking sector to the manufacturing sector was 1.69 in 1980 but increased to the level of 2.27 in 1984, the banking sector's wage increase outpacing wage increases for both office and production workers in other sectors. This seems to have contributed to the aggressive effort for OA by the banking industry in recent years. OA has reduced skill requirements for some office work. For example, as a result of the on-line system, the window service at the banks requires a very simple skill instead of

Table 14. Growth of production and employment by sector and industry

Code	Industry	Ratio of production index 1980/75	Ratio of production index 1985/80	Employment (1,000 persons) 1975	1980	1985	1985/80
	All economy			1,597	2,561	3,082	1.20
	Service industries			453	738	1,018	1.38
	Manufacturing as a whole	2.16	1.67	1,094	1,734	1,969	1.14
	Production			922	1,374	1,484	1.08
	Office			172	360	485	1.35
38	Metalworking industries	2.58	2.42	255	506	663	1.31
	Production			218	392	488	1.24
	Office			37	114	175	1.54
381	Fabricated metal	2.95	1.93	53	106	124	1.17
	Production			45	84	98	1.16
	Office			8	22	26	1.18
382	General machinery	1.90	2.88	42	79	97	1.23
	Production			36	56	63	1.11
	Office			6	22	34	1.55
383	Electrical machinery	3.08	2.55	112	202	252	1.25
	Production			99	160	191	1.19
	Office			13	42	60	1.43
384	Transport equipment	2.02	2.65	36	91	163	1.79
	Production			28	67	115	1.72
	Office			8	24	48	2.0
385	Measuring equipment, etc.	2.99	1.26	12	29	28	0.97
	Production			10	24	22	0.92
	Office			2	5	6	1.20

Source: Ministry of Labour, Report on Monthly Labour Survey, (Various issues), and Bank of Korea, Economic Statistics Yearbook (1986).

sophisticated training in calculating interest on deposits and loans, etc. All of this contributed to reducing the earnings differential between office and production workers. The government wage policy, which has been consistently in favour of production workers during recent years, has accelerated this trend.

Among the five metalworking industries, the transport equipment industry has the highest average monthly earnings (321 thousand Won) which is followed by machinery (279 thousand Won). The former also recorded the highest increase in average monthly earnings (66 per cent) between 1980 and 1984, reflecting the industry's strong demand in recent years. The high wage increase for production workers in the transport equipment industry may partially reflect the industry's recent demand for more skilled workers to pursue FA. As we confirmed through the field study, many firms found it difficult to keep FA personnel who tended to be attracted by higher wages offered by other firms.

2. Survey findings

Most of our sample firms had experienced overall employment growth even after introducing FA or OA equipment mainly because of growth of their business. Indeed, these firms argued that, in fact, without such a demand increase they could hardly have justified investment in those machines. However, on the particular production lines or offices where FA or OA equipment was introduced, such equipment usually had labour-saving effects (Table 15).

Robots and machining centres were mostly applied, respectively, on newly-built automobile assembly lines and on production lines built exclusively for specific projects such as aerospace and construction equipment projects. Thus, they did not displace any labour. CAD/CAM user firms, such as the shipbuilders and engineering firms, also had to hire some new engineers and technicians to use the system so that they had a positive change in employment in the division of CAD/CAM operation. They felt the main advantage of CAD/CAM was not immediate labour savings but productivity increase and potential labour savings in the future. The rest of the firms could reduce manpower inputs with FA, especially NC lathes and robots. Those who lost their work have been absorbed in other divisions where their skills are still utilised. Most of the firms interviewed stated that the NC machines would not reduce employment immediately but restrain employment growth in the future. In Table 15, change in employment level at the production lines where robots and machining centres had been introduced reflects the employment change in a division as a whole, which includes the newly created department or team that introduced such equipment. Most CAD/CAM user firms kept conventional design drawing staff on their pay roll. Some were sent to training programmes and others to laboratories and other R and D facilities.

OA user companies also experienced an increase in overall employment, but at slower rates than during the 1970s. Banks, insurance companies and

investment firms reported significant cuts in manpower related to routine operations such as window service and customer file management. Trading firms and the firms in the machinery and electronics industries were able to reduce office manpower by 8 per cent and 5 per cent respectively, using computers and other OA equipment (Table 15).

In general, the magnitude of the increase in monthly earnings was relatively smaller for those workers using simple equipment such as NC lathes, word processors and facsimile machines, than for those using more sophisticated equipment such as CAD/CAM and computers. For machines such as NC lathes and word processors, the skills required were relatively simple, and existing employees could easily acquire them after a short period of training. For more sophisticated equipment such as CAD/CAM, robots and computers, the firms' existing staff in general could not meet skill requirements (Table 16). A majority of our sample firms, both FA and OA users, however, reported difficulty in recruiting qualified computer and CAD/CAM personnel. They were often obliged to offer higher wages to FA or OA personnel and consequently also adjust compensation to the existing staff. Still, the turnover rate of the highly trained FA and OA personnel was much higher than that of the average workers.

