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Developments in the field of informatics and semiconductors in selected developing countries

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Introduction

The present report contains an analysis of the status and development strategies followed in connection with specific segments of the electronics industry in a group of Latin American and Asian countries[1]. It is based on previous UNIDO studies and on other documents and reports available on those countries[2].

The study concentrates on the informatics industry and on components (particularly, semiconductors) manufacture. Although these branches are rather incipient in the countries considered, they are among the most dynamic segments of the "electronics complex" and seem to offer significant opportunities for latecomer countries. Microcomputers production, for instance, increased in South Korea at a 90% annual growth rate from 1983 to 1987, and at a 70% annual rate in Mexico between 1985 and 1987. The first mentioned country recently entered into world competition in the field of semiconductors, and captured around

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1 Argentina, Brazil, Mexico, India, Malaysia, Singapore, South Korea.

2 See, in particular, UNIDO, State-of-the art series on microelectronics Nº 1, Venezuela, Nº 2 India and Nº 3 South Korea, IS 489/492 and 490, 1984; UNIDO, Overview of the microelectronics industry in selected developing countries, IS.500, 1984; UNIDO, The electronics industry in the Asean countries, Summary and principal conclusions, ID/WG/478/3 (SPEC), 1988.

9% of the world market for certain memory chips (256 KDRAMs) in 1987.

Interesting developments can also be identified in the six other countries selected for the study. India is making since last decade important efforts in the electronics field, including in the area of minicomputers and semiconductors. Computers sales grew at an average of 70% over 1984-1986. Currently, it is undertaking an endogenous development in the field of supercomputers. Singapore has become one of the most successful international suppliers of computer peripherals and parts, in particular to the United States. Malaysia is one of the largest world producers and exporters of semiconductors[3]. In the case of Latin American countries, Brazil's informatics market is the largest in the Third World; national firms established in the framework of the national informatics policy account for more than 50% of that market. Argentina recently put into execution a policy aimed at fostering local informatics production Venezuela, finally, has been one of the main importers of informatics equipment in Latin America, and reached the highest number of per capita computer installations in the region.

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3 In 1983 United States imported, under tariff regulations 806.3 and 807, semiconductors from Malaysia for U$S 1.049,74, almost half of all semiconductors imports from ASEAN countries.

The selection of countries made for this review, as indicated by the precedent paragraphs, has not been based on a unique and common criterion. This report to highlights the basic strategies followed in those countries and their results. It tries to identify common features and explain the main differences. Certainly, the diversity in the overall paths and in the context in which the electronics industry has been established, makes it extremely difficult to comparatively assess the successess and failures of different countries. In most cases, there are no in-depth country studies, though the interest created by recent developments is starting to stimulate new and valuable research[4]. A point of particular interest is the extent to which the impressive results obtained by some countries in the informatics and semiconductor fields can be interpreted as an evidence of a "technological leap-frogging", as suggested by some theories on the emergence of a new "techno-economic paradigm" based on microelectronics technology[5].

Section 1 of the report contains information on the size and relative importance of informatics goods and components in the selected countries, both in terms of local electronics production

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4 E.g. the UNIDO program of work for a World Consultation on the Electronics Industry; OECD Development Center research project on the electronics industry in New Industrialised Countries (NIC's)

5 See L. Soete, "International diffusion of technology, industrial development and technological leap-frogging", World Development, vol.13 No 3, March 1985.

and internationally. Section 2 briefly describes the productive patterns prevailing in those fields, particularly as regards to the levels of integration of local parts and components supplies. Section 3 compares the existing industrial structures, and the role of big and small and medium enterprises therein. Section 4 discusses the market-approaches of different countries, and particularly the export-led strategies of some asian countries. Section 5 refers to the State's role in the development of the industrial areas considered and Section 6 to the forms of participation of foreign direct investment in that process. Section 7 analyses the mechanisms employed for importation of technology, while Section 8 deals with local research and development (R&D) efforts. In order to complete the scenario of hardware production, a brief comment on software development is included in Section 9. The last substantive Section Nº 10, contains some elements on the human resources problems faced in various countries and on the educational approaches applied. Section 11 includes the main conclusions of the study.

1. Production capacities

The size of informatics and components production as well as its relative importance in local electronics sectors, significantly vary among and witnin the countries considered.

As indicated in table 1, Singapore and Brazil, followed by South Korea, are the largest producers of informatics goods among the countries considered[6]. These three countries also have the largest output in electronics components, though in this case the first place is held by South Korea, followed by Singapore and Malaysia. In the manufacture -not merely assembly- of semiconductors, in particular, South Korea is the most advanced country in the developing world.

The size of informatics and components production in these countries is not only significant vis-à-vis the rest of developing countries (including those considered in this study). It is also important in international terms, as shown by table 2. Singapore and Brazil rank among the ten major producer countries in the informatics field, while South Korea ranks 12th. A major difference, however, between the two asian countries, on the one side, and Brazil, on the other, is that the former basically

6 The already mentioned rapid growth of microcomputers' production in South Korea, may change in the short term this country's relative position as informatics producer.

produce for export markets, while brazilian exports in the informatics field are only a very minor part of total production. In the area of components, the performance of some of the countries dealt with is more impressive: South Korea, Singapore, and Malaysia rank third, fourth and fifth, respectively, by their production of active components.

In overall terms, as a percentage of world informatics production, the participation of the countries considered here is still small. It is around 1,5% in the case of Singapore and Brazil each, and about 1% for South Korea. Their share is considerable higher, however, in the field of components, where the two mentioned asian countries jointly account for 12,24% of world production of active components and around 5% of passive components[7]. The Brazilian participation is far less significant (1%, and 1,71% respectively) (see table 3).

The participation of informatics and components production in total domestic electronics production also varies considerably in the eight countries studied here. They represent a significant part (more than or about a quarter of total electronics output) in Singapore and Brazil for informatics

7 This production is mostly based on assembly operations. See section 2 below.

products, and in Malaysia, Indonesia, Singapore and South Korea for active components. Informatics and components (passive and active) constitute more than three quarters of electronics production in Singapore. In Malaysia 70,02% of electronics production is accounted for active components (see table 4).

The cases of Argentine, Mexico and Venezuela present features quite distinctive from those of the countries referred to in the precedent paragraphs. None of them has a significant informatics or components production neither in terms of local electronics production nor at the international level.

The figures presented in this section indicate that notwithstanding the recent progress, the role of the selected countries in world informatics production is marginal[8]. In fact, the new entrants have not substantially challenged the solid domination of industrialised countries, which control around 94% of world production in the field. As discussed later, the latters' superiority is not reflected merely in production statistics. They also lead the innovation process and control the marketing and distribution chanells for the exnort of informatics goods from the most successful countries in the

8 The picture does not change very much if Hong Kong and Taiwan are included therein they account for 0,72% and 1,02% of informatics world production, respectively, according to the same source employed in Tables 1 to 4.

field. The informatics development in the countries reviewed is, so far, not only technologically but also commercially dependent.

On the other side, the tables presented above show that the selected countries have a more significant participation in electronics components production than in informatics goods. Such a participation is based, nevertheless, principally on the simple assembly of those products, with a strong presence of foreign owned subsidiaries, as illustrated by the case of Malaysia[9].

Finally, it is interesting to note the regional differences existing in the areas dealt with here. Asian countries are in terms of output -and clearly of trade balance[10]- well ahead Latin American countries. If in addition to South Korea, Singapore, India and Malaysia, the two other "tigers" (Hong Kong and Taiwan) and other ASEAN countries[11] are taken into account, the total output in informatics goods reaches U$S 4.2 billion and more than U$S 12 billion in the components area. In Latin America, only

9 In South Korea, while national firms made considerable investments for semiconductors production, foreign subsidiaries operating in the country are concerned only with semiconductors, assembly (see also section.2.below).

10 See section.4 below.

11 Indonesia, Phillipines, and Thailand.

Brazil has a comparable level of production in the field of informatics goods[12].

12 In contrast, the two asian continental economies -India and China- have a minor role in informatics production in international terms. India's annual production of microcomputers, for instance, was about 40.000 units in 1988 (information supplied by A.Parthasarathi, Additional Secretary, Ministry of Science and Technology, India, february 1989). A similar number of units has been reported for China.

