36. Martin Fransman, "Promoting Technological Capability in the Capital Goods Sector: The Case of Singapore," *Research Policy*, February 1984, pp. 33−54.

37. The establishment of Charter Semiconductor reflects an attempt to ensure that investments in local capabilities are not forgotten in the midst of aggressive efforts to attract foreign investment from around the world.

38. While Singapore remains the world's leading site for disk drive production, Singapore officials are anxious to diversify the country's technological base away from such a heavy emphasis on disk drive manufacturing. Interviews in Singapore, May 1992.

39. A. J. Youngson, ed., *Hong Kong: Economic Growth and Policy* (London: Oxford University Press, 1982).

40. Martin Fransman, "Learning and the Capital Goods Sector under Free Trade: The Case of Hong Kong," *World Development* 10(11), 1982, pp. 991−1014.

41. Overall, between 40 percent and 50 percent of Hong Kong's electronics exports are derived from the operation of foreign firms in the colony.

42. About 80 percent of Hong Kong's electronics manufacturers employ fewer than 50 workers.

43. Victor F. S. Sit, "Dynamism in Small Industries: The Case of Hong Kong," *Asian Survey*, April 1982.

44. Bruce Guile, ed., *Technology and Global Industry* (Washington, D.C.: National Academy Press, 1987).

45. Dieter Ernst and David O'Connor, *Technology and Global Competition: The Challenge for the Newly Industrialized Economies* (Paris: OECD, 1989).

13—
Development of the Brazilian Electronics Industry: A Study of the Competitiveness of Four Subsectors

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The purpose of this chapter is to discuss the impact of the industrial policy, regime on specialization and the competitive standing of the Brazilian electronics industry. In view of the industry's diversity, the analysis will focus on four representative segments: microelectronics, banking automation, color televisions, and public digital exchanges. They span the industry's major subsectors (components, consumer and professional electronics) and, in their diversity, serve to illustrate this chapter's key proposition: that the lack of specialization has been a major constraint to the development of the electronics industry in Brazil.

The chapter argues that in the absence of specialization, producers (and research institutions) are forced to spread their resources among many competing activities. In particular, given a still narrow technical base and a broad research, development, and production agenda, an insufficient degree of specialization precludes Brazilian firms from accumulating the critical mass of technological assets necessary to improve the industry's competitive position in the most promising product areas.

That Brazilian electronics firms have been insufficiently selective in product and activity choice is a reflection of a policy regime that has moved the economy beyond the limits of efficient import−substitution, not only in electronics, but in practically all industrial activities. The Brazilian economy was, until recently, extremely closed. In 1989 the ratio of imports to gross domestic product (GDP) in Brazil was 5.7 percent, lower than Japan's (an economy nine times as large as Brazil's) and one−fifth that of the Republic of Korea's (Table 13.1). The extent of import−substitution diversification and the absence of intraindustry specialization is suggested by extremely low ratios of manufactured imports to manufactured value added (Table 13.1).

In electronics (as in many other sectors), a strategy of across−the−board import substitution has stimulated entry into new areas notwithstanding their potential to become internationally competitive. It has also led to excess entry in a number of segments. Newcomers, attracted by domestic market rents, have had to share with incumbents an aggregate demand limited to local sales. This has prevented both incumbents and entrants from reaping the substantial economies of scale that characterize most of the industry's production and development activities. In spite of the 1987 recession, few firms have exited, and production scales continue to be excessively fragmented.

A high degree of policy−induced horizontal diversification throughout the industry and the implied fragmentation of production have stimulated firms to integrate vertically.2 Domestic content requirements and other import restrictions have had a similar effect. For a number of producers, vertical integration has been the means to ensure product reliability and overall performance standards, even if it implies higher costs and dispersion of efforts.3

The lack of intraindustry specialization and the predominance of firms that are horizontally diversified and vertically integrated to an uneconomic degree help explain why the Brazilian electronics industry has been unable in most segments to approach the international price−performance frontier. There are, moreover, some indications that the competitive standing of the Brazilian electronics sector has deteriorated in the current decade.

Table 13.1
Share of Manufactured Imports in Manufactured Value Added in 1988 and Share of Merchandise Imports in GDP in 1989, Selected Countries
(percent)

Indicator	*Brazil*	*Indonesia*	*Japan*	*Korea*	*Mexico*	*Thailand*	*Turkey*
Merchandise imports/GDP	5.7	17.4	7.4	28.9	11.0	37.0	22.0
Manufactured imports/ manufactured value added	8.3	75.9	9.4	62.5	31.0	100.1	59.8

Source: World Bank, *World Development Report*, Washington, D.C., 1991; and World Bank, *World Tables*, 1991.

Table 13.2 shows changes in revealed comparative advantage (RCA) for the electronics industry over the 20−year period 1965−85.4 Two facts stand out regarding the competitive structure of the industry's major segments. First is their weak standing within the overall pattern of specialization and trade of the Brazilian economy. As of 1985, no segment had an RCA index above 0.45; the industry commanded a disproportionately low share of Brazilian exports when compared with the share held by other industries in world exports.

Second, there is a disturbing trend over the period. The systematic improvements in the RCA index for all segments between 1965 and 1980 (except for office machines, which suffered an inflection in 1975) turned into competitive losses in the current decade. Indeed, for all segments, the rates of growth in RCA were negative and significant during 1980−85, in contrast to the whole 1965−85 period. It is worth stressing that this reversal was not specific to the electronics industry, but rather characterized many of the technologically more sophisticated sectors of Brazilian industry, including electric and nonelectric machinery and transport equipment. However, what is specific to electronics is that, on average, the erosion of the industry's competitive position was by 1985 the most pronounced among all industrial segments. Only telecommunications equipment presented an RCA index—0.44—that was broadly in line with nonelectric machinery and transport equipment in 1985 (respectively 0.48 and 0.46).

The competitive losses of the electronics industry are particularly striking in view of the comparative advantage in Brazilian labor costs, the skill composition of Brazil's labor force, and a significant domestic market base. Labor costs are low for all categories of workers, technicians, and engineers. Table 13.3 reveals that, compared with four other major producers of electronics products, Brazil not only had the lowest average hourly wages (including fringe benefits) in 1985 (except for Korea), but it was the only economy where wage rates deteriorated between 1981 and 1985—they fell by nearly 25 percent in this relatively short period. Since 1985 average wages in the subsector have further deteriorated, and by early 1990 they had reached $1.10 per hour.

Even more significant than average wage levels are salary levels for engineers and technical personnel. Major electronics firms pay senior engineers (those with 10 years of experience) anywhere from one−third to one−sixth of comparable salaries in the United States (the difference is even more

Table 13.2
Brazil: Changes in Revealed Comparative Advantage, 1965−85

						Growth rates	
SITC sector no.	*1965*	*1970*	*1975*	*1980*	*1985*	*1965−85*	*1980−85*
714 Office machines	0.22	0.68	1.10	0.98	0.28	1.2	−22.2
724 Telecommunications equipment	0.01	0.11	0.44	0.46	0.44	21.0	−0.9
725 Domestic electrical equipment	0.08	0.14	0.33	0.33	0.23	5.4	−7.0
729 Electrical machinery NES	0.13	0.13	0.34	0.45	0.23	2.9	−12.6
861 Instruments, apparatus	0.02	0.02	0.11	0.23	0.14	10.2	−79.5

Source: Author's calculations based on U.N. trade statistics.

Table 13.3
Changes in Average Wages, Electrical and Electronic Industry Equipment, Selected Economies, 1981−85
(US$/hour)

Economy	*1981*	*1982*	*1983*	*1984*	*1985*
United States	10.33	11.28	11.90	12.48	12.98
Japan	5.62	5.19	5.54	5.78	6.04
Korea	1.16	1.26	1.29	1.36	1.38
Taiwan (China)	1.18	1.26	1.31	1.53	1.51
Brazil	2.07	2.42	1.71	1.44	1.49

Source: The Long−Term Credit Bank of Japan and Instituto de Planejamento Economico e Social, "Current Brazilian Economy and Business Opportunities," mimeo, June 1988, p. 151.

pronounced if the comparison is made with European and Japanese salary levels, in view of the devaluation of the U.S. dollar since 1985). Equally relevant, these firms do not find the supply of engineers and skilled personnel a major constraint in attaining a competitive market position in certain design−intensive slices of the production process. The point that should be stressed is that, potentially, Brazil has a competitive advantage not only in unskilled and semi−skilled labor−intensive areas, but also in those segments that are design and engineering intensive.

Even though the domestic market for electronics is not large relative to the scale requirements of many products, it is nonetheless significant in the sense that it provides a dynamic setting where entry is stimulated, resources are mobilized, and where learning can take place, both by doing and through producer−user interaction. Since producers of electronics goods rarely become internationally competitive soon after start−up, a dynamic domestic market becomes nearly a precondition for successful export penetration. Moreover, in many areas where economies of scale in production are less relevant, and satisfying user needs through design and engineering−intensive customization leads to one−of−a−kind products, domestic firms can find new profitable niches or substitute imports efficiently even in markets of limited size.