Out of 30 FA users in our sample, 17 firms (57 per cent) had deployed existing workers within the same division, e.g. a mechanic for conventional lathes for NC lathes, 12 firms (40 per cent) had set up a new work organisation by transferring employees from different divisions, and 14 firms (47 per cent) had hired new people.

The need for change in the work organisation appears to be highly correlated with the degree of skill requirements: for more sophisticated equipment a specific division or section was created, while little organisational change took place for simpler equipment. The organisational change, if any, was not drastic in most cases. Many firms mentioned that because FA and OA in their firm was still experimental, they did not want to change work organisation too much for the time being. Even in the banking sector where a relatively high degree of OA was accomplished, there was no significant change in work organisation because supporting activities other than the on-line system at the window were not yet fully computerised.

Regarding the productivity change, many firms expressed difficulty in isolating the productivity effect of FA and OA from those of other factors. In some cases, they did not have long enough experience to observe the productivity change. For these reasons, the productivity change reported in Table 16 may not be accurate. The productivity increase by using robots and

Table 15. Microelectronics and the change in employment level* 1981-84

FA user co. (sample size)		Change in overall employment level of the firm (%)	Change in employment level at the production lines/offices where the new technology had been introduced (%)
By industry			
Shipbuilding	(4)	12	4
Automobile	(10)	18	-5
General machinery	(10)	8	-10
Mould & tools	(4)	5	-9
Engineering	(2)	10	5
Weighted average	(30)	11.6	-4.3
By type of equipment			
NC machines	(24)	7	-4
Machining centres	(4)	15	5
CAD/CAM	(6)	11	4
Robots	(3)	18	-10
Weighted average	(30)	11.6	-4.3
OA user			
Banking sector	(4)	2	-10
Trading	(3)	5	-8
Machinery & electronics	(3)	5	-5

Note: * For the FA user the change in the employment level of production workers and for the OA user the change in employment level of office workers after introducing FA or OA equipment.

Source: Field survey

NC machines was relatively high. Among industries, the automobile and machinery industries reported rather high productivity gains. Machining centres were too new for assessment and they were also used for new products. Among OA user firms, banks reported the highest (8 per cent) productivity increase.

While the overall productivity increase after introducing microelectronics being cited above does not seem to be substantial, the

Table 16. Microelectronics and skill requirements. Work organisation and productivity increase: Survey results

	Skill requirements	Change in work organisation	Productivity* change (%)
By equipment			
NC machines	average	little	15
Machining centre	high	significant	-
CAD/CAM	high	significant	12
Robots	average	little	20
Computer	high	significant	12
Word processor	average	little	-
Facsimile	low	little	-
Copy machine	low	little	-
By industry			
Shipbuilding	high	significant	5
Automobile	high	significant	15
Machinery	average	little	12
Banking	high	significant	8
Trading	middle	little	5
Others	middle	little	6

Note: * "Productivity" is measured in terms of amount of output per worker and the percentages were calculated in the following way: 100 [(output per worker after the introduction of FA or OA equipment) - (output per worker before introducing equipment)]/(output per worker before introducing equipment). Therefore, time dimension to observe productivity change may differ from one firm to another.

Sources: Field survey.

productivity gain in individual divisions, has been reported to be significant. The sample firms in the automobile industry reported productivity gains in the division where FA was introduced ranging from around

40 per cent (Firm E) to over 300 per cent (Firm A). Firm A (300 per cent) was a new entry firm in the automobile parts manufacturing where NC machines were used and the proportion of this new business line in the firm's total value-added was less than 10 per cent. The sample firms in the machinery industry reported about 30-40 per cent gain in productivity of the workshops where FA was introduced and emphasised the fact that they could diversify their products. OA user firms' productivity gains in the particular division where OA was used were more difficult to be assessed. However, most of the firms reported that there was a 10-20 per cent overall productivity gain.

Regarding constraints on the application of new equipment, many firms with FA equipment mentioned the shortage of qualified engineers and mechanics to handle FA equipment effectively. Both in-house training and training abroad at the technology suppliers' plant required much more time and money than they had expected. Another constraint was related to the wage differential between FA manpower and non-FA manpower, particularly where they recruited engineers and mechanics from outside. Since they usually recruited them from other firms within the same industry, the shortage of such manpower and competition over the existing workers inflated wages. The company officials felt that the differentials within the company between FA personnel and the rest was causing a serious problem in their employment policy.

IV. The Impact of Microelectronics on Indigenous Technological Capacity

The importation of FA and OA machines at the initial stage of their diffusion affects both users and potential suppliers of such equipment. In particular, when equipment industries are promoted for import substitution and future export as has been the case in Korea, the crucial issue is whether local equipment industries will succeed in building indigenous technological capacity. In what follows, we will explore the subject on the basis of some macro-level data and findings of our field study since our sample included firms in the equipment industries. Technological constraints felt by both users and suppliers of FA and OA equipment are also briefly discussed.