Table 1

Production of informatics goods and of electronics components in selected countries
U$S million

	Informatics	Components passive	Components active
India (1986)	185	308	155
Malaysia (1986)	69	160	1554
South Korea (1986)	900	1294	1905
Singapur (1986)	1409	1298	1679
Argentina (1983)	64	n.a.	n.a.
Brazil (1986)	1400	892	418
México (1984)	250	n.a.	83*
Venezuela (1987)	100**	n.a.	n.a.

Source: For Asian countries and Brazil, calculations made by GERDIC on the bases of Mackintosh Yearbook, Electronics Data 1987, Benn Electronics, Luton 1987, quoted in UNIDO, Estudio global sobre la electrónica mundial, ID/WG.478/2 (SPEC), 3.9.88. For Argentina and Mexico, Interamerican Development Bank, Progreso Económico y Social en América Latina, Informe 1988, Washington, 1988. For Venezuela, Fernando Martínez Móttola, "Electrónica e informática: alternativas para Venezuela", Integración Latinoamericana, INTAL, Buenos Aires, Nº 138, septiembre 1988.

* Available data do not discriminate between passive and active components.

n.a.: not available.

Table 2

Major producers of informatic goods
(1986)

	U$S million
United States	43.773
Japan	19.630
Fed.Rep.of Germany	8.742
United Kingdom	5.461
France	4.129
Italy	3.615
Singapore	1.409
Brazil	1.400
Netherlands	1.491
Canada	1.153
Ireland	1.003
South Korea	900

Major producers of active components
(1986)

	U$S million
United States	14.900
Japan	12.770
South Korea	1.905
Singapore	1.679
Malaysia	1.544
Fed.Rep.of Germany	1.332
France	1.245
Phillipines	1.103
United Kingdom	1.013
Taiwan	941
Netherlands	572
Italy	484
Brazil	418

Source: Mackintosch Yearbook, op.cit. in Table 1.

Table 3

Production of informatics goods and components as a percentage of world production in selected countries (1986)

(%)

	Informatics	Components passive	Components active
India	0,19	0,59	0,37
Malaysia	0,07	0,31	3,68
South Korea	0,94	2,48	4,54
Singapore	1,47	2,49	4,00
Brazil	1,46	1,71	1,00

Source: Mackintosh Yearbook, op.cit. in table 1.

Table 4

Production of informatics goods and components as a percentage of total local electronics production in selected countries (1986)

(%)

	Informatics	Components passive	Components active
India	7,16	11,92	6,80
Malaysia	3,13	7,26	70,02
Singapore	25,17	23,19	29,99
South Korea	11,50	16,50	24,33
Argentina	12,50	n.a.	n.a.
Brazil	27,21	17,34	8,12

Source: Mackintosch Yearbook, op.cit. in Table 1, and Interamerican Development Bank, op. cit., for Argentina.

2. Productive patterns

The figures mentioned in the previous section do not tell very much, as suggested before, about the productive patterns prevailing in the considered countries. In fact, important differences can be identified as regards to the levels of domestic and technological content involved.

In the majority of those countries, the development of the electronics industry has been based on assembly techniques and low domestic value-added. Components production is a typical case. It has largely concentrated on the assembly of imported parts by low cost -especially female- labour, with a very weak impact on the creation of endogenous industrial and technological capabilities. The same approach has prevailed in general, in the production of informatics goods, including microcomputers. Even in the case of countries with outstanding performarce such as South Korea, the industry structure shows an important imbalance. Though a significant production of semiconductors has been achieved in that country, most of the semiconductors' domestic demand for various informatics and electronics products is met by imports. In turn, 85% of semiconductors' local production is exported

If it is true that mere assembly has characterised to a large extent electronics industries in developing countries, it would be incorrect to depict in such a way the current situation in the countries selected for this study. On the one side, some of them have made considerable efforts since last decade to develop local sourcing of certain parts and components and to foster a "learning by doing" process. On the other, new developments are taking place in several countries towards greater productive integration, even in technologically complex areas such as semiconductors.

The objectives of the national electronics policy in India have included "to achieve technological self-reliance (not in terms of shutting out foreign technology, but in inducing it where necessary and then adapting and developing it appropriately while meeting the technological needs of our strategic electronic products maximally indigenously) to use the technological and industrial capacity built to meet domestic needs, as the springboard for our exports"; and "to strive to realize an electronics industry that is well integrated as between its different subectors"[13]. The search for local integration, however, does not go beyond some reachable objectives. Indian Government, for instance, allows the import of microprocessors

13 Department of Electronics, Electronics in India in comparison with electronics in South Korea, Taiwan, Singapore and Hong Kong, New Delhi, nov. 1982, p.1-2

for microcomputers production, on the assumption that it would be unreasonable (due to major economic and technological constraints) to expect local production of such components to take place at present.

In three of the Latin American countries studied here (Argentina, Brazil, Mexico), a peculiar situation has arisen out. While local electronics industry (particularly consumer electronics) is based mainly on low domestic content assembly operations, the national informatics policies have attempted to use the development of a computers and peripherals industry as an opportunity to set up a more integrated local production. In Brazil and Argentina, consumer electronics production is concentrated to a large extent in free trade zones (Manaus and Tierra del Fuego, respectively) where imported parts and components are assembled. In the case of Argentina, in particular, the existence of such a zone has been a powerful disincentive for the development of a more integrated electronics industry. The mexican case presents similar features due to the activities of "maquiladoras" (assembly firms).

The brazilian policy seems to have attained some of its goals in terms of a gradual but substantial inprovement in the use of local parts and components in informatics production since 1981. In accordance with one study, the "nationalisation" index was 80% for computer peripherals and 95% for microcomputers in 1984. That index would have reached even 98% for nationally develop COBRA 500 minicomputers[14]. In Mexico, the goals established by the government in 1981 as to local integration were relaxed soon thereafter, in order to ensure competitive prices and promote exports of the internal production. The argentine experience, finally, is too recent to be assessed, but the operation in the country of pure assembly firms and the tariff structure, seem to jeopardise the development of parts and components' local suppliers.

In the case of semiconductors production, South Korea has made a notable effort to nationalise all stages of manufacture. In 1974 Samsung Semiconductors and Telecommunications Co Ltd. started its first wafer production. It was followed in 1979 by Gold Star Semiconductors Ltd. Currently, there are five wafer fabricators in South Korea, with an estimated output of U$S 550 million in 1987[15].

The semiconductors industry is also undertaking a backward integration process in the form of wafer fabrication in Singapore

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14 See Paulo Bastos Tigre, Industria brasileira de computadores. Perspectivas ate os anos 90, Ed Campus, Rio de Janeiro, 1987, p.71.

15 Samsung will invest U$S 500 million for completion of its fourth semiconductor plant to make 4MD and 16 MDRAM chips. Hyundai planned a U$S 385 million investment for a similar purpose. See Financial Times, 24.10.88.

and Malaysia. In Singapore, in effect, recent developments are transforming the industry from the production of simple bipolar integrated circuits to more sophisticated products. SGS/ATES and Hewlett Packard have invested in diffusion units for integrated circuits for mass consumer products and for gallium arsenide circuits, respectively. ATT has invested in a design unit, Unizon (Japan) in a production line for discrete semiconductors and integrated circuits, while a joint-venture (involving National Semiconductors, Sierra Semiconductors and Singapore Technology Corporation) has been set up to establish a U$S 50 million unit for CMOS integrated circuits[16]. In the case of Malaysia, Motorola will produce discrete transitors and INTEL received government authorization to set up a U$S 100 million microprocessors' manufacturing unit.

The mere assembly, on the one side, and the integration of local parts and components, on the other, are approaches with clear trade-offs. The former generally permits to produce at competitive prices (though that is not necessarily the case) and, hence, facilitates the local diffusion and use of the technology as well as the undertaking of exports. The impact of this approach on employment, labour qualifications, industrial and technological development is generally weak. In contrast, the

16 See UNIDO, The electronics industry in the Asean countries. Singapore, ID/WG.478/7 (SPEC), 9.9.88

development of local sourcing would require a certain delinking from the international market, but may assure the creation of a domestically - integrated industry, the upgrading of technological capabilities and more jobs, particularly for qualified personnel. A good part of the recent history of electronics industry in developing countries reflects, in fact, the tension between these two approaches.