The Brazilian domestic market is not marginal as a breeding ground for electronics firms. In consumer electronics, its size has oscillated between 4 percent and 6 percent of the world market in the period 1977−86. In telecommunications equipment, it has varied between 1.3 percent and 2.5 percent. In semiconductors, its size has varied between 1 percent and 1.5 percent. In computers and peripherals, it has hovered around 1.5 percent. Although these shares are translated into market sizes that are sufficiently large to induce entry, their implicit scales are nonetheless too small to stimulate and sustain firm growth on an efficient and innovative basis. One finds, therefore, a number of firms in each segment, but few, and often none, with sufficient resources to move their product lines to the international price−performance frontier.

If fragmentation of production from excess entry characterizes most segments of the electronics industry, a mere reconcentration of capital around fewer, and supposedly stronger groups, will not make the industry internationally competitive. For an increasing number of products, scale requirements are such that only a sharp reduction in the number of producers would allow economies of scale to be reaped. In several cases (such as color televisions, facsimile machines, and video cassette recorders), the optimal number of firms would be one. In these circumstances, the probability of firms exercising market power would be high. Rents could be reaped without significant managerial efforts, unless new entrants and competing imports continuously forced incumbents to improve their competitive standing.

Moreover, technical efficiency may be only marginally affected by a movement toward reconcentration of capital if the degree of intrafirm diversification and intraindustry specialization remains unchanged. In fact, closing the price−performance gap (or at least ensuring that it is not further widened) now requires considerable restructuring of the electronics industry to allow an increased degree of specialization. Sectoral competitiveness is predicated upon concentrating resources in higher value added, engineering labor−intensive niches, using the considerable advantage in labor costs and of an entry−supportive domestic market to expand exports progressively.

The point of departure of this chapter is, in sum, that the electronics industry in Brazil is excessively diversified, producing "too little of too many things." In the informatics segment, for example, a number of product groups have consistently lagged in design and quality, but nonetheless they continue to be produced in relatively small volumes behind high barriers to competition. This is the case with many peripherals, such as high−speed printers, disk drives, mid−size and large memory units, mini and supermini computers, certain types of technologically more sophisticated automation and telecommunications equipment, and most of the newer generation of consumer electronics products (such as microwave ovens, camcorders, compact disk players, and liquid crystal display [LCD] color televisions). Particularly for products

that have become high−volume commodities or that have undergone radical improvements during this decade, the price−performance differential between the international and domestic markets has actually widened since the mid−1980s.5

Specialization, supported by a more open and flexible trade and industrial policy regime, should be pursued along four key dimensions:

Horizontally, across product lines. Firms would undertake to produce only what is most competitive.

Vertically, along the input−output chain. Producers would shed what can be efficiently made by domestic or foreign vendors.

Among different production stages. Firms would focus on the design and manufacturing activities that are within their level of competence and learning capabilities.

Specialization should be carried out systemically. Producers, when designing and assembling systems (providing a solution), would be able to source system components domestically or abroad.

The first section, Microelectronics, argues that the microelectronics segment in Brazil has lacked both product and production activity focus. Its development now depends, *inter alia*, on a higher degree of both horizontal and production−flow specialization. It will first be necessary to refocus the segment on a subset of application−specific integrated circuits (ASICs)—those that integrate (and miniaturize) products for which Brazil has an actual or emerging competitive advantage (certain types of telecommunication and bank automation equipment, for example). Second, the government should support producers in their efforts to achieve proficiency in design by facilitating access to tools (work stations, software, project libraries, plotters); by actively promoting in−house, laboratory, and university training of design engineers and related specialists; and by supporting "infant" users of locally−designed ASICs. Finally, integrated circuit (IC) policy should stimulate producers to break down and learn one specific set of manufacturing steps at a time (such as placement and testing) while engaging in cooperative foundry arrangements.

The second section, Banking Automation, discusses the case of banking automation and introduces the notion of systemic specialization. Systems are made up of discrete elements (such as minicomputers and input−output (I/O) devices) and a way of interlinking them to function according to certain objectives (the solution). Banking, point−of−sales and, to a lesser extent, industrial automation are segments of the informatics sector in which

Brazilian producers have an actual or potential comparative advantage. The key entry barrier to the international market is the lack of access by system houses to a broader, higher performance and more competitively priced range of products than is currently allowed by government policy. It is argued that Brazilian producers should be allowed to specialize systemically by sourcing individual components on the most economic basis while exploiting their competitive advantage in low conceptualization and design costs.

The third section, Color Televisions, examines the competitive standing of color televisions, the archetypal consumer electronics product. Its backward linkages have played a critical role in the development of the components industry in other countries. Color televisions, as an increasingly integrated product, have required IC design capabilities that have yet to be developed in Brazil. As a result, Brazilian color television producers continue to depend on the proprietary technology of foreign partners or suppliers and lack the flexibility to export because of restrictive contractual clauses. Yet, without entering the international market, producers cannot gain the scales that will generate the resources necessary to master the design of color television ASICs. However, if more emphasis had been given in Brazil to the build−up of design capabilities for custom and semi−custom ICs, television manufacturers could have undertaken the design of these ASICs jointly with specialty houses. Thus, a key technological entry barrier for Brazilian color televisions in the international market can be construed as a second−order outcome of the absence of an adequate specialization pattern in microelectronics.[6]

The fourth section, Telecommunications Equipment: The Tropicos Public Telephone Exchange System, focuses on the importance of selectivity in product development. It examines the case of digital switching equipment for small and medium−sized public telephone exchanges, the so−called Tropico project. This project has been undertaken by the *Centro de Pesquisa e Desenvolvimento* (CPqD) of TELEBRAS, the major telecommunications equipment research and development (R&D) center in Latin America. CPqD's dispersion of resources among many projects prevented the Tropico exchange family from becoming (at least so far) a cost−effective and timely alternative to imported equipment. This is not to say that there are no important external economies associated with the project, particularly in the form of product spinoffs, specialist training, and the build−up of technological capabilities. Significant economic costs have also been associated with the delays in

introducing digital technology in the Brazilian network. A longer time horizon will be needed to assess if the benefits reaped with the development of the Tropico family outweigh the costs associated with this project.

The section, Concluding Remarks, summarizes the key arguments of the chapter and draws some additional lessons from the individual case studies. In particular, it attempts to elaborate briefly on other emerging issues by examining the perspective indicated in this introductory section and the material laid out in the case studies.

Microelectronics

Market Dynamics

The world semiconductor market is expanding at a rapid rate, driven fundamentally by the growth of digital circuits (Table 13.4). The rate of growth of ASICs in particular was expected to reach over 22 percent in the period 1986−88, substantially above the average for all integrated circuits.[7] On the other hand, both discrete devices and linear circuits have been growing at moderate rates (respectively, 4.5 percent and 7.7 percent), in line with the view that demand for less sophisticated circuits will be tapering off in the next few years.

The explosive growth in demand for integrated circuits is a reflection of their extremely high rates of diffusion. The use of ICs has become generalized, with a broad range of applications in capital and consumer goods. With the number of transistorsper chip growing geometrically since 1950—40 years ago a chip could hold some 10 transistors, whereas this magnitude is now in the order of 100,000−4,000,000—their functional possibilities have been extended, and their economy−wide impact felt beyond the electronics industry.

Table 13.4
World Semiconductor Market, 1986−88

	US$ millions			*Growth* b *(%)*
Type of component	*1986*	*1987*	*1988* a	
Integrated circuits	25,702	28,235	33,091	13.5
Linear	6,353	6,640	7,379	7.7
Digital c	15,852	17,475	20,466	13.6
ASICsd	3,497	4,120	5,246	22.5
Discrete devicese	6,085	6,185	6,642	4.5
Total	31,787	34,420	39,733	11.8

a . Forecast.

b . Average per annum growth 1986−88.

c . Microprocessors, memories, standard logic devices.

d . Standard cell, gate array, programmable logic devices.

e . Diodes, transistors, tryristors, varactors, and so on.

Source: Electronics, January 1988.

Nonetheless, integrated circuits play a particularly critical role in the so−called high−technology or R&D−intensive sectors (being most important for the electronics complex itself) where projects and functional specifications of many products are reflected, in a homological sense, on the project and specifications of a set of ICs. At the extreme, as circuits become increasingly integrated (that is, as the number of devices per chip increases), they would be reflected in a single chip. The ability to introduce new products becomes, in this sense, predicated upon the ability to introduce new integrated circuits.

This has an immediate and important corollary: projecting new products for the electronics (and, to a lesser extent, other industries) will depend increasingly on acquiring, either in−house or through specialist firms, the capabilities of designing integrated circuits. The very nature of this work requires substantial interaction between user and producer. In many ways, the project is a joint venture where initial specifications are supplied by the buyer and critically evaluated, in a first instance, by the circuit designer. After a number of interactions, a common design is agreed upon.

The intensity of user−producer interaction, and the very fact that product design and circuit design will be increasingly one and the same activity, suggests that design capabilities should be fostered domestically. Achieving proficiency in IC design becomes, in this perspective, a strategic requirement for industrial competitiveness. How to foster these capabilities in industrializing countries then becomes a critical policy issue for the microelectronics segment, particularly since those countries are minor participants in world markets and have limited technological resources.