1. The trend in technology development

According to the data compiled by the Ministry of Science and Technology (MOST) and published by Korea Industrial Research Institutes (1986), a total of 3,538 cases of technology imports under licensing arrangements were approved between 1962 and 1985 (Table 17). The industries involved were agriculture, manufacturing, communication, electricity, construction, and

Table 17. Technological imports approved and payments 1962-84

(number of cases and million dollars)

	Approval		Payment	
	All/ Machinery industry	All industries	All/ Machinery industry	All industries
1962-66	6	33	0.0	0.8
1967-71	58	285	1.1	16.3
1972-76	116	434	13.4	96.5
1977-81	403	1,225	89.3	451.4
1982	62	308	20.6	115.7
1983	82	362	25.1	149.5
1984	123	437	49.4	213.2
1985	126	454	53.5	295.5
Total	976	3,538	252.5	1,338.9

Source: Korea Industrial Research Institutes (1986).

others. The total payments by all industries reached 295.5 million dollars in 1985 and the cumulative total payments during the 24 years amounted to 1,338.9 million dollars. The technology imports increased significantly after 1978, in terms of both the number of cases and amount. The Korean machine tool and computer industries, as well as the transport equipment industry (automobile and shipbuilding), developed rapidly after 1978, and the demand for foreign technology consisted mainly of technology imports by large enterprises in these industries. The machinery industry had a cumulative total of 976 cases (27.6 per cent of all industries) at 252.5 million dollars (18.9 per cent). The industry ranks at the top in terms of number of cases, the second being the electronics and electrical industry (701 cases with 19.8 per cent). A total of 48 cases are identified as technological imports related to machine tool manufacturing. Japan (1,935 cases or 54.7 per cent of the total) was the main supplier of technology, followed by the United States (824 cases) and the Federal Republic of Germany (192 cases). The dependence on Japan has been even greater in the case of the machinery industry with 598 cases (61.3 per cent). The licensing period of 5 to 10 years and the technology fee amounting

to 3-5 per cent of the net sales, have been the most common among the agreements approved in 1984. In the machinery industry, there were 23 cases where more than 100 thousand dollars was paid as a downpayment.

The official patent statistics show a stable and strong positive trend in all industries and particularly in the machinery industry in recent years (Table 18). The patent applications by this industry accounted for 19.7 per cent of all patent applications during the period 1978-85. Its applications for utility models accounted for 27.9 per cent of all utility model applications. The machinery industry has been the largest applicant in both cases. According to Kim (1981), a total of 157 patent applications (43 by Korean) and 252 utility model applications (225 by Korean) were filed in the same industry. (The patent statistics by sub-category are available only after 1982 when the international patent classification (IPC) system was first adopted.) The proportion of applications by Koreans has been much higher in the case of utility models than patents, due to a greater involvement of local efforts.[16] What is significant to our study is that electrical and electronic machinery has been the largest area of concentration, as is clear from Table 18.

The R and D expenditure may be considered as an indicator of the scale of efforts at indigenous technology capacity building. The ratio of R and D expenditure to GNP in Korea rose steadily from 0.56 per cent in 1979 to 1.06 per cent by 1983.[17] According to the Ministry of Science and Technology, a total of 621,749 million Won was spent on R and D in 1983 of which only 1,678 million Won (0.27 per cent) went to R and D expenditure on FA. The expenditure on CAD/CAM system development was reported to be only 30 million Won. But the R and D expenditure on robot production increased substantially in recent years: 14,755 million Won (1984), 23,403 million Won (1985), and 31,036 million Won (1986). The R and D/sales ratio reached 5.3 per cent in 1986 (MTI, 1986).

According to the Report on Industrial Census (1983), the R and D expenditure per establishment in the fabricated metalworking industries was 180 million Won, as compared with 130 million Won in the manufacturing sector as a whole. Within this industry, the transport equipment industry ranks first with 465 million Won, followed by the electrical and electronics machinery industry (258 million Won). The relatively small R and D expenditure by the general machinery industry (50 million Won) seems to be due to two factors. First, this industry depended more on imported technology than the transport equipment or electrical and electronics industry. As we confirmed through the field survey, their R and D expenditure was relatively

Table 18. Recent trends in patent and utility model applications by Koreans and foreign nationals