3. Industrial structure

The dimension and specialisation pattern of enterprises involved in the local production of informatics products and semiconductors present a range of different situations by country and sectors concerned.

Powerful industrial conglomerates dominate the electronics industry in South Korea. In particular, Samsung, Goldstar, Hyundai and Deewoo Group account for about 50% of microcomputers production and for 100% of semiconductors' wafer fabrication. Their large financial resources, the learning process made in the field of consumer electronics, the setting up of a R&D infraestructure and the exploitation of economies of scale, are among those big firms' advantages to operate in new high-technology fields.

In India, the electronics industry is also heavily centered around large firms. As far as microcomputers are concerned, four major producers (HCL, Sterling, Wipo and Eiko) dominate the market. In the field of main-frames and of minicomputers, ECIL and International Computers Ltd. (ICL-India) are the major players. The top ten manufacturers account for 80% of the output in the computers market, while the remaining 20% is accounted for by 70 small units mostly engaged in assembly activities.

Two main differences between the Indian and the South Korean cases can be mentioned. First, in India the most important enterprises in the field are public-owned. However, the predominance of public sector firms does not exclude, as indicated, the participation of foreign and national private firms, including smaller size enterprise. ICL is the computer company with the largest turnover (RS. 29 crores in 1986). A handful of private indian firms also produce minicomputers[17]. Second, the indian firms are mainly specialised in the manufacture of various types of electronics equipment, and do not cover such a wide range of products as the South Korean conglomerates do. These large integrated corporations are best positioned to finance the high investments required to compete internationally an to enter into new and capital intensive fields, such as semiconductors production.

Computer industry established in the Latin American countries considered here also follows a specialisation pattern. Small and medium enterprises are predominant in Argentina, Mexico and Venezuela. In Argentina, the average number of employees per firm was 110 persons in 1983[18]. The eleven firms that

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17 See Ashok Parthasarathi, "Informatics for development: The indian experience": paper prepared for the 2nd Session of the North-South Round table of the Society for International Development, Tokyo, october 1-3, 1987

18 Interamerican Development Bank, op.cit. p.128.

obtained promotional incentives for computer production in the country, planned a total investment of about U$S 40 million and a total employment of 3.700 persons by 1992.

In Mexico, the expansion of the domestic market allowed the emergence of about one hundred micro and minicomputers and peripherals producers, which had created 6000 jobs by 1987. 71% of the enterprises operate in the field of microcomputers and peripherals. Due to its low level of automation and equipment investment, nevertheless, they only account for 23% of total fixed assets[19]. In the case of Venezuela, over one hundred enterprises participate in a U$S 100 million market of "professional" electronics goods (telecommunication, industrial control, data processing and componentes)[20].

In the brazilian case, more than 200 firms produced computers and peripherals in 1987. A number of large firms -at least in terms of the country's industrial structure- have emerged in the framework of the "market reservation" policy applied there. While IBM and Unisys are the major actors both in terms of aggregate sales and employment, in the field of microcomputers, minicomputers and peripherals five national firms had each more than one thousand employees in 1985. The growing

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19 See Ricardo Zermeño Gonzàlez, "La industria de cômputo en Mèxico: situaciôn actual y perspectivas", Mèxico, 1988.
20 See Fernando Martînez Môttola, op.cit.

competition that characterised those markets, has led to a significant decline in the level of concentration since 1979. The five top firms controlled 88,8% of the market in that year, but only 47,4% in 1984[21].

It is also interesting to note that out of the ten major national informatics firms, five (Itautec, Cobra, SID, Labo and Edisa) are directly or indirectly controlled by large financial institutions. The informatisation process undertaken by these institutions was an important component in the demand of equipment manufactured by the controlled informatics enterprises.

21 See Paulo Bastos Tigre, op. cit. p. 68. If the ten major national firms are considered, the respective figures are 98% and 67,5%.

4. Internal and export markets

One major difference in the electronics development approaches followed in the countries selected for this study, relates to the role played by domestic and export demand. Two very clear models have been applied. India, Argentina and Brazil have emphasised production for the domestic market. Import substitution has been one of the main objectives, in particular, of the informatics policies implemented in those countries during this decade. In contrast, South Korea, Singapur, Malaysia and - to some extent - Mexico, have opted for an export-oriented model.

The brazilian and indian policies are good examples of the first approach. The exploitation of their large internal markets has been considered the basis for industry's development. Brazilian computer market exceeds U$S 3 billion annually. It is clearly the greatest market in Latin America and, currently, largely exceeds those of other continental economies in the Third world. The estimated value of computer systems sold in India was RS 280 crores in 1986[22]. However, the potential growth of the market, as shown by the escalating sales of microcomputers, is still considerable.

22 Approximately U$S 280 (at the average exchange rate over the 1980's)

Notwithstanding the relatively small dimension of the argentine computer market, the national policy designed in 1984 also emphasised development for the internal market, as the first step in the building up of a national industry. Exports requirements for the granting of promotional incentives were considerably low (about 7% of production). In Argentina (as well as in Brazil) most exports in the informatics field are accounted for by transnational corporations (particularly IBM). National firms are very marginally interested or involved so far in export activities.

In contrast, almost 90% of South Korean microcomputers production and a large part of peripherals are exported, mainly to United States and Japan. Most exports take place on an OEM basis[23]. South Korea, for instance, has supplied under that scheme IBM with monitors and banking terminals, Amstrad with computers and Texas Instruments with semiconductors. The sucess obtained[24] shows the quality and cost-efficiency achieved by South Korean industry in large scale production. At the same time, nevertheless, the predominence of the OEM modality is an indicator of a substantial weakness in marketing abilities. In

23 An "Original Equipment Manufacture" (OEM) relationship takes place when a firm contracts the production, under its own brand name, of determined products.
24 According to data of the Electronic Industries Association of Korea, exports of computer hardware and parts totalled U$S 1,3 billion in 1987.

fact, South Korean firms have failed till now to establish their own brand names in export markets.

South Korea experience in informatics constitutes a good example of an export-led industrial development in a country with a limited domestic market. The small size of such a market forced local firm to seek basically for foreign buyers. The export oriented approach has been combined with strong import barriers[25]. Only recently as a result of United States and European demands a process of liberalisation has been implemented that gradually reached different informatics products. The South Korean experience seems to show that the existence of an open domestic market is not a precondition to become competitive at the international level, as often argued by the opponents to national policies based on the protection of incipient industries in high technology fields.

In the case of Singapore more than 85% of the country's electronic production is exported (60% of which to the United States). Office equipment and informatic products (particularly computer peripherals) increased their share in total electronics exports from 6% to 46% between 1980 and 1987, while that of components fell from 43% to 25%[26]. The role of transnational