The world semiconductor market is dominated by Japan (with an estimated share of 47.6 percent in 1988), the United States (with 38.3 percent), Germany, the United Kingdom, France, and Italy. Brazil is still a marginal player, with slightly less than 1.0 percent of the market, with apparent demand outstripping domestic supply by 0.4 percent and filled in by imports (exports are small, and limited to discrete devices and linear ICs).

Within Brazil's demand structure, discrete components play a much more important role than they do worldwide (Table 13.5). Yet they are losing importance to digital ICs, the demand for which is

growing at a faster pace than either linear ICs or discrete devices. Such a trend is in line with demand dynamics in the rest of the world. Correspondingly, domestic IC production during 1986−88 expanded at nearly the same rate as digital IC demand (6.9 percent vs. 7.6 percent), whereas IC imports in 1988 were basically the same as two years earlier.

The profile of semiconductor demand in Brazil is suggestive of the stage of development of the electronics industry and particularly its semiconductor segment. The heavy concentration in discrete devices (33.7 percent of total semiconductor demand in Brazil in 1988, as opposed to 16.7 percent for world demand) not only reflects the preponderance of consumer electronics—mostly radios and televisions—relative to professional equipment (Table 13.6), but also the less demanding designs and lower performance characteristics of these and other IC−using products.

Despite efforts at expanding digital IC output, the composition of both imports and domestic semiconductor production reveals the still incipient stage of the semiconductor segment itself. At the end of 1986, there were 22 semiconductor producers in Brazil, half of which were foreign firms engaged just in mounting and testing discrete components (and linear circuits in a few cases), although one firm undertook all steps for manufacturing power diodes. Four national firms were dedicated to linear and digital ICs, of which only one (SID) dominated the diffusion cycle in bipolar technology for diodes and transistors; two others were engaged in the complete cycle for hybrid circuits; another two manufactured light−emit−ting diodes (LEDs); and one each focused on potency diodes, varistors, and solar cells.

Most locally produced digital circuits are standard logic bipolar devices (such as TTL, I2L, and ECL, whereas digital IC imports are heavily concentrated in scale−intensive and complex−to−manufacture memories and microprocessors. Some linear circuits are mounted locally with imported wafers (such as potency amplifiers), whereas most of those that are imported are circuits for car radios and color televisions. Almost all ASICs are imported; however, there are no reliable estimates of what proportion of imported ICs are application specific.

Concerning the local production of ASICs, only two firms have so far been able to dominate the project cycle (Vertice and Itaucom), although CPqD (of TELEBRAS) has designed both custom, semi−custom, and hybrid circuits (in addition to optoelectronics components). An estimated 38 ASIC projects were carried out between 1986 and mid−1988 (this number might be closer to 50, depending on how a project is defined), of which 8 have reached production stage, even though at relatively small scales; 18 are in progress; and the remainder (14) have been abandoned. There is no question that this is a poor record, particularly in view of Brazil's potential comparative advantage in ASIC design.[8] Improving such a record will de−

Table 13.5
The Brazilian Semiconductor Market, 1986−90

	US$ millions				*Growth* b *(%)*
Type of component	*1986*	*1987*	*1988*	*1990* a	
Integrated circuits	223	172	230	410	1.6
Digital	113	91	131	282	7.6

Linear	110	81	99	128	−5.1
Domestic production	70	76	80	−	6.9
Imports	173	114	171	−	−0.6
Exports	20	18	21	−	2.5
Discrete devicesc	139	139	135	140	−1.5
Optoelectronic devices	8	6	6	6	−13.4
Total	370	317	371	556	0.1

− Not available.

a . Projected.

b . Average annual growth rates 1986−88.

c . Disaggregated data unavailable.

Source: GEICOM; Ministry of Communications.

Table 13.6
Brazil: Demand, 1987 and 1990

Industrial segment	*1987*	*1990* a
Consumer electronics	46	35
Informatics	23	30
Telecommunications	7	11
Automotive	19	19
Industry	5	5

a . Projected.

Source: GEICOM.

pend on having a more selective and focused structure of incentives for microelectronics, with an increased emphasis on specialization in design−intensive products and the more labor−intensive steps of the IC production cycle.

Specialization as the Focus of Semiconductor Policy

Clearly, Brazilian producers should not be encouraged to undertake the production of commodity chips (such as memories and microprocessors of wide use). The reasons are fairly straightforward: a new large−scale foundry costs anywhere from $100 to $250 million; the production process is becoming increasingly capital−intensive; minimum efficient production scales are, as a result, on a sharp rise; and the growth in scales of integration continues to accelerate, from a current upper bound of 1 million transistors per chip in the late 1980s to densities 100 times as large by the early 1990s. The use of C−MOS submicra technology (with ranges of 0.5 to 0.3 micron) is expected to then make viable memory chips of 16 to 64 megabytes, with a concomitant increase of speed from 1.0 ns to 0.05 nanoseconds (ns). In sum, entry barriers for commodity chips are high and rising, and the small window of opportunity opened at the bottom of the last price cycle has now been closed.

Many characteristics of the ASICs stand in contrast to those of commodity chips and are summarized in Table 13.7. Although the trend is for major commodity producers to migrate to the production of ASICs, making entry for industrializing newcomers more risky, ASIC production is nonetheless technologically more accessible (for most applications, a 2 micra technology is adequate), less costly (ASIC foundry costs are in the range of $40−$70 million) and, as a result, scale economies are less pronounced. Indeed, minimum efficient scales (MESs) range from 200,000 for a full custom IC to 50,000 or less for semi−custom gate array chips. Most important, however, is that ASICs are relatively more design−intensive (on a per−unit basis) than other classes of ICs, conferring potential competitive advantage to countries where engineering costs are low.

The above suggests that Brazilian IC producers should concentrate their resources in learning to design and efficiently manufacture ASICs. In particular, in view of smaller development costs and project time, lower MES requirements, and a high proportion of premounted transistors, entry barriers might be lowest for semi−custom ICs projected in gate array technology. Nonetheless, the choice of what class of ASICs to produce is predicated not only on their technological characteristics but on an existing (or rapidly emerging) market for products that require the use of ASICs. These factors naturally suggest areas in which domestic ASIC producers should be specializing. Within these criteria, the product focus might be on dedicated and semi−dedicated ASICs for certain types of bank automation devices, color televisions, telecommunications, and automotive equipment, for example.

Even if a sharp focus on certain classes of ASICs is necessary to sustain entry on a competitive basis for Brazilian semiconductor firms, it is in all prob−

Table 13.7
Major Characteristics of ASICs

		Development		
Component type	*Percentage pre−fabricated of wafer*	*Cost (US$ thousands)*	*Time (months)*	*Minimum efficient scales (output per year)*
Full custom	0	100−200	12−18	>200,000
Semicustom				
Standard cell	0	50−100	8−12	30,000−200,000
Gate array	80	25−50	4−8	<30,000

Source: GEICOM.

ability not sufficient. Some of the 1C production stages are sufficiently complex from a manufacturing standpoint, and subject to large enough economies of scale, that shedding or postponing these stages would be equally essential for attaining international competitiveness. Figure 13.1 describes the production steps for a typical IC. One set of steps is design−intensive, where costs are fundamentally determined by the price of specialized labor. Another set of steps is manufacturing−intensive, where the costs of capital and its productivity are the dominant competitive factors. These two sets can, in principle, be regarded as separable activities.9

Attaining proficiency at the design stage of IC production is within reach of Brazilian producers. On one hand, attaining such proficiency is predicated on the access of firms to computer−aided design (CAD) work stations, design software, specific project libraries, minicomputers, and plotters. Yet, such accoutrements are generally available in the international market at competitive prices, since rivalry among foundries has intensified. In fact, foundries in other countries are often eager to supply some of those tools (such as libraries) as part of their market development efforts. In the current environment, Brazilian firms could take advantage of such arrangements and avoid being locked in with particular suppliers. In the specific case of project libraries, the Brazilian government is planning to establish a freely assembled central library, in order to concentrate demand and gain scale in certain diffusion technologies.

Figure 13.1
An Integrated Circuit Production Cycle

A. Design stage

I. Objectives and functional specifications of the project

II. Project

1. Electric and logic specifications

2. Test vectors

3. Automatic extraction of netlist

III. Project validation

1. Simulation of electric/logic functions

2. Simulation of failures (test vector)

3. Extraction of electrical diagram

IV. Layout

1. Mask design

2. Symbolic edition

3. Graphic edition

4. Placement and routing

V. Layout validation

1. Check project rules

2. Extract parameters

3. Extract electric circuit

B. Foundry stage

VI. Complete project (tape)

1. Generate data base/PG−tape

2. Generate test program

VII. Mask preparation

1. Generate reticules

2. Compare with project data

3. Mask generation

VIII. Wafer fabrication

1. Physical−chemical processing

2. Wafer generation

IX. Placement and testing

1. Encapsulation

2. Electrical tests

3. Life tests

Source: GEICOM.

More fundamentally, however, competitiveness in design is dependent on the skills and cost of design engineers. According to Brazilian design houses, an adequate supply of trainable engineers is available, which would take from six months to two years to develop into a capable team of ASIC designers. Not only is the supply of skilled technicians not regarded as a binding constraint to IC design development in Brazil it is actually perceived as a competitive factor in which Brazil has a major advantage. The cost of a design engineer is in fact only a fraction (one−third to one−sixth) of an equivalent technician in developed countries. A policy of encouraging production−flow specialization in design (and the parallel development of some of the necessary tools, such as certain types of design software) might thus be the most sensible approach to ASIC development in Brazil.