MODEL	PATENT					UTILITY				
					Average growth					Average growth
Industry	1982	1983	1984	1985	rate (%)	1982	1983	1984	1985	rate (%)
All industries	5,923	6,394	8,633	10,587	21.8	10,669	11,485	14,765	18,548	20.6
Korean	1,556	1,599	2,014	2,703	20.9	9,500	10,345	13,814	17,615	23.3
Foreign	4,368	4,795	6,619	7,884	22.3	1,169	1,140	815	933	-6.9
All machinery	2,475	2,758	3,984	5,465	31.0	4,666	5,515	7,786	10,180	30.0
Korean	455	556	796	1,296	42.7	3,863	4,862	7,153	9,577	35.6
Foreign	2,025	2,202	3,188	4,169	28.1	803	653	633	603	-8.8
Fabricated metal products	371	347	501	600	19.2	587	699	889	1,160	25.5
Korean	71	83	110	178	37.0	541	666	828	1,112	27.2
Foreign	300	264	391	422	14.6	46	33	61	48	11.7
General machinery	348	388	540	600	20.5	811	978	1,364	1,616	26.1
Korean	63	86	122	134	29.4	682	893	1,253	1,519	30.8
Foreign	285	302	418	566	26.5	129	85	111	97	-5.3
Electrical machinery	1,313	1,552	2,285	3,290	36.4	1,857	2,647	3,956	5,380	42.6
Korean	283	293	448	798	51.3	1,495	2,250	3,645	5,068	50.5
Foreign	1,075	1,259	1,837	2,492	32.8	362	397	311	312	-3.8
Transport equipment	346	357	465	582	19.5	1,276	1,090	1,417	1,793	13.9
Korean	72	76	90	127	21.7	1,046	963	1,280	1,662	18.2
Foreign	274	281	375	455	19.1	230	127	137	131	-13.7
Measuring and optical equipment	182	114	193	293	27.9	135	101	160	231	25.8
Korean	91	18	26	59	30.3	99	90	147	216	35.7
Foreign	91	96	167	234	39.8	36	11	13	15	-11.9

Sources: Office of Patents.

small and only a few companies had their own laboratories. Second, the average size of firms in the general machinery industry is smaller than that in the transport equipment or electrical and electronics industry, in both number of employees and capital. The ratio of R and D expenditure to total value added in manufacturing is 2.6 per cent. The corresponding R and D ratios in the machinery (except electrical), electrical and electronics, and the transport equipment industry are estimated at 3.1 per cent, 6.5 per cent and 5.3 per cent respectively. In terms of both R and D expenditure per establishment and per employee, the transport equipment ranks first with 465 million Won and 0.7 million Won respectively. The machinery (except electrical) industry lags far behind the transport equipment industry with 50 million Won and 0.3 million Won respectively.

It is also important to remember that FA equipment is often developed outside the general machinery industry. According to the KAIST survey (1985) factory automation in Korea was based on in-house design and manufacturing (34.6 per cent of respondents), imports (22.6 per cent), in-house design but manufactured by other local firms (12.4 per cent), order to local firms (14.7 per cent), foreign design but manufactured by local firms (7.9 per cent), and others (7.9 per cent). In the general machinery industry in-house design and manufacturing accounted for 33.3 per cent, followed by "order to other local firms" (25.5 per cent). In the transport equipment industry, the percentage of "in-house design and manufacture" was as high as 51.7 per cent.

Table 19. Composition of manpower in computer industry (1985)

(1,000 persons)

	Directors	Technology development personnel	Production personnel	Support personnel	Total
Computer manufacturers (A)	0.2 (1.6%)	2.6 (25.4%)	4.2 (41.9%)	3.2 (30.1%)	10.3 (100%)
Electronics industry (B)	1.3 (0.6%)	11.7 (5.4%)	173.1 (79.5%)	31.6 (14.5%)	217.7 (100%)
(A / B)	13.6%	22.5%	2.5%	10.1%	4.7%

Source: Electronic Industries Association of Korea

There has been no similar survey on OA.[18] The intensity of R and D efforts in the related area can be broadly assessed on the basis of manpower allocation given in Table 19, which indicates that the proportion of technology development personnel in the total manpower of computer manufacturing (25.4 per cent) is much higher than that of the electronics industry as a whole (5.4 per cent).

2. Indigenous technology development: Survey findings

The already cited statistics on technology imports patents and utility models indicates parallel trends of local firms' inventive capacity and technology imports. While it is still too early to establish effects of microelectronics and related technology imports on the development of indigenous technological capacity on the basis of macro data, findings in our enterprise level survey provide some clue to this question. Most sample firms argued that technology imports were not only inevitable at the initial stage but provided a necessary base for adaptation and modification to their specific needs and ultimately for their own indigenous technology development. Seven of our sample firms had technology import contracts. All six contracts signed in and after 1983 were related to microelectronics. Apart from two contracts involving machining centres developed in the Federal Republic of Germany, all the contracts were with Japanese firms such as Hitachi-Seiko, Kojima and Sizuoka. None of the sample firms reported technology import related to conventional machinery after 1983.

Regarding the effects of microelectronics on their technological capacity, most sample firms conceded that at the beginning they had not been sure if they would be able to keep their own technological capacity while relying on foreign technology even in utilising the system: only three sample firms used locally-developed FA machines and the rest relied either entirely or partially on imports. As their employees became used to the machines and more confident, their creative effort and abilities were stimulated. Many of the chief engineers in our survey stated that the newly introduced microelectronic systems provided a strengthened basis for their inventive effort. Some of them further reported that their R and D activity became more substantial after introducing microelectronics.