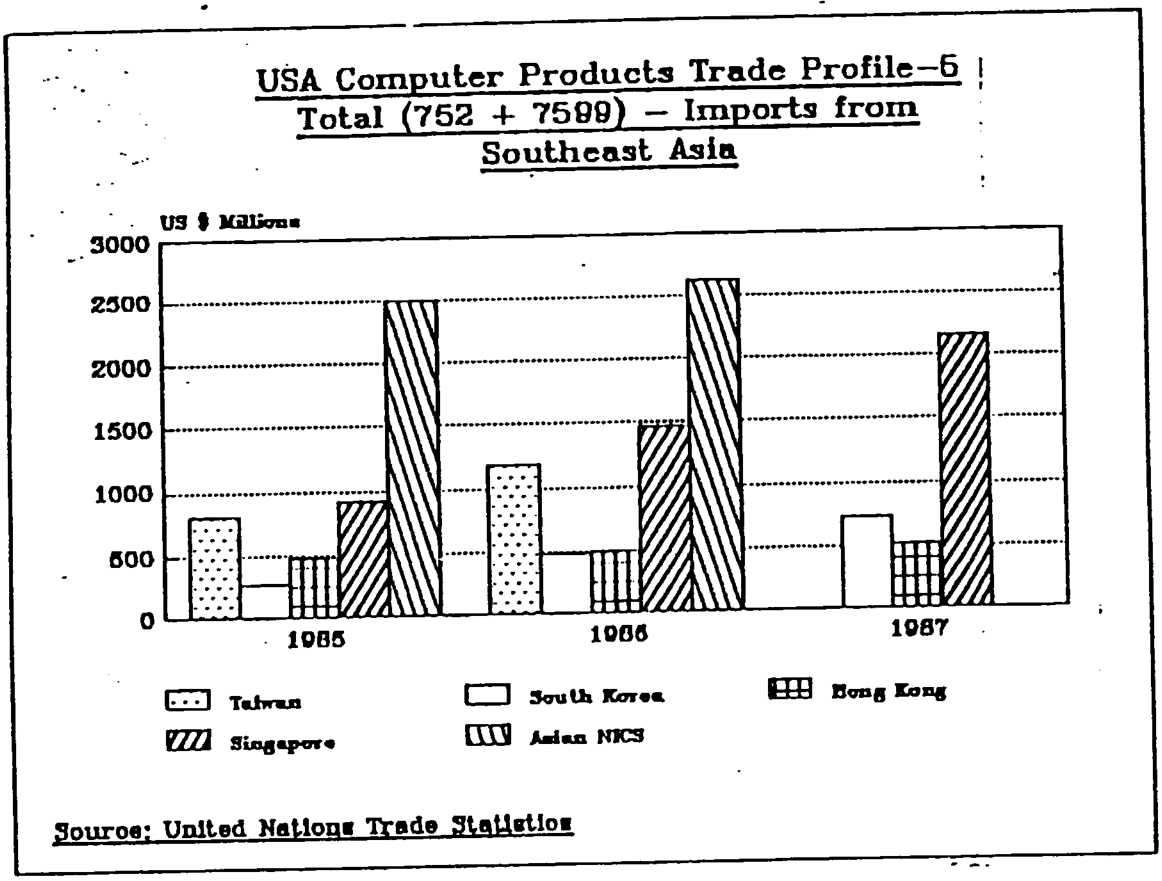
25 Restrictions have included limitations for foreign companies to import (and distribute) their own products in South Korea.
26 See UNIDO, ID/WG.478/7(SPEC), op. cit. p. 18

corporations in such exports is considerable. In Malaysia, likewise, almost 90% of electronics production -mostly controlled by foreign-owned industry- is exported. The largest part of such production (about 85%) corresponds to semiconductors.

The export performance of Singapore and South Korea is illustrated by their share in the markets of United States and Japan. The former has become the largest source of imports to the United States, in peripherals and parts, and the latter plays a similar role -but with quite lower values- in Japan. United States imports of automatic data processing equipment and parts from Singapur reached more than U$S 4 billion between 1985 and 1987 and exceeded U$s 1 billion in the case of South Korea in the same period (see Figure 1).

The informatics policy designed by the Mexican government also emphasised the setting up of a competitive industry and the expansion of exports. The participation of foreign companies in the governmental program has been viewed as one of the means to attein such objectives. Between 1983 and 1987 exports of informatics products increased at a 127% annual rate. The exports-imports ratio dramatically increased from 1,6% to 68%. Imports also reflected a substantial growth of parts and

Figure 1


USA Computer Products Trade Profile-6
Total (752 + 7599) - Imports from
Southeast Asia
US $ Millions
3000
2500
2000
1500
1000
500
0
1985
1986
1987
Taiwan
South Korea
Hong Kong
Singapore
Asian NICS
Source: United Nations Trade Statistics

components (from 9% to 45% of total imports of informatics goods between 1981 and 1987)[27].

More generally, table 5 indicates the trade balance in informatic goods and components of some of the selected countries considered here in 1986. It confirms the impressive results of the export-oriented scheme in Singapore and South Korea not only in the informatics field, but also in components (particularly active) as well as the importance of Malaysian exports of locally assembled active components. As regards to countries with an import substitution strategy, it is interesting to note that while India presents deficit in both subsectors, Brazil has managed to obtain a modest superavit in informatics products as well as in components.

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27 See Ricardo Zemeño Gonzâlez, op.cit.

Table 5

Trade balance in informatics products and components in selected countries
(U$S million)

	Informatics	Components passive	Components active
India	- 41	- 71	- 144
Malaysia	- 96	- 97	1457
South Korea	230	178	1049
Singapore	668	366	1410
Brazil	100	92	- 76

Source: Mackintosh Yearbook, op.cit. in Table 1

5. State's role in industry development

The history and present situation of the electronics industry are closely linked to State direct or indirect intervention, on the one side, and to the activities of large transnational corporations, on the other. The experiences of the countries reviewed in this report present a wide variety of schemes under which the relationships among States, trasnational corporations and other firms are organised[28].

State intervention has been prominent, in particular, in the industrial strategies in informatics and semiconductors in India, and Brazil. In addition to provinding the general framework and support for industrial development, the State undertook there productive activities. In India, the public sector company ECIL, for instance, since 1969 manufactured computer systems ranging from 8 bit and 16 bit systems and supplied to over 200 installations in the country. ECIL is engaged in hardware design, software development, manufacturing, marketing and maintenance, including of the 32 bit computer' System 332' developed and manufactured indigenously[29].

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28 See also section 6 below.
29 UNIDO, IS.492, op. cit., p.42.

Two State owned firms -Bharat Electronics Ltd. (BEL) and Semiconductor Complex Ltd. (SCL)- produce integrated circuits in India. The BEL facility is vertically integrated in terms of CAD and mask production. In 1984, the company decided to manufacture microprocessors and memory chips using RCA technology. SCL has focused on the supply of modules and electronic circuit blocks for watches and clocks assembled in India, among other items[30].

In the case of Brazil, the federal government enterprise for computer services SERPRO initiated the production of computer hardware in 1970. These productive activities were later on transferred to the State company COBRA which developed terminals and minicomputers for internal commercialisation. On the basis of the "COBRA 500" minicomputer launched in 1980, the enterprise became the leading computer firm in that segment in Brazil. In 1981 it had made around half of all minicomputer installations and accounted for one third of total sales in the domestic market[31].

Certainly, the definition by Indian and Brazilian governments of the basic parameters of the informatics policies,

30 See C. Edquist and S. Jacobsson, "The integrated circuits industries of India and the Republic of Korea in an international techno-economic context", Industry and Development, Nº 21, UNIDO p.44-45

31 See Paulo Bastos Tigre, Computadores Brasileros. Industria, tenología e dependencia, Ed. Campus, Rio de Janeiro, 1984.

has been decisive in framing the patterns of industrial and technological development in that sector. In both cases, informatics has been regarded as strategic for the country's autonomy and not only in terms of new market opportunities.

The goverment's role has also been significant in other countries, such as Argentina, Mexico, South Korea and Singapore, but its action has not involved direct production. Support of R&D activities, granting of fiscal incentives and national buying policies, are among the instruments most frequently applied to foster national development in this field[32].

Fiscal incentives have been accorded to nationally owned enterprises under brazilian law 7232, for hardware, components and software production. They usually take the form of tax exemptions and access to financial support. In Argentina, likewise, Decree 652 (1986) provided for various tax exemptions for enterprises that committed themselves to certain levels of production, R&D and integration of local parts and components. The benefits also included special tariff rebates for the importation of necessary parts and components for limited periods.

32 For government support to R&D activities, see point 8 below.

In Mexico, the government informatics policy of 1981 also provided for fiscal incentives, financial support for new investments, export incentives and facilities to acquire components and subassemblies from "maquila" firms.

South Korean government has been largely involved in the support of the electronics industry development through various means. Currently, for instance, tax and financial measures have been adopted to help local firms to face won appreciation and the impact of trade liberalisation policies.

Singapore government developed a set of incentives and support mechanims accessible to both local and foreign electronics enterprises. The governmental support was, in contrast, less pronounced in Malaysia. The 1986 Promotion of Investment Act contemplates, however, incentives and tax holidays for a wide range of electronics products.

National buying policies have been used to different degrees to create internal demand for informatics products in several countries reviewed here (e.g. Argentina, Brazil, Mexico, South Korea). Hardware acquisitions by public agencies constitute, in some cases, an important component of domestic demand. In Mexico, for instance, after the nationalisation of banking entitities, such agencies account for more than half of the internal computers' demand. Programs for the introduction of informatics into school have also been conceived to promote local production, among other objectives. The acquisition of 5000 8 bit computers by the South Korean government was, in that sense, at the inception of the computer industry in that country. Local production has also been targeted in programs established in Argentina and Mexico[33].