The slow accretion of circuit design capabilities and the underdeveloped stage of ASIC production in Brazil is partly the result of a misguided policy focus. The first National Informatics Plan (PLANIN) not only attempted to promote too many activities in this area, but, equally important, focused on the manufacture of ICs (by no fewer than three producers) as its major policy goal in microelectronics, as opposed to, first and foremost, achieving proficiency in design. Instead, the emphasis should have been on fostering design activities by facilitating access to tools, supporting the training of design engineers and specialists, and developing a market for locally−designed ASICs. In particular, PLANIN should have backed new users attempting to improve the functional quality, and other performance characteristics of their products by incorporating ASICs.

The emphasis on ASIC design as part of a strategy of production−flow specialization should be complemented by a similar specialization policy with respect to IC manufacturing. Three firms were licensed to establish IC foundries in Brazil: SID, Itaucom, and Elebra. Of the three, SID is cur−

rently at the most advanced stage of manufacturing. After acquiring a production line for analog circuits from Philco (a Ford subsidiary), it has been able to produce linear ICs with a 2 micra level of integration within the time established by SEI (the regulatory agency that implements the Brazilian Informatics Law). However, it is only capable of encapsulating and testing digital ICs. Itaucom has basically the same capabilities as SID, whereas Elebra has exited.10

The manufacturing of ICs in Brazil appears to be saddled with problems of excess entry. If ASIC design activity is consistent with a fragmented firm structure, the same is clearly not true with manufacturing. In view of the large fixed and sunk costs to establish an efficient and internationally competitive foundry, the Government of Brazil should promote a cooperative arrangement among producers. Coproduction of ICs should be the policy objective. It already appears that Elebra and Itaucom will establish a yet unspecified link−up; SID might be nudged to join. Preparation of masks might be undertaken separately, possibly by a government−supported institution (such as CTI), in the demonstrated presence of strong externalities.11

At the same time, no attempt should be made to force individual producers to internalize certain grossly uneconomic production steps (such as generation of masks and physical−chemical processing).12 The foundry stage has already de facto been broken down, as producers have attempted to learn and become competitive in some of the less complex steps where fixed costs are relatively small and variable costs more significant (such as encapsulation, electric, and life tests). Until a cooperative venture gets off the ground, local producers should not be prevented from contracting with foreign foundries for the preparation of masks and wafer fabrication. Such an approach to manufacturing is possibly the only way to make IC manufacturing economically viable in Brazil. Combined with an emphasis on developing ASIC design capabilities, it might ensure the competitiveness of a niche−oriented industry in Brazil in the 1990s.

Banking Automation

The Brazilian Banking Industry

The banking industry in Brazil is made up of 103 commercial banks (5 federally−owned, 24 state−owned, 56 owned by private Brazilian groups, and 18 by foreign banks) with approximately 15,000 branches spread over a large territory. In addition to traditional banking functions, the industry performs some tasks that differentiate it from the U.S. or European systems. In particular, the government relies to a great extent on banks to act as intermediaries for its taxation and transfer activities, and all utilities use it for collecting customer payments for bills. Most of these transactions involve the public use of on−premise teller services. The volume of paper that any single branch typically has to deal with is, as a result, disproportionate to the amount of demand deposits and financial papers held for its clientele. The client base of any given branch is potentially anyone who either pays taxes or bills or receives any type of transfer from the government. As noted below, these characteristics of the industry have important implications for the volume and composition of demand of data processing equipment.

The number and composition of transactions that flow through the system are indicative of its multiservice intensity. At end 1988, checks were balanced at a rate of 3 billion per year (twice as many as at the beginning of the decade, which itself was four times the number of checks balanced in 1970). In the mid−1980s, banks were annually processing 8−9 million income tax statements; 10−11 million transactions related to other types of taxes (such as taxes on industrial production, sales of goods and services, and property); 20−22 million monthly payments and other items for social security; and over 35 million yearly payments for the PIS/PASEP (*Programa de Integração Social/Programa de Assistencia ao Sevidor Publico*) and FGTS (*Fundo de Garantia de Tempo de Serviçco*) assistance programs. To these figures should be added the payments and transfers of over 400 other federal agencies dealing with 30 million individuals, the more than 70 million monthly utility bills paid at individual branches, and the tax transactions related to state and municipal governments.

There is another significant reason for the growth of a multibranch banking system, in addition to its intensive use for government−related transactions. Since 1973 the rate of inflation has accelerated (with a short interregnum in 1986). It led to an increase in the velocity of transactions, as agents diversified their portfolio away from cash into bank−intermediated financial assets. It also stimulated banks to extend themselves and open more branches and offer more services in an effort to capture the inflation tax from clients who maintained positive cash balances on demand deposits.[13] The Cruzado Plan of 1986 put a break on this expansionary movement, since banks decided to rationalize their operations in view of the sudden drop of inflation. After the Plan, banks' management became more risk−averse, so that in spite of

the reacceleration of inflation, branch expansion has been taking place at a more moderate pace. New emphasis, however, is being put on portfolio control and quick response to shifting client needs.[14]

Industry−Generated Demand for Informatics Resources

The size and characteristics of the Brazilian banking system, along with the transaction environment in which it operates, have generated considerable demand for informatics resources. The introduction of data processing equipment in the 1960s coincides with the advent of financial conglomerates and the growth in concentration of financial activities.15 This movement led to the standardization of routines and activities, a precondition for the introduction of automation. It also increased banks' management control responsibilities with the incorporation of an enlarged branch base and additional services, thus making automation an operational requirement.16

At an early stage, the efforts to automate banking operations led to the introduction of centralized data processing units operating on a batch basis. As a result, data processing activities migrated away from individual branches to the centralized facilities. Typically, files were transferred manually from the branch to a regional or central office to be processed by a mainframe computer. The system's architecture, if not totally standardized, was nonetheless conventional, centered around a self−contained processing unit.

The system's topology was first modified during 1972−74 with decentralization of data entry functions. However, the most significant changes in the prevailing architecture were proposed from 1976 onward, with configurations comprising online branches and distributed data processing. Two concurrent factors promoted entry in equipment and systems for banking automation: the new informatics policy (set in mid−1976), which reserved the domestic market and reoriented demand in favor of national producers of data processing equipment, and the increasingly decentralized data handling by the banking system, relying less on mainframes and more on micro and mini computers. In 1980 domestic prototypes for on−line branches and other features of complex banking automation systems were introduced. Until 1986, when demand tapered off, banks were responsible for approximately 50 percent of the sales of computers, peripherals and related equipment of the domestic industry.

The informatics needs of the banking industry are quite diversified. They include, in addition to operational support systems (normally undertaken by centralized data processing units), those oriented to management information (based on microcomputer networks linked to minicomputers or mainframes); branch automation (to which data processing can be distributed or not); self service (for example, with the use of automatic teller machines and in−branch cash dispensers); electronic transfer of funds; credit and debit card payment; and audio response and other types of financial information and home banking.

In response to these needs, a number of systems were developed by domestic firms. The most sophisticated and functionally complete supply banking services, through a network of in− or out−branch intelligent terminals (including customer terminals), connected to a bank network or to a bank−serviced network. Data bases with client information are either centralized, stored, and processed in a host mainframe (controlling a certain number of bank branches) or distributed to each branch, and are resident in a mini or supermini, with interbranch connection made by a second small computer. The central element of this type of network is a set of programs to control data flow, being thus responsible for the interface between application software, data files, and branches.

Banking Automation and its Competitive Standing

As of 1988 there were six major and generally highly−competitive systems suppliers (Itautec, SID, Digirede, Edisa, Digilab, and Procomp) and four others of lesser importance (Table 13.8). Except for Procomp—a newcomer in the market in 1985 that was highly successful as a supplier of banking terminals—all other producers are associated with a financial group or conglomerate, which not only constitutes an important market for their products, but offers them access to group financial and other resources. In addition, several other firms are specialized in specific system components (such as modems, minicomputers, and peripherals).

According to industry sources, by mid−1988 system prices were 30 percent less expensive than internationally available products of comparable quality and performance. Users, while concurring with this assessment, note that individually, equipment prices are anywhere from two to four times higher.17 Moreover, whereas certain types of equipment are regarded as technologically equivalent to what is available in the international market (banking terminals, automated teller machines, (ATMs), cash dispensers, modems, and low−capacity printers), others are perceived as substantially outdated (microcomputers, supermicros, minis, superminis, serial printers, disk units, and

Table 13.8
Brazil: Banking Automation System Suppliers and Installed Base, 1987

	CPU/concentrator		*Banking/terminal*		*A TM*		*Cash dispenser*	
Firm	*Quantity*	*%*	*Quantity*	*%*	*Quantity*	*%*	*Quantity*	*%*
Cobra	−	−	680	0.6	0	0	0	0
Digilab	80	1.1	7,424	7.0	0	0	99	27.8
Digirede	1,804	24.3	25,864	24.4	0	0	0	0
Edisa	32	0.4	9,226	8.7	0	0	0	0
Itautec	2,820	38.0	24,300	22.9	310	36.0	100	28.1
Procomp	360	4.8	1,800	1.7	0	0	30	8.4
Racimec	0	0	795	0.7	0	0	0	0
Sid	2,325	31.3	36,058	33.9	523	60.7	127	35.7
Unsysis	0	0	0	0	29	3.4	0	0
Zanthus	6	0.1	181	0.2	0	0	0	0
Total	7,427	100.0	106,328	100.0	862	100.0	356	100.0

− Not available.