The impact of microelectronics on indigenous technology development may be illustrated most clearly by the following two cases. The first case is related to Tong-Il Co., which started developing its own NC unit in 1979 and completed the development of an NC unit programmable in Korean in 1985. So far, most NC units are imported from Fanuc of Japan which established a joint venture, Korea Numeric Corp. in 1978. Engineers at Tong-Il Co. felt that

without the development of their own NC unit, they would not be able to compete in export markets, as well as the domestic market in the long run because the price of imported NC units occupied almost half of the total cost of NC machines. In addition, they felt a need for developing an NC unit which is programmable in the local language. Imported Fanuc NC units provided them with the base for such development even though the Korean firm has entered a technical tie-up with a firm in the Federal Republic of Germany to compete against Fanuc.

The second case is related to the development of robot production. There are currently five companies producing robots among which Dae Woo Heavy Machinery Co. and Korea Numeric Co. seem to be technological leaders. The latter company as a joint venture of Fanuc depends entirely on imported technology while the former relies on their own development in collaboration with the Massachusetts Institute of Technology of the United States who provides technical consultancy and drawings. The current localisation rates for multi-purpose robots and transfer robots are reported to be 40 per cent and 10 per cent respectively (MTI, 1986). According to the MTI report (1986), the R and D expenditure by the robot manufacturers increased from 23.4 billion Won in 1985 to 31.0 billion Won in 1986 which raised the R and D/sales ratio from 4.9 per cent to 5.3 per cent. Their R and D staff rose to 1,208 persons in 1986 including six Ph.D's and 83 MS degree holders. Our field survey discovered that there were not enough high-level R and D staff working for the development of NC lathes and milling machines but there were some high-level engineers for machining centres and robots. The companies which have developed machining centres and robots had their own laboratories and enough capital to recruit high-level R and D personnel from abroad.

Kim (1980) argues that an imported technology is linked to indigenous technological development through three stages: the implementation stage where the technological concern is how to implement the imported technology with limited engineering know-how; the assimilation stage when such technology is quickly diffused within the country; and the improvement stage when local efforts in research, development, and engineering (R D and E) are pursued. The imported microelectronic technology fits in well with this model. For example, the NC lathe technology has now reached the improvement stage, the NC milling technology is still at the assimilation stage, and the machining centre and robot at the improvement stage. As more equipment approaches the improvement stage, the demand for higher-level R and D personnel engineers will grow. It is interesting to note that foreign investments are more active in the OA equipment business than in the FA equipment business. According to

the Information Industry Yearbook (1985), there are 28 cases of foreign investments in the computer market: six cases for computer leasing and sales, 13 cases for the peripheral system, six cases for software and information processing, and three cases in the system control area. All three copy machine makers (Sindo-Ricoh, Korea-Xerox and Lotte-Cannon) are joint-ventures which also make facsimiles. However, in the case of the FA equipment industry, there are three joint-ventures reported but only Korea Numeric Co. seems to be active. These foreign investments must have affected indigenous technological development.

These views appear to be supported by the following evidence. First, 18 of our sample firms had expanded R and D facilities (laboratories or R and D centres) after introducing microelectronics, often using them for on-the-job training. Second, out of the nine sample firms which released their 1984 R and D expenditure figure for our study, five devoted more than 5 per cent of their annual sales ratio to R and D and three firms were maintaining more than 10 per cent of total employees as R and D staff. Their R and D expenditure ranged from 100 million Won to 1,200 million Won. The average R and D/sales ratio of NC machine makers (12.1 per cent) was much higher than that of conventional machine makers (4.1 per cent). Third, although the history of Korean microelectronic equipment is short, the localisation ratios of NC lathes and NC milling machines have been rising and a total of 14 cases of technology development had been registered by the end of 1984 (Table 20). While major parts such as ball-bearings, NC units, oil pressure vessels, and servo motors still need to be imported, major NC machine manufacturers have developed various components:

Firm A	bed	1978
	gear	1979
	spindle	1979
	lead screw	1979
Firm B	spindle unit	1982
	oil motor	1983
	oil-pressure parts	1983
	oil-pressure cylinder	1983
Firm C	chip conveyer	1983
	wiper	1985
	condfeux	1985
	NC unit	1986
Firm D	spindle cylinder	1983
	lead screw	1982
	special pipe	1981
	spindle bearing	1984
	precision motor	1985

Table 20. Technology imports and localisation and development trend in NC machine production

1. Technology Imports (no. of approval)

	1982	1983	1984	1985
NC lathes	1	1	-	2
NC milling	-	1	-	-
Machining centre	-	1	2	2
Robots	1	1	-	-

2. Localisation ratio (%)*

	1980	1981	1982	1983	1984	1985
NC lathes	40	50	55	58	60	75
NC milling	-	-	50	55	60	70
Machining	-	-	45	50	55	70
Machining centre robots	-	-	-	-	-	40

3. Local Development: localisation ratio (%) by firm**

NC lathes (8 cases)	1980	1983	1985
Firm A	40	87	95
Firm B	-	32	70
6 other cases (average)		25	50

NC milling (4 cases)	1982	1985
Firm A	50	75
Firm C	60	70
2 other cases (average)	45	50

Machining centre (2 cases)	1983	1985
Firm B	25.4	75
Firm C model 1	70	n.a.
2	74	77
3	75	76
4	73	77

NC unit*** Firm B (1979-85): developed programmable unit in Korean.