33 Mexican "Microsep program", for instance, is based on the supply of locally assembled 8 bit micromputers. Argentine government has recently contracted with a national firm the design and development of an equipment for educational purpose, tc be domestically produced.

6. Foreign participation

The role of foreign direct investments -and particularly of transnational corporations- in the countries and sectors considered in this report respond to considerably different patterns. While in all selected countries some form of foreign capital participation is allowed, the extent and modalities thereof diverge significantly. Three main situations may be observed, as described below.

In some countries foreign direct investments have been actively promoted and play a major role in production of informatics goods and semiconductors. A typical case is that of Malaysia, where foreign owned subsidiaries -mostly from United States- account for the largest part of production, particularly in the semiconductors field. Singapore, likewise, is the ASEAN country which is most open to foreign industrial investments. 64 out of 104 firms in the area of components, and 16 out of 25 in industrial electronics are of foreign origin[34].

At the other extreme, India and Brazil have set forth strict rules for foreign direct investments participation. In India, in particular, a policy aimed at limiting the operation of foreign wholly-owned subsidiaries and requiring the establisment of

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34 See UNIDO, ID/WG.478/7 (SPEC), op. cit., p. 30.

joint-ventures with local partners caused IBM to leave the country at the end of last decade. That policy, however, did not prevent some firms, such as International Computers Ltd (ICL-India), to actively participate in the expanding indian market active. Recently, a number of joint ventures have been negotiated with Control Data Corporation, Digital Equipment Corporation, Data General, Olivetti and Tolerant for the manufacture of mainframes, super-minicomputers and other equipment[35].

The informatics policy in Brazil has been structured on the principle of "market reservation" for local firms. This principle means that neither imports nor foreign direct investments are permitted in certain reserved segments of the market. These include minicomputers, microcomputers and peripherals. According to the "Informatics law" No 7232 of 1984, foreign participation in those areas is only permitted up to 30% of the enterprise's capital, provided that the effective control of its operation remains in local partners' hands. Although the exclusion referred to has created friction with United States, it has not prevented american firms to benefit from the notable expansion of the brazilian informatics market. IBM Brazil is, in fact, the

35 See Ashok Parthasarathi, op. cit. p. 3.

largest company in the country both by sales and by number of employees[36].

In a third group of countries, finally, the situation is not as clear cut as in those referred to before. In Argentina, the informatics policy established in 1984 promoted the establishment of joint-ventures with foreign firms (Burroughs and Bull associated, as a result, with private local firms). Though no written rule was adopted, wholly-owned foreign subsidiaries were not considered an approppriate means to enhance the local absorption and development of technology. In Mexico, the policy announced -never formalised- in 1981 was also based on the establishment of joint ventures and the refusal of wholly-owned subsidiaries. However, after a long debate and in the context of a susbtantial change in the overall foreign investment policy, a hundred percent investment by IBM for microcomputers manufacture was accepted. In Venezuela, likewise, amendments to the foreign investments regulation have relaxed authorization procedures in the informatics field[37]. However, no substantial foreign investments have taken place so far in that field. In the case of South Korea, finally, the government has also significantly

36 IBM Brazil turnover was, in 1985, seven times higher than that of the second top firm (Burroughs) and was the largest employer in the sector (with 5000 employees, IBM is followed by COBRA with 2700). See Balanco Anual Gazeta Mercantil, 1986.
37 Decree 1200/86 on foreign direct investments and transfer of technology, 1986.

intervened to orient foreign direct investment and to set up the conditions for foreign firms participation.

The various approaches followed reflect different perceptions on the advantages and disadvantages that the participation of transnational corporations may carry out. Countries concerned with building up indigenous industrial and technological capabilities in the framework of long-term self-reliance objectives, have viewed such a participation as a serious potential risk. The marketing power and technological superiority of transnational corporations can, in fact, create unsurmontable barriers to set up new national enterprises, if these are forced to compete in an open market with the former. In addition, such corporations are reluctant to transfer technology to and to localise R&D activities in developing countries. Hence, he operation of foreign subsidiarias generally have a low technological impact. Their contribution, in particular, to the upgrading of local design and engineering capabilities is generally weak, although they may help to improve the quality standards of local suppliers and to train certain kind of labour (mainly for assembly and eventually testing tasks).

In some countries (e.g. Brazil), even the role of joint-ventures between national partners and transnational corporations has been regarded unfavourably. On the one side, it is feared that the asymmetry of effective commercial, financial and technological power between the partners could lead soon or later to a subordinated role of the local party. On the other, in order to undertake a local learning process and attain a certain self-reliance, it is necessary to strongly involve national professionals and entrepreneus.

In contrtast, other strategies have tried to rely on transnational corporations' productive or marketing abilities, particularly in order to generate exports. In the mexican case, for instance, it was clear that a significant trade off existed between the acceptance of foreign direct investments to promote exports and other national objectives, such as an indigenous technological development in the field, the creation of stronger linkages with local suppliers, and the establishment of market reserved areas for national production. In the case of South Korea, instead, the relationships with transnational corporations under OEM agreements, aim at taking advantages from the latters' marketing capabilities, rather than from their productive strenghth. The specifications communicated under those agreements have also helped South Korean industry to improve design and engineering capabilities.

7. Technology transfer

The development of the informatics and semiconductors industries in developing countries, in general, and in those countries considered here, in particular, has been based to a great extent on the transfer of foreign technology through licenses and similar arrangements. Different situations, however, have arisen out depending upon the nature of the industrial activities undertaken and the firms and government strategies.

In the field of semiconductors, assembly operations made in South Korea, Malaysia and other countries by transnational corporations have not encompassed any significant transfer of know-how . Assembly utilizes technology almost exclusively embodied in imported capital goods. The assembly operator requires little training to reach peak efficiency and acquires few generalizable skills[38].

When South Korea and India initiated manufacturing activities of integrated circuits, however, they were able to obtain licenses from foreign sources. In 1983 Samsung Semiconductors and Telecommunications Co. Ltd. made an agreement

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38 See UNCTC, Transnational Corporations in the International Semiconductor Industry, New York, 1986, p.XXV.

to introduce 16K static random access memory (SRAM) and 256K ROM from Sharp in Japan. In the same year it established a firm in California for the purpose of technology absorption and design of ICs, and made an agreement with MICRON of the United States to produce 64K and 256K DRAM[39].

On its side, Gold Star Semiconductors Ltd. began to work on 8-bit microprocessors under license from Zilog in 1983, and on CMOS technology under an agreement with LSI Logic. During the last five years the number of licenses and royalty payments in the semiconductors industry increased considerably in South Korea. The main source of technology have been firms from United States and to a minor extent from Japan.

In India, Bharat Electronics Ltd. entered into a collaboration agreement on CMOS technologies with RCA. Semiconductor Complex Ltd. did the same with American Microsystems Inc. for LSI circuits.

On the basis of the imported technology, the recipient firms undertook a learning process which apparently allowed them to autonomonsly envisage new technological steps. For instance, while Samsung Semiconductors and Telecommunications started production of 256 K DRAM on the basis of an imported design, it ...

39 See C. Edquist and S. Jacobsson, op. cit., p.28.

claimed to have built up the process itself. Indian Semiconductor Complex Ltd. developed in house 3-micron CMOS and NMOS technology, although it had the option to obtain it under an agreement entered into with American Microsystems[40].

Two interesting features can be pointed out in connection with the South Korean experience. On the one side, licensing increased at the same time that local research and development expanded considerably. The latter was not, hence, an alternative but a complementary tool aimed basically at improving the capabilities for selecting and negotiating foreign technolgies and enhancing product development. On the other, the four large conglomerates (Samsung, Goldstar, Hyundai, Daewoo) decided to establish foreign research subsidiaries particularly in the United States in order to ensure access to new technological developments. That is the case, for instance, of Goldstar with United Microtek and of Daewoo with Zymos (in the latter case for CMOS technology for application specific integrated circuits - ASIC's).