Source: Secretaria Especial de Informatica, *Parque de Equipamentos de Informatica,* August 1988, p. 43.

streamer tapes). Software quality is perceived to be good, with prices being competitive in applications (and undistinguishable in systems).

In spite of the high prices and, in many instances, of the poor performance of domestic equipment, the fact that Brazilian systems are already internationally competitive suggests that Brazilian system producers could penetrate the international market at much faster rates and become major players if they were able to source their components domestically or internationally.18 They should thus be allowed to specialize effectively in what they do best: the design of systems and their customization to specific client needs.

This does not imply that Brazil should not be building systems components, but that in building them, it should be more selective and export−focused. The Brazilian domestic market does have a critical role: it should be sufficiently large and fast growing to amortize set−up and other entry costs. Its scale, however, should not be counted on to finance the development of successive generations of equipment. Accordingly, Brazilian producers appear to be potentially competitive to equip online and mid− to low−volume agencies, particularly those with teller terminals, data concentrators, and modems.19 This seems to be equally the case with units for audio response (some of which have been sold recently to Portugal) and point−of−sales cash dispensers.20 Producers might now attempt to move aggressively with those products, individually or with system parts, to the international market.

Conversely, it might be worth shedding low−volume and limited−market components, an example of which would be ATMs. By mid−1988 there were three ATM networks in Brazil: Itau's, with 253 units; Bradesco's, with 296 (including one mobile unit); and Tecnologia Bancaria (a consortium of 25 banks and 3 credit card companies), with 137.21 However, market growth potential is limited, in no small reason due to the below−cost fee banks are allowed to charge per transaction (four cruzados as of August 1988, equivalent to less than two cents). The system is estimated to grow, at most, to twice the current size. This incremental demand of 630−650 ATMs over several years will be divided between at least five firms; the implied scales appear to be far from sufficient to price these units on a competitive basis and break into the international market.

Economies of Scope in Point−of−Sales Automation

The emphasis on *systemic specialization* to take advantage of low engineering costs in Brazil—they make up 30−35 percent of the total system cost—would also be justifiable for other engineering−intensive, customer−specific areas. Examples would be point−of−sales automation (for supermarkets and other high− and mid−volume retail outlets) and, to a lesser extent, industrial automation.

In many ways, the competitive potential of point−of−sales automation is even larger than banking automation. There are at least three reasons for this advantage. First, many systems are technologically related to those developed for the banking industry, and therefore, part of their development costs have already been amortized. Second, even more than in banking, each retail business system must be customized, since every solution is necessarily tailored to client−specific characteristics. Moreover, many of these are small solutions. As a result, engineering costs for retail and other point−of−sales automation systems—being up to 40 percent of total costs—are even more significant than in banking automation. Third, the domestic market is significant and has grown at a relatively high rate since 1984, having attracted in the period 1984−87 six new entrants (Table 13.9). The domestic market constitutes an important base for local system houses to acquire the necessary experience prior to entering the international market.

Thus, the competitive advantage of Brazilian point−of−sales systems, although introduced in the domestic market recently (1984), is already significant—their prices are approximately 30 percent lower than comparable systems available internationally. Also contributing to this price differential is the heavy weighting of point−of−sales systems in components—point−of−sales terminals, data concentrators, communication clusters, and software—that are among the most competitive equipment Brazil manufactures. It is suggestive of the competitive potential of Brazilian−designed systems that Itautec, one of the leading firms in point−of−sales automation, was able to bid successfully for installing its system in three supermarket chains in Portugal (Continente, Modelo, and Saco Cheio), competing, *inter alia,* with Nixdorf and Sweda.22

Although the same advantage in low engineering costs characterizes the area of industrial automation, one cannot infer that a competitive position as strong as point−of−sales or banking automation is achievable in the very short term. First, the technological similarities are not present; industrial automation systems are *sui generis* and somewhat unrelated to automation of banking, retail, and other services. In this sense, system firms and others have to start from scratch and fully amortize their development costs in the new product. Second, the Brazilian market is limited, not only in size, but also in the more fundamental sense that the Brazilian industry's automation culture is shallow. It has yet to form a critical mass of engineers, technicians, and other personnel who can either staff systems firms or closely interact with them. Third, there is a perception that the competitive potential of individual components (programmable logic devices for process controllers, CNC centers, CAD or compter−aided manufacturing (CAM) systems, and robots) is quite limited, although to differing degrees.

Table 13.9
Brazil: Installed Base of Point−of−Sales Terminals, 1984 and 1987

	1984		*1987*	
Firm	*Quantity*	*%*	*Quantity*	*%*
Dirirede	0	0	106	1.8
Itautec	0	0	700	12.0
Labo	0	0	140	2.4
Microservo	0	0	55	1.0
NCR	127	34.6	127	2.2
Racimec	60	16.3	1,640	28.0
Sedasa	100	27.2	1,106	18.9
Sid	0	0	115	1.9
Swedata	0	0	1,171	20.0
Zanthus	79	21.5	700	11.9
Total	367	100.0	5,860	100.0

Source: Secretaria Especial de Informatica, *op. cit.* p. 57.

Thus, even if systems integration in industrial automation often involves the provision of a customized, one−of−a−kind solution—being therefore *per force* engineering−intensive—it does not imply that just having an elastic supply of engineers and specialists is a sufficient condition for becoming competitive in the area. As suggested, a number of limiting factors prevent Brazilian firms from gaining comparative advantage, at least in the short term. Thus, even more than in the case of service−areas automation, the systemic specialization approach and a high degree of selectivity in the manufacture of system components should be pursued for industrial automation.

In sum, for all areas of automation, there should be less emphasis on manufacturing *per se* (except in cases where the potential to achieve international competitiveness is substantial and within a reasonable time frame—say, two to three years) and more on the development of system design capabilities. Fostering systemic specialization should be pursued first by redressing the asymmetry in incentives between manufacture and design; second, by promoting training in−house, at research institutions, and at universities, in critical areas of system design; and third, by promoting the export of embodied or disembodied system projects.

Color Televisions

Consumption Structure

Until the beginning of this decade, color televisions were the single most important product of the consumer electronics industry, in terms both of

growth dynamics and backward linkages with the components sector. More recently considerable enlargement of the home electronics consumption basket has occurred in developed countries, with the rapid diffusion of video cassette recorders (VCRs), laser discs, microcomputers, and other products. Progressively, color televisions are losing their status as the engine of growth of consumer electronics, as buyers diversify their expenditures towards

AVC (audio−video−computer) systems.

In Brazil, color televisions are still the major product of the consumer electronics segment. Once the color transmission system was defined in 1972 (the government opted for Telefunken's patented PAL−M, then regarded as the technically superior alternative) and Brazil's major television network started to transmit in color, color televisions were rapidly accepted by consumers. By 1980, domestic market sales amounted to over 1.2 million sets (Table 13.10). Between 1980 and 1987, the rate of growth of sales was 7.4 percent, above that of audio systems (5.0 percent) and in sharp contrast with black−and−white televisions and radios (both experienced negative growth rates during the period).

If color televisions have been the most dynamic item in the Brazilian consumer electronics industry, their exports have been marginal in terms of volume, value, and proportion of output (Table 13.11). In 1987 the industry exported slightly over 2 percent of its production, evidence of its overwhelming domestic market orientation. Exports of consumer electronics were significant for only car audio systems (radios, cassettes, and radio cassettes), and most of these were of intrafirm nature (for example, those from Philco to Ford Motor Co.) as part of a broader strategy of decentralizing production activities of these firms.

Configuration of the Industry

Nine firms currently produce color televisions in Brazil, supplying close to 100 percent of domestic requirements (Table 13.12). Although the level of output concentration is relatively high (the four−firm concentration ratio in 1988 was over 67 percent) and has been quite stable since 1980, the size distribution of output and market share dynamics, in particular, suggest that the degree of competition in the industry is significant. In fact, there is no clear market leader. Sharp's apparent leadership in 1986, for instance, was lost to Philips in 1988. Moreover, market shares have oscillated drastically for most producers—there was, for example, a rapid growth in shares (and subsequent decline) of Evadim and the progressive loss of shares by Telefunken and Sanyo. Finally, two entries took place in 1986 (CCE and Dismac), although only CCE consolidated its position due to relatively high sunk costs involved in setting up production facilities, distribution networks, and after−sales services.

The government's 1972 decision to implant in a relatively short term the PAL−M system forced the black−and−white television industry to embark in a major restructuring effort to launch a new and technologically far more complex product line. This involved establishing new technological links and setting up new (or relocated) plants in the

Table 13.10
Brazil: Main Consumer Electronics Products in Domestic Market Sales, 1980 and 1987
(thousands)

Product	*1980*	*1987*	*Growth* a
Color TVs	1,238	2,037	7.4
Black and white TVs	1,614	772	−10.0
VCRs	0	280	n.a.
Radios	5,190	4,200	−3.0
Auto radios	833	870	0.6
Audio systems	1,455	2,050	5.0

n.a. Not applicable.

a . Average annual growth rates 1980−87.