Notes: * 1980-84 data are from MTI and 1985 data are estimates from field survey.
** 1980-83 data are from KIET (1984) and 1985 data are estimates from our field survey.
*** quoted from Korean Economic Daily (February 25, 1986).

Sources: KIET (1984), MTI and our own field survey.

This may be interpreted as a sign of significant efforts by Korean firms at building up indigenous technology capacity.

Findings of our field survey may be somewhat too positive in this respect, because of the high proportion of large enterprises in the sample. However, there are some additional indications of efforts by many firms to improve indigenous technology capacity. The most systematic material on this subject is the Medium and Long-term National R and D Plan drafted by the Ministry of Science and Technology.[20] That part of this plan which is related to FA (Table 21) was evaluated at the end of 1985. Some significant progress was identified. For example, a local firm succeeded in developing a NC unit in February 1986, and an assembly robot was developed by two local firms in 1985.

Finally, regarding the constraint on microelectronic FA equipment, 22 out of 30 FA user firms mentioned the shortage of professional engineers and technicians. Many of them were eager to strengthen their adaptive skills and inventive capacity, and were seriously concerned about this problem. Lack of FA-related information and know-how was another frequent constraint (18 firms). Many firms wanted the Government to establish both an R and D centre and a large-scale training institute for FA which are easily accessible to them. Fourteen firms in the machinery and automobile industries complained about the lack of qualified subcontractors. They felt that they could not cut down costs of production further and upgrade their technology without help of qualified subcontractors. In reply to our question as to what parts and components and specific technologies were in need of improvement, NC machine tool builders mentioned high precision ball-bearings, oil-pressure chucks, servomotors and linear scales, as well as technologies for manufacturing or processing oil-pressure vessels, ATC units, pallet tables and gears.

V. Summary and Conclusion

Introduction of microelectronics has been a recent event in Korea. The history of FA is less than 10 years and that of OA at most 5 years. However, as we discussed so far using both macro-level data and micro-level information from the field study, the trend toward FA and OA has been quite impressive. The development of the microelectronic machinery industry has been encouraged by the government's programme and by strong demand from key industries such as electronics and automobile industries. Our field survey discovered that while increasing labour cost was a primary reason for OA, it remained as a secondary motivation for FA. Firms pursuing FA had to pay more for FA personnel and

Table 21. FA-related R & D plan (1984)

Area	Year	Targets
CAD/CAM technology	Second year (1985)	- Completion of basic CAD/CAM system on turn-key base - Development of optimal design s/w - Automatic control system using inverse dynamics s/w - CAD/CAM for mould & die
	Third year (1986)	- Development of expert system - Interface technology of quality control and assembly - Automatic optimal design of crane - Development of automatic control programe for NC machines
	after 1986	- Technology diffusion and acceleration of FA - Package development for pressure vessel - Software development for automatic production plan, quality control, and assembly
Automatic assembly (robotics)	First year (1984)	- Multi-purpose standard type robots
	Second year	- 3-dimension digitizer - 3-dimension vision sensor - intellectual robots
	Third year (1986)	- Intellectual robots for assembly - Remote-controlled robots for atomic plant and removal of radioactive waste - Development of robotic language
	after 1986	- Robot arms for ocean submarine
FMS technology	First year (1984)	- Upgrading jig & fixture and pallet system - Simplification of APC
	Second year (1985)	- Central control system and pool system for central tool management - Development of manufacturing cell
	Third year (1986)	- Automatic transfer and tool inspection system - Unmanned assembly line
	after 1986	- Further development in central control system and unmanned assembly line
Oil and air pressure technology	First year (1984)	- Development of test facility for oil and pressure devices
	Second year (1985)	- Obtaining international recognition on the quality of local products
	Third year (1986)	- Localisation of gear pump and piston pump - NC oil & air pressure system and controller
	after 1986	- Control system programming for energy-efficient machines
NC technology	First year (1984)	- Small NC control unit - Large NC programming
	Second year (1985)	- System development for testing machinery
	Third year (1986)	- High speed high precision metal cutting machinery (Design Program)
	after 1986	- Upgrading machinery through adaptation control system

Source: The Ministry of Science and Technology: Science and Technology Yearbook (1984)

subsequently for other workers as well, without any significant employment reduction. In contrast, OA users have been able to save labour costs considerably. The primary motivation for FA has been to meet the quality standard imposed by customers and contractors. In this regard, the development and fast growth of the electronics and automobile industries seem to have been crucially related to the acceleration of FA in Korea. These export-oriented industries require high standards of precision and quality of parts and components, and therefore equipment.