In the informatics field, licensing has also played an important role in the creation of minicomputer production in Brazil an India. The first stage of the brazilian informatics industry, for instance, was closely linked to the establishment

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40 Idem p.28

of licensing agreements with various foreign firms (the first one with Ferranti in 1974). Until 1981, eighteen agreements had been entered into by fourteen national firms and sixteen foreign licensors. Most recipient firms viewed such agreements as an important tool to foster the development of local technological capabilities[41].

The standarisation that took place in the area of microcomputers allowed many firms to enter into that dynamic market through "reverse engineering" and "emulation" of foreign products. PC "clones" produced in Asia accounted for 8,3% of world PC market in 1987[42]. South Korea and Singapore have excelled in the production of high volumes of computer peripherals[43]. Numerous firms in Brazil, Mexico, Argentina and Venezuela and Malaysia assemble microcomputers and peripherals as well, though mainly for the domestic market.

Even in the case of the most successful countries, like South Korea, the dependance on foreign designs and on imported components for microcomputers production is still high. Though in South Korea, Brazil and other countries production of 80386

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41 Paulo Bastos Tigre, Computadores brasileiros, Industria, Tecnología e Dependencia, Río de Janeiro, Ed., Campus, 1985, p.151.
42 Data from Intelligent Electron Dataquest.
43 Peripherals account for the largest part of informatics production and exports in both countries.

32 bit machines has already started, the impact of new leading firms' strategies aimed at reducing the imitation of their machines is still an open question[44].

The government attitudes in connection with the transfer of technology vary among diferent countries and over time. In most of them (South Korea, India, Argentina, Mexico, Venezuela) transfer of technology agreements have been subject to prior authorization or registration, in order to limit royalty payments abroad, avoid restrictive practices, ensure the granting of appropriate guarantees, promote the compatibility of the technology to be transferred with national needs and conditions, exclude the licensing of trademarks not linked to an effective transfer of know how, and / or enhance the assimilation of foreign technologies. In the framework of a process of liberalisation of foreign direct investments and technology transfer regulations that involved a large number of developing countries, those countries mentioned before introduced during this decade important changes in their regulations or administrative practices, that considerably relaxed applied controls. Argentine policy on the field, for instance, was liberalised in 1981; the same ocurred in South Korea in 1984 and

44 With the introduction of the IBM PS/2 with a veiled architecture and the threat of legal suits for "piracy", for instance, the scenario for clones' production may be altered in the future.

1988[45], and in Venezuela in 1986. In the latter case, the new regulation (Decree 1200/86) provided for a special treatment for technology transfer contracts relating to high technology fields.

Unlike the countries just mentioned, brazilian technology transfer policy has been maintained without substantial changes during this decade. In the field of informatics, in particular, licensing has been viewed as a first step to obtain the knowledge necessary to enter into new fields. The contracts, however, must be limited in time and not renewable, in order to stimulate the local recipient firm to assimilate the technology and become independent from the supplier in a short time.

In addition to the formal means of acquiring technology abroad, in some of the countries dealt with informal mechanisms therefor have had great importance. The overseas education and training of scientist and engineers (particularly in the United States) was critical for South Korean development at the technical and managerial levels. The government was successful in the implementation of a scheme to bring back over 1200 scientists and engineers since 1968[46]. Other countries affected

45 The approval system was replaced by one of simple registration.
46 See Ministry of Science and Technology, "Introduction to Science and Technology", Republic of South Korea, 1987. A plan for training of South Korean graduates overseas was implemented since the sixties. In 1965, around 90% of graduates were sent abroad for that purpose.

by important brain drain, like Argentina, have not been so successful in their attempts to recover their professionals trained abroad.

8. <u>Research and development activities</u>

It is difficult to assess the extent and composition of R&D activities undertaken in the countries under consideration. Not suprisingly, two of the countries with largest production in the fields dealt with here, Brazil and South Korea, are the most relatively advanced in terms of R&D infraestructure at the public and private level. In India there is also a number of enterprises (e.g. Bharat Electronics Ltd., Semiconductor Complex Ltd.) and organisations with considerable R&D activities. In Singapore, an important increase in R&D expenditures as a percentage of GNP has taken place during this decade (from 0,6% in 1985 to an estimated 1% in 1988)[47]. The weight of foreign direct investments in the electronics field, and its very limited role in R&D, in part explain the Singapore's handicaps in that area.

In Argentina, Mexico and Venezuela some efforts have been made in the 1980's in order to widen the R&D infraestructure in the area. The overall expenditures, however, are limited as well as the number and qualifications of available researchers.

A major difference among the countries that have advanced more in creating a R&D infraestructure in informatics and

47 See UNIDO, ID/WG.478/7 (SPEC), op.cit., p.37.

semiconductors and the remainder, is the extent of industry participation in that effort. In South Korea, for instance, about 30% of total R&D expenditure in those sectors is accounted for by private firms. The willingness to reinforce the capabilities for appropriate selecting, assimilating and adapting foreign technologies and the fears about growing difficulties to obtain access to them, stimulated national firms, particularly the big conglomerates with activities in the field, to invest in R&D facilities since last decade. Samsung, GoldStar, Daewoo and Hyundai have made significant investments in the area, as illustrated by the setting up of the Samsung Advanced Institute of Technology (considered as one of the largest in the country). As mentioned before, actions taken by those enterprises have included the establishment of research facilities abroad, especially in the United States.In the case of Brazil, likewise, it is estimated that national informatics firms devote 6% of their sales to R&D. In terms of employment of professionals for hardware/software development, national firms accounted for 189 professionals per U$S 100 million in sales, while the ratio for multinational firms was only 19 (estimated data for 1986)[48].

In most of the countries considered the government has had an important role either by promoting R&D in the field or by

48 See Secretaria Especial de Informàtica, Panorama do setor de informàtica, Bol. Inf. V.7, No 16, August 1987, p. 14.

executing it in public laboratories. In India, for instance, several institutions have strengths of varying levels in some or all aspects of microlectronics technology, such as the Central Electronics Engineering Research Institute, the Tata Institute of Fundamental Research, Indian Telephone Industries, and the Indian Institutes of Technology at Delhi, Kanpur, Kharagpur, Madras and Bombay. In South Korea, the government set up the Korea Institute of Science and Technology (KIST) in 1966, later transformed (with the merger of KAIS) into the Advanced Institute of Science and Technology (KAIST). In the specific fields dealt with here, the Electronics and Telecommunications Research Institute is active in the development and commercialisation of technologies. Research projects include the development of 4M DRAM and gallium arsenide semiconductors South Korean government has also provided financial support for R&D undertaken at the firm level. Currently, emphasis is given to promote R&D in small and medium enterprises.

In Singapore, a Science Park was established in 1979 conceived in the image of the Cambridge Science Park. The National Computer Board and many R&D establishments have been set up there, including twenty nine private organisations which occupy either "starter units" or "Cintechs" (in the case of software activities)[49]. A "science park" is also being

49 See UNIDO, ID/WG.478/7(SPEC), op. cit., p. 37.

established in Malaysia, where a semiconductor research institute would be localised there by 1990. The Malaysian Institute of Microelectronics Systems -created in 1984 by the governement- promotes product development and research. It has entered into various collaborative research projects involving foreign subsidiaries operating in the country.

Several governmental institutions undertake R&D activities in informatics and/or microelectronics in the Latin American countries reviewed in this report. Among them, the Centro de Tecnología Informática -which is setting up a mask fabric for integrated circuits-, the laboratory of the State enterprise Telebras, the Federal University of Rio de Janeiro may be cited in Brazil. In Argentina, various national universities and other institutions execute projects of different nature. The government also provides funds and a framework for the relationship with private enterprises under the National Program of Informatics and Electronics. In Mexico CONACYT finances R&D projects, in addition to those covered by universities and other public entities[50]. In Venezuela, finally, among other institutions, the Engineering Reserach Foundation works on integrated circuits design and other areas of electronics and

50 As a result of the negotiation that took place in order to allow a one hundred percent investment by IBM, a design center is to be established at the Politécnico of Mexico, with an investment exceeding U$S 5 million.

system engineering. It has a center for digital imaging processing build up as a joint-venture by the Foundation, the Venezuelan Institute for Scientific Research (IVIC), the Central Office for Statistics and Informatics (OCEI) and IBM.

The perception of funding and human resources limitations for R&D in the Latin American countries and areas considered here, has prompted the establishment of cooperation agreements, such as the joint research project "ETHOS" agreed upon and in execution since 1985 between Argentina and Brazil[51].