Source: GEICOM.

Table 13.11
Brazil: Consumer Electronics Exports, 1987

	Exports		*Exports/output* a (%)
Product	*Thousands*	*US$ millions*	
Color TVs	44	38.2 b	2.1
Color TV kits b	213	−	−
Black and white TV kits	7	−	−
Auto AM/FM radios	2,485	108.3	74.1
Auto radio cassettes	1,455	250.6	−
Auto casettes	3,200	−	−
Audio systems	66	4.1	3.1

− Not available.

a . Ratio of volumes.

b . Includes color TV.

Source: GEICOM.

Table 13.12
Brazil: Firm Size Distribution of the Color TV Industry, Selected Years (output levels)

	1980		*1983*		*1986*		*1988*	
Producer	*Thousands*	*%*	*Thousands*	*%*	*Thousands*	*%*	*Thousands*	*%*
CCE	0	0	0	0	2.8	1.3	85.0	4.2
Dismac	0	0	0	0	2.0	0.9	0	0
Evadim	76.2	5.2	209.8	17.3	266.0	12.0	158.0	7.7
Philco	286.8	19.5	151.8	12.5	343.0	15.5	255.0	12.5
Philips	186.8	12.7	158.2	13.1	370.0	16.7	438.0	21.4
Sanyo	135.9	9.3	100.0	8.3	130.0	5.9	75.0	3.7
Semp	174.1	11.9	105.4	8.7	233.0	10.5	202.0	9.9
Sharp	299.6	20.4	275.9	22.8	420.0	19.0	425.0	20.8

Springer National	117.3	8.0	101.2	8.4	250.0	11.3	253.0	12.4
Telefunken	190.2	13.0	105.7	8.7	174.0	7.9	150.0	7.4
Output of four largest firms		65.6		65.7		63.2		67.1

Source: GEICOM.

Manaus region (in the state of Amazonas). The concentration of the color television industry in the Manaus industrial park was determined by compelling fiscal incentives. These incentives include federal income tax and industrial value−added tax exemptions, state sales−tax credits, and access to a firm−specific quota of imported inputs at reduced or zero duty (until 1976 there was no limit on this quota—thereafter it was fixed on a yearly basis and rationed among producers). The net impact of these incentives has been translated into an estimated average unit cost advantage of 30 percent for those firms with color television assembly plants established in Manaus. No firm could thus afford to locate its plants anywhere else, and indeed, by the early 1980s, 100 percent of the industry was established in the Manaus industrial free zone.

Despite the substantial restructuring the industry underwent to produce color televisions, its domestic orientation led to plant sizes below MES. In fact, if plant−specific MESs are currently in the range of 400−600K units, 81 percent of color television output is under MES.23 Yet firm−specific MESs (particularly for R&D and marketing purposes) are in the range of 800−1.5 million. Thus, observed output levels seem to be far below what would be necessary to reap available firm−level and plant−level scale economies. Even the output of the largest producer (Sharp) would be anywhere between one−half and one−fourth of what would be minimally efficient to attain international competitiveness.

The scales practiced by domestic color television plants are explained fundamentally by the small size of the domestic market relative to a significant number of firms with sufficient technological, marketing, and financial staying power to survive intensive domestic competition. Thus, moving existing firms to international scales would require them to export a substantial proportion of their output, unless there was a major (and highly unlikely) change in the industry's configuration, with a drastic reduction in the number of producers to two or three. What, then, are the constraints on expanding color television exports?

Determinants of International Competitiveness

Many factors explain the inability of Brazilian producers to penetrate export markets. First, the process technology employed by color television producers is associated with low levels of automation. Even though color television assembly lines are generally more automated than other consumer electronics plants (with producers increasingly relying on automatic insertion and testing machines), post−assembly inspection, for example, remains a manual process.24 Generally, local producers regard themselves as being considerably behind Korean and Japanese firms. The basic reason is that small production scales do not lend themselves to high levels of automation.25

The gap between Brazilian and East Asian producers is likely to widen with the introduction of surface−mount technology (SMT).26 The use of SMT components necessarily requires programmable equipment with placement capabilities far larger than current automatic insertion machines (which range from 5,000 to 12,500 components per hour). In fact, no producer could economically invest in SMT equipment at current levels of production. If, on average, there are 400 components per color television unit, and the capability of a typical SMT printed circuit board (PCB) assembler is 4 million components per day, it would take at least 3 million color television sets to justify the acquisition of such machinery (on the assumption that ail components are produced in SMT, which is still not the case). Nonetheless, the increasing quality requirements and the changing functional characteristics of color televisions might not leave much choice for producers, who would need to incorporate SMT by either introducing SMT equipment (even if not fully using it) or importing SMT−based PCBs. However, producers would not likely be able to import SMT componentry for color televisions on a more cost−effective basis or with fewer strings attached (particularly export restrictions) than they have been able to import ICs and other semiconductor devices. To put this proposition in perspective, it is necessary to examine briefly the links between technology suppliers and local color television manufacturers.

All major color television producers (with the exception of Evadin) are either joint ventures with, or subsidiaries of, the dominant world suppliers of color television technology (Table 13.13). The asymmetric nature of these links has been reflected in what is possibly an excessive concentration of semiconductor purchases in the country of the technology supplier, relatively high IC prices, and contractual export restrictions on the use of proprietary (custom−made) ICs. Combined with lags in production technology, they have been the key obstacles to entrance into international markets.

Table 13.13
Brazil: Ownership Pattern and Origin of Technology of Color TV Producers, 1990

Producer	*Type of associations* a	*Origin of technology*
CCE	N	Samsung
Dismac	N	−
Evadin	N	Mitsubishi
Philco	N	Hitachi
Philips	F	Philips
Sanyo	JVF	Sanyo
Semp	JVN	Toshiba
Sharp	JVN	Sharp
Springer National	JVN	Matsushita
Telefunken	N	Telefunken a

− Not available.

a . Searching for new source of technology.

JVN Joint venture with national ownership

JVF Joint venture with foreign ownership

F Fully foreign

N Fully national

Source: Margarida A. C. Baptista, *A Industria Electronica de Consumo a Nivel Internacional e no Brasil,* master's thesis, Univ. de Estadual de Campinas, 1987; author's compilation.

A preliminary examination of semiconductor imports by country of origin reveals a strong (even though slightly declining) association with the nationality of the technology supplier (Table 13.14). In 1985, there were three instances in which 100 percent of semiconductor imports originated in the country where the technology supplier had its headquarters. In the majority of other cases, most (but not all) semiconductor imports fit this pattern. The only exception was Philips, explained by its more decentralized decision−making structure (in contrast with that of Japanese firms) and the ability to source U.S. purchases from North American Philips.

Not only semiconductor purchases seem to be biased toward particular countries, but there is also *prima facie* evidence that the unit prices that Brazilian firms paid for ICs are well above what has been paid by other countries (Table 13.15). Even allowing for the fact that Brazilian producers have

Table 13.14
Brazil: Semiconductor Imports by Selected Color TV Producers, 1983 and 1985

Producer	*Imported from*	*1983*	*1985 (Jan−Oct.)*
Evadin	Japan	100.0	100.0
Philco	Japan	96.0	81.3
	United States	3.4	15.3
	Germany	0.5	3.3
	Mexico	0.1	0
Philips	United States	92.9	16.8
	Holland	5.0	41.4
	Japan	1.3	26.9
	Germany		8.6
	Taiwan (China)	2.4	3.6
	Hong Kong	0.1	0
	Mexico	1.3	0
	France		2.7
	Italy	0.1	0
Sanyo	Japan	100.0	100.0
Semp	Japan	100.0	79.8
	United States		13.7
	Taiwan (China)		6.5
Sharp	Japan	100.0	100.0
Springer−National	Japan	98.8	78.7
	Singapore	1.2	21.3
Telefunken	Germany	89.6	85.8
	United States	5.2	14.2
	Japan	4.6	

Source: Margarida A. C. Baptista, *A Industria Electronica de Consumo a Nivel Internacional e no Brasil,* master's thesis, Univ. de Estadual de Campinas, 1987, Table V.6.

imported relatively small volumes of ICs (when compared with Southeast Asian countries, for example) and allowing for differences in IC specifications, there appears to be substantial overpricing by Japanese suppliers.

These distortions (excessive concentration of semiconductor purchases in the country where the technology supplier is established and where there are high IC unit prices) are particularly worrisome, since the relationships between suppliers of technology and local firms have deepened with the growing integration of color television's internal architecture. The experience of a typical Brazilian producer reflects the kind of technical change that color televisions have undergone in the last decade, first as semiconductor devices substituted for vacuum tubes, then as integrated circuits took the place of discrete components, and finally as the number of ICs proper were reduced as each undertook an increasing number of functions (Table 13.16).