At the same time, we should not understate other complementary factors underlying the recent drive for automation. As Watanabe (1983) notes, reliable supplies of electricity and quality metals are important preconditions for the Third World countries' successful application of FA equipment as NC machines. The availability of manpower to operate FA equipment and adapt new technology to existing conditions is another precondition for FA. Since the late 1970s, these conditions seem to have existed in Korea. Even though many firms told us that they were short of high level FA manpower, they had managed to train existing staff or transfer some technicians from other divisions to handle FA equipment. NC machines are used without significant difficulty even by relatively small firms. Since more sophisticated FA equipment such as machining centres, CAD/CAM and robots are currently being used by large enterprises who have better manpower, the shortage of FA manpower has not been that serious. However, for further development of the FA and OA equipment industry and for smooth acceleration of FA and OA, both the firms and the Government pay more attention to better engineering education, on-the-job training, and vocational school programms. Many firms wanted to recruit FA-minded and FA-oriented mechanics. They anticipated that there would be a large demand for mechanics with programming ability and engineers capable of system analysis.

Regarding the development prospects for the FA and OA equipment industry, a number of features of Korean industries have important bearings. First, most machinery manufacturers in Korea have less than 10 years or, at most, 15 years of experience. For this reason, their indigenous technology capacity and technology adaptation skills are much more limited than, say, their Japanese counterparts. Second, because of the short history of industrial development, the subcontracting system in Korea is underdeveloped. The machinery industry is composed of a few large enterprises and a large number of small and medium-scale firms. The link between the two groups is quite weak. They cater to different segments of the market, operating fairly independently. The Government has tried to let the latter group specialise in

particular products and let the former group play the role of a general exporter, technology supplier, and contractor. The subcontracting system in the automobile industry is also weak compared with that in Japan. Since small and medium-sized firms are to form an important market for such FA equipment as NC machines, the promotion of the latter group and the strengthening subcontracting structure has important implications for the development of FA. Third, as a representative of a large machinery manufacturing firm noted, investment in expensive CAD/CAM, machining centres and large NC machines cannot be justified unless a substantial proportion of products is exported: the small size of the domestic market makes Korean firms conscious of, and in some sense preoccupied with, the export market even before competition in the domestic market. This trend may make them rely more on imported technology at least initially, than otherwise.

In this connection, it is interesting to note our sample firms' view on the strategy for the development of the local microelectronic equipment industry. They felt that the development of such industry would promote their own technological capacity: for example, if the development permits prices of microelectronic machines to fall, this will accelerate their diffusion and thus promote their industry's technological capacity building. However, they also pointed out that as a result of recent government policy to promote the machinery industry, they were restricted from importing some equipment which was vital in developing their technology. Particularly, firms in the automobile industry stressed that the development plan of the machinery industry should not be over-ambitious because it might hamper FA in other industries. With some exceptions, notably NC lathes,[19] locally produced NC machines were still not so reliable as imports, while in view of increasing demand for precision work by their customers, they needed high-quality equipment.

The overall impact of microelectronics on employment has not been as substantial as one would have anticipated. This is mainly due to the limited diffusion of FA and OA and the fairly rapid growth of industries. However, at the level of individual production lines and offices where microelectronic machinery has been used, productivity gains and labour savings have been significant. The work organisation and skill requirements will change more as the application of FA equipment increases. The problem of training and retraining has not been very serious, largely because technology suppliers trained employees and provided built-in NC tape programmes. But such requirements will grow as firms begin to develop their own programmes.

The impact of microelectronics on indigenous technology capacity development is clear. As some company engineers pointed out, even though they

had learned "mecha-tronics (combination of mechanics with electronics)" at colleges and through publications, the actual work on an NC machine, for example, creates a totally different training/learning impact. Their knowledge and experience with conventional machines enabled them to follow the training programme provided by the equipment supplier, but it was not enough for adapting the technology and developing their own. An engineer in a machinery manufacturing firm told us that the CAD/CAM system the company had acquired two years before provided him strong motivation to work as a member of the R and D team. Nevertheless, more concerted efforts by both the Government and the private sector seem to be necessary for the purpose of maximising such positive effects. In addition to large-scale long-term R and D projects supported by government institutions such as KAIST, there ought to be some programmes assisting smaller-scale activites for technological progress, since what really matters in a developing country is indigenous technology capacity building for technology adaptation, and in this regard, engineer education and joint R and D programmes between industries and academic institutions are essential. Many smaller firms in the machinery and automobile industries were hoping to be able to have a good FA training institution for their employees and a reliable technology-assistance centre. They felt that the technology assistance by foreign suppliers was too costly and often not readily available, while assistance provided by local equipment suppliers was not up to standard.

In summary, the introduction of microelectronics in Korea seems to have produced positive impacts on technological development. Negative employment impact has been negligible because of the limited diffusion of FA and OA. In the future, however, the rising labour costs will come to play a similar role to that evidenced in the advanced countries, and labour savings may become an important objective of FA as well as OA.

Notes

1 The World Bank: World Development Report 1984, (Washington D.C.), 1984.

2 Similar ratios in Japan and in the United States were 3.5 per cent in 1981 and around 5.5 per cent in 1983, respectively.