Some forms of indirect governmental support for R&D has also been practised in those countries to different degrees. In the case of Brazil, in particular, Law 7232 contemplates the granting of incentives to national enterprises that undertake research for the production of semiconductors and optoelectronics components. In addition, the Financiadora de Estudos e Projetos (FINEP) financed about sixty projects between 1973 and 1983 in the area of informatics, which were in part executed by the Federal University of Rio de Janeiro and the State-owned enterprise COBRA.

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51 See Carlos M. Correa, Tecnolopgía y desarrollo de la informåtica en el contexto Norte-Sur, Ed. Eudeba. 1989.

9. Software development[52]

Studies on the size and structure of software markets in developing countries are scarce. Overall, developing countries are largely dependent on hardware and software imports. The latter include mainly basic software, application tools and other types of packaged software. Some countries also import custom software, particularly for public administration projects. However, applications such as for administrative and accountancy tasks, are generally developed by local firms. In a few cases (e.g. Brazil, India) the development of basic software, including operating systems, has been envisaged by public and private enterprises[53].

Locally developed software accounts for a minor part of the market in the Latina American countries considered in this report. In Argentina, a survey established that only 30% of the market (in value) was covered by local production[54]. That

52 This section is substantially based on a first draft of Carlos M. Correa, "The legal protection of software. Implications for latecomer strategies in newly industrialising countries and middle-income countries, paper prepared for the OECD Development Center, 1989.

53 In Brazil, for instance, an operating system for minicomputers and systems-like MS-DOS and UNIX has been developed by national enterprises. The government of India has also promoted the local development of a substitute for UNIX.

54 Subsecretaría de Informåtica y Desarrollo, "Producciòn y comercio de software en la Argentina", doc. Nº 35, Buenos Aires, 1987.

proportion was about 40-45% in Mexico for 1987, according to official estimates. For Brazil, a recent estimate indicates that only a quarter of the total market is provided for by local software producers (in-house development excluded)[55]. In Venezuela, finally, local software industry is also incipient and basically limited to the supply of application solution programs.

The situation in Asia, even in those developing countries which have created important capabilities in hardware manufacture, does not substantially differ in general terms from the one depicted for Latin America. Although 71% of South Korean software supply is accounted for by local firms, software imports are growing fast (at an annual 101% rate between 1983 and 1985) and local suppliers have a low level of specialization and of technical capabilities[56]. Some countries have made, nevertheless, significant efforts to increase domestic software production and, particularly, to develop export opportunities. The best known example is India. As early as in 1970 indian government devised policy measures in order to expand software exports, on the basis of perceived comparative advantages in terms of personnel costs and qualifications and the use of

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55 See C. Pereira Lucena, 1988, "A tecnología de software no Brasil: a caminho de uma participacao no mercado internacional", paper prepared for the Centro de Estudos em Política Cientifica e Technologica do Ministerio de Ciencia e Tecnologia, 1988.
56 See UNIDO, Software industry: development approach (by S. Yu and Y. Kim), ID/WG.478/1 (SPEC), 1988, p.52-53.

English language. The very ambitious objectives set forth, however, were not achieved after fifteen years of application of those measures. In 1986 the policy was changed -and liberalised-, while some arrangements with transnational corporations (Burroughs, Texas Instruments) started to produce some results. In the financial year 1987-88 exports for RS. 80 crore were attained. "But of course, pointed out the Secretary of the Department of Electronic, a significant part of it is in people (manpower) exports or body shopping or whatever". The establishment of "software technology parks" in India, with direct satellite link with companies in United States is currently being promoted[57].

Singapore also put in practice in 1982 a policy, including the granting of subsidies and the establishment jointly with transnational corporations (IBM, ICL, NEC) of training centers and research projects, in order to become a software exporter by 1990. Bull and Data General Corporation have also undertaken software activities. The latter, in particular, decided a U$S 42 million investment (over five years) to set up a software centre. The development of software engineering tools (CASE) by a Singapore firm (which has opened a subsidiary in the United States) has been recently reported[58].

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57 <u>Computers Today</u>, september, 1988, p. 11.
58 <u>American Programmer</u>, vol. 1, Nº 7, september, 1988, p. 1.

Isolated cases of software exports have been identified in Argentina, Brazil, Venezuela and Mexico. The number of cases identified, the nature of the products involved and the ecomomic dimension of the operations made do not justify, nevertheless, the optimism that prevails in Latin America on the opportunities offered by software industry.

Software production has been identified, in fact, as a promising field of action in many developing countries. While, it is argued, newcomers face high barriers for entering into the production of hardware, with low capital investment and the mobilisation of local qualified personnel it is relatively easy to exploit the growth potential of the software sector. Paradoxically, up to now a few NIC's have evidenced, as described above, their ability to successfully enter into some segments of hardware production and international trade, while the efforts made to establish software capabilities have not had, at least up to now, significant results.

Among the obstacles faced by developing countries to enter into the software field, the dimension of the domestic market, the present structure of local supply and the weakness of marketing capabilities are outstanding.

Estimations for market size in Latin American countries indicate about U$S 150 million for Argentina[59] and Mexico[60], and U$S 700 million for Brazil[61]. South Korean software market was roughly estimated to be U$S 76 million in 1985, growing at an annual rate of about 52% since 1983%[62].

The structure of software local supply in those countries -for which information is available- invariably indicate a considerable fragmentation and the predominance of small enterprises. In South Korea, for instance, about 1.000 firms have been identified, almost half of which have less than fifteen employees. In Argentina, similarly, 82% of more than 120 firms selling software have less than ten employees. In both cases, investments in equipment and software tools are considerably low. Similar characteristics of software supply have been observed in Venezuela.

Finally, as mentioned before, in most cases local "software houses" in the countries under consideration concentrate on relatively simple, custom made, application software and lack technical capabilities as well as capital to undertake larger software development projects, and particularly standard

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59 Network, Año 1, Nº 5, Buenos Aires, october 1988
60 Information supplied by the Instituto Nacional de Estadística, Geografía e Informática (INEGI), México, 1988.
61 See C. Pereira Lucena, op.cit.
62 UNIDO, ID/WG.478 (SPEC), op.cit., p.51.

software. Moreover, even in those cases where technical competance is available, the marketing of software in export markets is an extremely difficult task, unless joint-ventures and other types of partnerships are established.

10. Human resources

No doubt, the development of human resources is one of the most critical components of any strategy for creating an industrial and technological basis in informatics and microelectronics. The lack of qualified personnel for reseach and development, design and engineering activities, managment and teaching (especially at the university level represent a significant bottleneck in most of the countries considered here. In the countries that have experienced a rapid development in those fields (such as South Korea and Singapore), the shortcomings as to available personnel emerge as an important limitation for future growth. In other cases, well illustrated by Argentina, the formation of professionals and technicians in electronics has clearly exceeded the actual demand, due to the drastic reduction of industry production during the second part of last decade. The paradox now is that a large number of engineers and technicians is available, but their qualifications are to a great extent below those necessary for industry development.

The need to develop human resources in informatics and microelectornics has been felt in all countries considered here. Their responses, however, diverge considerably both in nature and in scope. In some cases monover, efforts to improve graduate qualifications in overseas universities started in the 1960's and are already showing positive results. Massive overseas training was promoted in South Korea, as mentioned before, since 1965. Likewise, the extensive use of scholarschips for the training abroad of scientists and engineers a promoted by the Mariscal Sucre Foundation in Venezuela, was significant in training the founders of many indigenous firms currently active in the professional electronics field. A considerable number of Indian nationals also received post-graduate education in engineering in the United States and other developed countries[63].