Table 13.15
Japan: Volume and Unit Price of IC Exports, 1983

Importer	*Quantity (thousands)*	*Unit price (yen)*
Europe	141,389	365
Austria	4,891	238
Belgium	4,442	362
Denmark	690	522
France	5,273	476
Germany	76,003	349
Ireland	5,389	283
Italy	4,094	404
United Kingdom	29,268	413
North America	349,722	503
Canada	1,970	562
United States	334,661	510
Southeast Asia	670,634	157
Hong Kong	245,287	187
Korea	169,461	130
Singapore	101,097	137
Taiwan (China)	153,486	146
South America	13,694	589
Brazil	10,826	690

Total	1,196,221	289

Source: Japan Electronics Industry, *Japan Electronics Almanac* , Tokyo, Dempa Publishers, 1985, p. 244; reproduced from Margarida A. C. Baptista, *A Industria Electronica de Consumo a Nivel Internacional e no Brasil,* master's thesis, Univ. de Estadual de Campinas, 1987, Table V.9.

As the levels of integration grow, the importance of custom−made ICs for the functional characteristics of color televisions increases. In view of the proprietary nature of these critical custom−made ICs, the ability of local producers to penetrate export markets is diminished. Suppliers of technology are able to enforce export restrictions more effectively, as they become the exclusive source of components that determine the quality and overall product performance of color televisions.

Although Brazilian legislation forbids any kind of contractual arrangement that prevents local firms from exporting, such restrictions are de facto widespread in the industry. This is obviously difficult to document, but color television producers and officials from ABINEE (the electronics industry association) attribute the extremely low levels of exports mostly to tacit or explicit contractual restrictions. This does not imply that such arrangements are the sole factor constraining color television exports. As already suggested, low levels of automation and high component prices (not only of imports, but also of components locally produced) also explain why ex factory prices of Brazilian color televisions are an estimated 10−15 percent above international prices.27

Table 13.16
Evolution of Color TV Component Requirements, Brazilian Color TV Manufacturers, 1975−85
(index, 1975 − 100)

	Old model (last year produced)		*New models (1985)*	
Component	*1975*	*1983*	*A*	*B*
Vacuum tubes	100	n.a.	n.a.	n.a.
Transistors	100	73	54	35
ICs	100	900	500	400
Diodes	100	148	137	152
Capacitors	100	81	83	72
Resistors	100	85	70	46
Others	100	73	77	63
Total	100	84	76	60

n.a. Not applicable (product no longer produced).

Source: Margarida A. C. Baptista, *A Industria Electronica de Consumo a Nivel Internacional e no Brasil,* master's thesis, Univ. de Estadual de Campinas, 1987, Table V.5.

Such price differentials could be erased with ex−port−oriented investments that would substantially enlarge scales and increase the degree of automation. These investments are not taking place insofar as they are not part of a broader strategy of technology suppliers to diversify their export production bases and create capacity in Brazil (though export−oriented capacity is being established in more attractive sites, such as Mexico, to penetrate the U.S. market, and Portugal, to cater to the European Community (EC)). The ability of these suppliers to enforce such a strategy rests on the very unequal bargaining relationship that they have with local producers, backed ultimately by their monopolistic hold on the supply of custom−made ICs, the key set of color television components.

A Strategic Focus for National Firms

To become international players, Brazilian color television producers need to gain scales by investing in export−oriented facilities. Yet such investment is predicated on continuous access to new or improved designs and the componentry that embodies them. The basic obstacle facing local producers is the absence of local IC design houses with the capabilities to integrate an increasing number of color television functions into custom−made circuits. In Brazil such capabilities would need to be fostered by cooperative ventures between national producers and circuit design firms.

The acquisition of ASIC design capabilities in color televisions would require considerable technological efforts by design houses and managerial focus on the part of color television producers. In this sense, this effort is not consistent with extremely diversified production lines and the accompanying dispersion of development resources across products, which generally characterizes the product strategy of most color television firms. Except for Sanyo and Semp, all producers offer (or are developing) complete image and audio product lines, and many are considering ways of broadening their product range to include information systems. Thus, as demand shifts toward AVC systems, firms are responding by moving across product boundaries, even though it causes a greater fragmentation of their technological efforts (which is only partly offset by the presence of economies of scope in the development of AVC system components).

A sharper focus on developing color televisions should not preclude a marketing strategy offering consumers a broad and integrated product range. In fact, such a strategy might be a necessary condition for firms to enhance their ability to finance their development needs without resorting to debt or government subsidies. The key would be for firms to restructure their production operations so as to retain their core product (in this case color televisions) while purchasing on an original equipment manufacturer (OEM) basis all those system components that lack strong technological economies of scope with the core. Only through this process of horizontal disintegration would color television producers become internationally competitive.

Telecommunications Equipment: The Tropico Public Telephone Exchange System

Telecommunications Equipment Industry

Brazil boasts a well−developed telecommunications industry, a product, to a large extent, of TELEBRAS (the state telecommunications holding company) and government efforts to develop domestic production and technological capabilities in this key segment of the electronics sector.[28] By early 1987, 117 firms supplied over 90 percent of the diversified needs of TELEBRAS, such as for telephone and telex exchanges, multiplexes, HF/VHF/UHF radios, telexes, facsimile and telephone instruments, key systems, telephone wire and transmission cables, and modems (Table 13.17). Domestic value added in the production of such equipment ranged from 60−70 percent for electronic exchanges to nearly 100 percent for telephone instruments, VHF radios, and multiplex pulse code modulation (PCM).

The value of telecommunications equipment output has grown at a high rate in the current decade (over 9 percent on an yearly basis), with demand from the public and private sectors expanding at nearly an equal pace (Table

13.18). The industry is still characterized by excess capacity in most product lines (Table 13.17), and average capacity utilization in 1987 was less than 60 percent (on the assumption that the industry's potential product was $2 billion in that year). Capacity underutilization can be explained basically by the scarcity of imported inputs and the slowdown in the extremely high rates of growth in public investment, which peaked in the late 1970s.

Excess capacity is also explained by the inability of firms to penetrate export markets on a sustained basis. In the past, Brazilian firms have been able to bid successfully in a number of instances to supply equipment to other developing countries (mostly in Latin America).29 Yet net trade is negative and

Table 13.17
Brazil: Telecommunications Equipment Industry, Production Capacity and Output in Physican Units in 1980 and 1986

				Output	
Equipment	*Number of producers*	*Installed capacity*	*Unit*	*1980*	*1986*
Public exchanges	7	1,137,950	Terminal	505,100	782,033
Private exchanges	8	273,176	Terminal	197,800	203,299
Multiplex FDM	6	66,640	End channel	26,400	32,831
Multiplex PCM	4	92,660	End channel	29,300	55,562
Multiplex telegraphy	1	13,800	End channel	4,312	21,528
Telex centers	1	10,000	Terminal	0	7,232
Radio SHF − high capacity	4	1,180	Transceiver	353	266
Radio UHF − multichannel	5	3,320	Transceiver	590	2,839
Radio VHF/UHF monochrome, duplex	2	10,500	Transceiver	2,373	8,230
Radio HF/VHF/UHF − fixed, portable, and mobile use	24	64,324	Transceiver	21,920	28,876
Monochrome, multichannel carriers	2	41,400	Circuit	22,976	7,700
Telex and fax terminals	5	18,073	Terminal	11,720	6,605
Telephone instruments	7	1,900,000	Instrument	1,388,940	1,100,691
Public telephones	2	42,000	Instrument	14,620	55,411
Key systems	7	316,220	Instrument	157,400	153,332
Telephone wire, cables	17	32,800	Ton	10,000	15,500
Voice amplifiers, line extenders	4	68,000	Instrument	43,050	10,531
Modems	11	100,000	Instrument	0	44,962

Source: GEICOM.

in the range of \$60−\$70 million. Moreover, the competitive ability of local producers appears to have diminished since the beginning of this decade. Export−output ratios, after increasing from 3.6 percent in 1977 to 5.0 percent in 1980, have declined to the range of 2 percent to 3 percent. Such adverse evolution is consistent with observed indicators of revealed comparative advantage for this industrial segment, which improved significantly between 1970 and 1980, and declined slightly since then (Table 13.2).

At the beginning of this decade, prices of major telecommunications products were in fact comparable (after deducting taxes and duties) with those prevailing in international markets. Yet stiff competition among international suppliers has brought down international prices significantly since the mid−1980s (electronic exchanges, for example, currently range from \$120 to \$180 per line, although in 1983 they were approximately \$300). In a few cases (such as with microwave radios), price differences have been quite substantial all along and in favor of foreign equipment. In contrast, Brazil has maintained its competitive position in products such as multiplex PCMs and public telephone instruments (Table 13.19). Product quality is in most instances reportedly the same as that of equipment produced in developed countries. Generally, however, telecommunications equipment producers have faced difficulties in improving their competitive standing in the 1980s, in view of accelerated technical change and intense price rivalry in international markets. Domestically, the industry remains excessively fragmented, diversified, and protected from competition.

Table 13.18
Brazil: Telecommunications Equipment Industry, Value of Output, Selected Years

	US\$ millions			*Growth* a *(%)*
Sector	*1980*	*1983*	*1987*	
Public sector	484.1	513.8	927.9	9.7
Private sector	136.7	100.4	240.2	8.4
Total	620.8	614.2	1,168.1	9.3

a . Average annual growth rates 1980−87.