3 The automobile and electronics industries started on the basis of domestic demand - mainly domestic passenger cars and home electronics -- but later managed to increase exports. The production of passenger cars reached the record high of 166.7 thousand units in 1984. The production of integrated circuits (IC) increased from 943.2 thousand units in 1980 to 2,254.5 thousand units in 1984. Passenger car exports increased from 50.1 million dollars to 174.2 million dollars and office machines from 88.6 million dollars to 438.8 million dollars.

4 Watanabe (1983) notes the crucial role the automobile and electronics industries played in the diffusion of NC machines in Japan.

5 Electronics Bulletin, October 1983, gives the following data on the average hourly wage rate increase:

	1975	1980	Average annual growth rate (%): 1975-80
United States	US$6.00	US$9.00	8.4
Japan	3.05	5.88	14.0
Singapore	0.77	1.09	7.2
Hong Kong	0.71	1.51	16.3
Taiwan, China	0.48	1.25	21.1
Korea, Republic of	0.37	1.10	24.3

6 These firms were selected in collaboration with the Ministry of Trade and Industry, Korea Machine Tool Manufacturers' Association, Korea Mould & Tool Industry Cooperative and Korea Auto Industries Cooperative Association.

7 In a 1984 survey by the Small & Medium Industry Promotion Corporation (SMIPC), 37 out of a total of 52 NC lathes and 46 out of a total of 52 machining centres in the machine tool industry were owned by 12 enterprises with more than 300 employees.

8 Park (1983), pp. 105-6.

9 The industrial breakdown of the sample was metallic raw materials (19.2 per cent), machinery parts and components (9.0 per cent), general machinery (19.2 per cent), transport equipment (10.9 per cent), electrical and electronic machinery (21.4 per cent), precision machinery (3.0 per cent) and others (17.3 per cent). Firms which did not own any FA equipment were included in the sample, making its size distribution more even than our field study sample: the proportion of firms with more than 500 million Won of capital was 48.6 per cent, and that of firms with more than 300 employees was 53.1 per cent.

10 The KAIST survey on factory automation (1985) discovered the same problem.

11 cf. Watanabe (1983).

12 This is clear from the KAIST survey (1985). Among the 266 firms responding in this survey, the following were the main modes of automation: low cost automation (45.9 per cent), CAD (4.5 per cent), CAM (11.7 per cent), automation in production line (22.6 per cent), FMS (3.0 per cent), robots (1.1 per cent), and the rest (11.3 per cent).

13 KOMMA (Korea Machine Tool Manufacturers Association): Machine Tool Statistics Handbook, 1985.

14 Watanabe (1983), p. 18. He attributes the great popularity of NC machines among smaller firms largely to the extensive subcontracting system in the Japanese metal engineering industries.

15 This company stated in our interview that they had produced in-house about one-third (in value) of NC machines they used. Another one-third had been purchased from other local NC machine manufacturers, and the rest from abroad.

16 This is an almost universal phenomenon. See Watanabe (1985), p. 222.

Registrations of patents and utility models

	Patents				Utility Models			
Year	Total (1)	(machinery industry)	by Koreans (2)	% of (2) in (1) (3)	Total (4)	(machinery industry)	by Koreans (5)	% of (5) in (1) (6)
1947-73	4,077	n.a.	2,963	72.7	10,501	n.a.	10,466	99.7
1974	322	(29)	277	70.0	1,174	(530)	1,155	98.5
1975	442	(27)	212	48.0	1,045	(330)	1,032	98.5
1976	479	(46)	191	40.0	1,115	(286)	1,106	99.0
1977	274	(19)	104	38.0	577	(181)	577	100.0
1978	427	(37)	133	31.0	999	(337)	992	99.3
1979	1,419	(181)	258	18.0	1,781	(439)	1,556	87.4
1980	1,632	(208)	186	11.0	1,753	(289)	1,315	75.0
1981	1,808	(210)	232	12.8	1,691	(432)	1,300	76.9
1982	2,609	(420)	274	10.5	2,514	(492)	1,961	78.0
1983	2,433	(288)	245	10.0	2,079	(578)	1,225	59.0
1984	2,365	(356)	297	12.6	2,360	(609)	1,817	77.0
1985	2,268	(379)	349	15.4	2,327	(657)	1,873	80.5
Total	20,555	(2,200)	5,671	27.6	29,917	(5,160)	26,375	88.2

Source: Office of Patents, Patents Statistics Yearbook (1986).

17 Ministry of Science and Technology: Science and Technology Yearbook (1984).

18 Korea Information Industries' Association (KIIA) conducted a survey in 1983 but it was only for the use of large-scale computers.

19 With respect to after-service and availability of parts and components, sample firms rated local machines more highly than imports.

20 Drafting the plan was initiated by MOST in 1982 and completed in 1984 with the help of other ministries and research institutes such as KAIST. The plan was drafted as guidance for technology rather than strict plan. The plan is now incorporated in the Long-term Science and Technology Development Plan for the 2000's which is in drafting process. (MOST, 1985).

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