The opportunities for education in informatics and microelectronics technologies in the selected countries include in most cases several universities, specialized institutions and specific national programs. In Argentina, eighty eight universitary careers on informatics and in related disciplines are available. An explosive increase in educational demand on those areas took place during the last five years[64]. Important shortcomings as to the number and qualifications of professors (only a minority have concluded post-graduate studies) is a major problem still to be solved. Equipment and software for teaching

63 10.170 science and engineering doctorates were awarded to Indian citizens between 1960 and 1985 in the United states. See National Science Foundation, "Foreign citizens in U.S. Science and Engineering: History, Status and Outlook", Washington, 1987.
64 In 1986, the number of informatics and related careers students reached 36.000, equivalent to 5,6% of all universitary students. See Carlos M. Correa, op.cit.

activities are also scarce. In order to substantially improve the level of universitary education in the field, argentine government undertook various initiatives, among which two should be mentioned. On the one side, it set up a Latin American School of Informatics (ESLAI) with an aim to provide high-level formation to a selected group of argentine and other Latin American students. On the other, under the cooperation agreement entered into with Brazil in 1985, the government organised and financed annual Brazilian - Argentine Schools of Informatics (EBAI), where five hundred selected university students from both countries (and about fifty from other Latin American countries) receive courses from argentine and brazilian professors[65].

In Mexico, there are seventy four university careers on informatics and twenty three post grade programs. Until 1986, about 32.000 students had obtained a grade in that discipline. 35% of professors at universities have post grade studies and 9% have completed a doctorate.

Eighty seven institutions had high level courses and twenty five offered post-grade titles in Brazil, in 1986. The government approved, in 1987, a program for master and PHD studies abroad, which will benefit ten housand students by 1990.

65 EBAI professors are also requested to write a book on their respective subjects, which is later circulated in both countries.

The shortage of qualificed personnel is strongly perceived in the asian cuntries dealt with in this report. To reduce the gap, the role of universities in scientists and engineers formation tends to be complemented by specific programs. In India, for instance, "the gap between the availability and demand for skilled personnel to design, manufacture, apply, and maintain computers and develop software packages for using them, is estimated to rise to 80.000 by the end of Severth Five Year Plan (1989-1990). As against the requirement, the stock of professionals who have got computer education/training from recognised institutions is estimated to have been about 5.000 in 1985-86 while the number of professionals required to implement even the existing computer activities optimally is 12.000"[66]. Action to remedy this situation has included microprocessor training in the graduate and undergraduate curriculum; introduction of computer education (on a pilot basis) in secondary and higher secondary level schools; training of engineers from industries and other organizations in the field of microelectronics and its applications under the Appropriate Automation Promotion Programme (funded by Indian Government and UNDP/UNIDO). The Department of Electronics supports training and continuing education programs, while the state-owned Computer

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66 Ashok Parthasarathi, op.cit, p.5

Maintenance Corporation has set up training centers in twenty for places.

South Korean government has set forth as a goal for the year 2000, to increase the number of scientists and engineers from 11 to 30 per 10.000 inhabitants (a level comparable to that of Japan). Likewise, it plans to bring back 2000 overseas trained scientists and engineers[67]. Graduate and post-graduate training in South Korean universities has been reported as inadequate, except at a few institutions, but improving[68]. The government set up the Korea Science and Engineering Foundation and the Korea Research Foundation in order to promote and finance research at the university laboratories.

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67 Ministry of Science and Technology, op. cit.
68 See UNIDO IS/500, op.cit.

11. Summary and conclusions

Informatics and semiconductors constitute one of the most dramatic iullustrations of the industrial and technological North South asymmetry. Industrialized countries firms -and particularly transnational corporations- dominate the innovative process, an overwhelming part of world production, and the distribution and commercialization channels. A few developing countries have made, particularly during this decade, considerable efforts to enter into those new fields on the basis of a nationallly led development. Other have got some significant participation in the international trade of products assembled locally by subsidiaries of foreign firms.

The countries selected for this study reflect a considerable diversity of situations in terms of market size, production capacities, industrial strategies followed, and other features.

Some countries have reached important levels of output in terms of world production, such as Singapore, South Korea and Malaysia in active components and -to a minor extent- Singapore and Brazil in informatics goods. In overall terms, asian developing countries are quite ahead of Latin American countries as to the dimension of their respective production in those fields.

Production in the areas and countries considered in this report is, by its most part, based an the assembly of imported parts and components. This is characteristic in countries like Malaysia, but it is also a fact in other countries that have significantly advanced in the development of an electronic industry, such as South Korea. With the launching of informatics policies in Argentina, Brazil and Mexico, attempts were made to attain a higher local content in national production, with very different results. In South Korea, important investments were made to introduce semiconductors manufacture from wafer fabrication.

Moreover, in Brazil and India the large potential of the domestic market and the perception of the strategic character of microelectronics and informatics technologies, among other factors, determined the adoption of stragies having technological self-reliance in the field as a long term goal. These models are based on the assumption that a "learning by doing" process will enable local producers to catch up technologically with industrialised firms and to assure the development of a domestic industry.

The industrial structure prevailing in the countries considered show the predominance of relatively large firms, and of a quite concentrated local supply. South Korea is the outstanding example, with a few conglomerates dominating the industry. In contrast, in some Latin American countries (Argentina, Mexico, Venezuela) small and medium enterprises seem to prevail.

One major difference in the strategies followed, relates to the approach towards foreign markets. Large continental economies (Brazil, India) and other countries with long import substitution tradition (Argentina), have focused an the production for the domestic market, while asian countries dealt with (and Mexico) have clearly opted for an export-led model. The success reached by some of the latter countries (particularly Singapore and South Korea) is impressive as reflected in the exports to United States and other industrialised countries in recent years. A great part of such exports, however, are based on OEM arrangements, whereunder efficiency in production is combined with dependency on foreign firms' designs and, particularly, marketing networks. This weakness may become a dramatic shortcoming if protectionist trends in industrialised countries, particularly in the United States, are further strengthened.

It is interesting to note that, unlike sometimes assumed, success in exports has not been necessarily associated to open competition at the domestic market. South Korea is a good example in that sense.

The role of the State in the development of the sectors studied has been relevant in most selected countries. In some of them, it also included direct participation in production, as illustrated by the case of India. Different types of public incentives are available in those countries, including for R&D activities, public procurement, etc.

On the other side, foreign participation has also been important in general terms, but some countries have established significant limitations in order to enhance the role of nationally owned firms. Thus, while in Singapore and Malaysia foreign direct investments, and particularly transnational corporations, are the major industry's actors, in India and Brazil their role has been circumscribed as regards to the forms of ownership participation and to the type of products that they are allowed to produce. In the latter countries, as well as in South Korea, nationally-owned firms play an important role in the current development of the sectors considered.

Licensing of foreign technology has been an important tool to enter into the production of informatics goods and semiconductors in most countries. In some cases, those arrangments represented the first step in a process of technology absorption, that was later on complemented by an increased effort in R&D. Most of R&D in those fields in the countries reviewed has been financed or executed directly by public sector institutions. R&D within enterprises, however, has significantly expanded in some cases, such as in South Korea, Brazil and India. In overall terms, the R&D capabilities in the eight selected countries is limited and mostly concentrated on product development.

In the area of software production, despite the expectations on their potential for developing countries, so far local industries in the countries considered are incipient, excessively fragmented and technologically weak. Local supply is mainly limited to application custom-made software, though the development of some kind of basic software has been identified in Brazil, India and other countries.

Finally, notwithstanding the progress made in human resources development in the fields dealt with, all the countries reviewed face considerable problems, though of different nature. In some cases, the rapid expansion of informatics and microelectronics production and applications (e.g. South Korea, India, Singapore) has created a human resources demand very difficult to satisfy in the short term, particularly for high qualified jobs. In other countries (e.g. Argentina) the increaded interest for those disciplines can not be adequately met by educational institutions, due in particular to an acute lack of qualified teaching personnel.

In conclusion, the countries studied in this report present a wide range of achievements, development strategies, weaknesses and strenghts that make it extremely difficult to attempt a comparative assessment. The elements derived from their experience, however, provide very valuable materials to understand the factors that may be determinant of success or failure in high-technology fields. In particular, they may contribute to a more general -and much needed- discussion on the real opportunities that those fields offer for new industrialising countries. Of course, the study made is neither exhaustive nor deep enough to derive definite conclusions. It shows, however, that the establishment of industrial, technological and marketing capabilities in those fields is a very complex matter and that they do not necessarily come together. It also indicates that some common assumptions -e.g. on the easy possibilities that software production and exports may open- are not more than misleading simplifications. In fact, the building up of those capabilities in informatics and microelectronics, will still require important efforts and, most probalby, new strategies to survive in an extremely competitive and rapidly chaging context.