Source: GEICOM.

The Research and Development Center (CPqD) of TELEBRAS

TELEBRAS research activities were initiated in 1973 as a set of sponsored applied research projects contracted out to universities, with a few cases of product development directed to industry.30 These projects reflected the strategic goal of TELEBRAS of ensuring that Brazil would take advantage of

Table 13.19
Brazil: Telecommunications Equipment Industry, International Price Comparisons, 1986

Equipment	*Unit*	*Average unit price*	*International unit price*
Electromechanical exchanges	Equivalent line	280	n.a.
Electronic exchanges	Equivalent line	400−−450	120−180

Multiplex PCM	Channel end	200	360
Microwave radio − analog	Transceiver	40,000	22,000
Microwave radio − digital	Transceiver	60,000	22,000
Radio UHF	Transceiver	6,000	5,000
Radio VHF	Transceiver	900	1,200
Electronic teleprinter	Terminal	4,000	3,000
Telephone instrument	Instrument	32	30
Public telephone	Instrument	450	600

n.a. Not applicable (no longer sold on the international market).

Source: Ministry of Telecommunications.

the major breakthroughs in telecommunications technology of the late 1960s and early 1970s (such as digital PCM systems replacing analog devices, time division multiplexing systems superseding frequency division multiplexers, and stored program controlled (SPC) exchanges making electromechanical equipment obsolete) and leapfrog conventional technology, in which local firms had up to then made only marginal investments.

In 1976 CPqD was formally established as the research unit of TELEBRAS; in 1980 it became an integrated R&D facility, the largest and most sophisticated applications laboratory in Latin America. In 1988 the center had a staff of 400 professionals directly engaged in R&D work, in addition to personnel from industry and universities working on a sponsored research basis, either at the center's premises (in Campinas, São Paulo) or in their own institutions, depending on the task commissioned. CPqD's 1988 budget was on the order of $60 million (including $1.2 million earned from royalties) and is allocated to a broad research agenda, consisting of approximately 80 R&D projects, most of which ultimately aim at helping establish an integrated services digital network (ISDN) in Brazil.31

CPqD has been fairly successful in transferring many of the products it has developed to industrial firms for large−scale production. By the end of 1987, 75 different products developed singly by CPqD or in association with universities (which were in charge of carrying out most applied research) and industrial firms (generally focused on the later stages of development, such as prototyping) were being manufactured by 25 producers. A special program in product technology has aimed at transferring technology developed at the center, through the provision of a wide array of elements needed to make the transfer effective (including electromechanical packing, the thermodynamics project, printed circuit boards, components qualification, materials, process norms and parameters, and necessary documentation).32

Yet the key to successful technology transfer has been the practice of shifting teams of engineers and technicians from CPqD to the premises of industrial firms. These buffer groups are the *de facto* carriers of industrial knowledge that no amount of formal documentation could replace. The relative success of CPqD with marketable products that in the case of many other research institutions would have remained on the shelf is explained by its emphasis on transferring technological capabilities though these buffer teams.33

CPqD's accomplishments have not been small, including its managers' ability to assemble a task−oriented team of professionals in−house and in sponsored institutions, with a focus on applications. CPqD's role was crucial in improving the technological capabilities of telecommunications equipment producers (thus complementing TELEBRAS's provision of a stable market for their products through consistent procurement policies). Nonetheless, CPqD's product development efforts have suffered from the excessively broad scope of its research activities. In this sense, it mirrors the lack of specialization and product focus that characterizes the production of telecommunications equipment (and, more generally, of electronics products) in Brazil.

The Center's original priority was in the field of switching. This reflected CPqD's mandate of tackling more complex technologies, involving products with higher technical and development risk and with potentially larger markets. Yet, the perception that the country faced major technological

gaps for most telecommunications equipment and the unwillingness to adopt a sequential strategy for closing these gaps led CPqD's management to adopt a much less focused research agenda.34 A budget that varied from $30 million at the beginning of this decade to the current $60 million thus had to be allocated to an array of 80 research projects within 7 priority areas:

Electronics switching—the *Tropico family* of digital public switching exchanges.

Digital transmission, including digital multiplexers for telephone, data and text, and transmission equipment as digital radios, processors and codifiers.

Optical communications, such as optoelectronics devices, lasers, photodetectors, optical fibers, optical cables, application systems, and equipments.

Data and text communications, including development of concentrators, computer networks, supervision and control systems, testers, analyzers, and equipment for end users.

Satellite communications equipment, such as parabolic antennas, power transmitters, low noise amplifiers, and other elements for earth−to−satellite communications.

Outside plant materials, tools, and equipment, including optical cables splicing and quality testing, corrosion, electric protection, new alloys, and resins.

Components and materials, such as thick film and thin film hybrid circuits, custom−made ICs for decadic push−button telephone and other applications.

An absence of research focus and specialization has led to systematic delays in the CPqD research chronogram and, therefore, to delays in the market launching of its applications. Even when adjusted for skilled labor cost differences, a budget of $60 million is minute within the scope of CPqD's research agenda. Budgetary allocation would average less than $8 million per program or $1 million per project, whereas each program would in itself justify the whole budget. The experience of the development of the Tropico family of digital exchanges, possibly CPqD's most ambitious program, points to the costs of engaging in a major research undertaking within an institution that has scattered objectives and very limited resources.

The Tropico Program

Research on the Tropico family of digital SPC public telephone switching exchanges started in the mid−1970s.35 The Tropico family comprises a total of five products—two in production, one with start−up planned for 1989, and two others with no firm production dates yet:

Tropico C—a subscriber line concentrator for up to 192 lines, under production since September 1983.

Tropico R—small local−tandem exchange for up to 4,000 lines, field−tested in December 1984 and transferred to industrial firms soon thereafter. It has been in production since 1986.

Tropico RA—medium−size local−tandem exchanges for up to 20,000 lines, under development and scheduled to be delivered by the end of 1989.

Tropico L—large local−tandem exchange for up to 80,000 lines. It is still in the planning stage.

Tropico T—large toll exchange for up to 50,000 trunks, also at the planning stage.

The market for public exchanges in Brazil has averaged 540,000 lines annually between 1980 and 1986 (approximately $162 million yearly at $300 per line). In 1987 it jumped to 900,000 lines. TELEBRAS's long−term objective is to expand Brazil's installed base from 7.8 million lines (at the beginning of 1988) to 25 million terminals by the year 2000, of which 67 percent would be based on digital technology. The basic policy for production and procurement of telephone exchanges was initially set in the mid−1970s. An agreement was reached with large foreign firms that assigned them a slice of the Brazilian market of public telephone exchanges if they were to undertake the local manufacture of large−scale switching equipment. Thus, switching equipment for major cities was reserved for LM Ericsson (São Paulo), NEC (Rio de Janeiro), and Siemens (Curitiba). In the rest of the country, which accounted for 30 percent of the market, there was a measure of open competition. The basic price for the reserved market was established in 1975, with price escalations agreed thereafter.

The production of digital equipment at that time (1975) was reserved for products based on Brazilian technology, on the presumption that CPqD's Tropico design would be transferred to industry by the end of the decade. However, as the research and industrialization of the Tropico system was not forthcoming according to the initial chronogram, in May 1984 the Ministry of Telecommunications relaxed its restrictions. It allowed the introduction of large (over 10,000 lines) and medium−sized (4,000−10,000 lines) public exchanges based on foreign digital technology to be produced and installed in Brazil by three firms: LM Ericsson, NEC, and Siemens (later Equitel). The three were

to have Brazilian−owned majority voting shares (51 percent of the one−third voting shares). The small exchange market continued to be reserved for wholly−owned Brazilian firms using the Tropico technology.

The current policy dates back to 1985 and is a variation of the 1984 directive. It continues to assign the small digital exchange market to Tropico R equipment and allows the market for large public exchanges to be supplied by equipment based on foreign technology. Yet it guarantees 50 percent of the mid−sized market to Tropico RA (as soon as it becomes industrially available). Tropico R exchanges started to be delivered in 1986 (some 80,000 lines), and production was significantly expanded in 1987 (to 120,000 lines). Tropico R is currently produced by Elebra and PHT, whereas SESA and SID Teleinformatica have been licensed to start production. In addition, three other groups—Multitel, ABC, and Sul America—have displayed an interest in entering the small digital exchange market.

Starting in 1989, Tropico RA (which in its first stage will have 4,000−10,000 terminals, to be extended to 16,000 terminals at a second stage, and later to 20,000 terminals) will be produced by Elebra, PHT, and SID Teleinformatica. TELEBRAS has undertaken to contract with Elebra and PHT for 60,000 lines on a yearly basis over a five−year period upon their commitment to codevelop with CPqD the RA system, picking up 25 percent of development costs. The trend, however, is for producers of Tropico R to be licensed eventually to produce the RA equipment because of the significant economies of scope involved in the production of Tropico R. By 1990, five to six producers are expected to be sharing an estimated annual demand of 200,000−250,000 lines per year for Tropico's small and medium−sized terminals.

The procurement policies of TELEBRAS (and its operating subsidiaries) and CPqD's long−term technology development efforts have allowed Brazilian firms to acquire significant production and technological capabilities in the area of digital switching technology. Whether these articulated efforts have been worthwhile is a fairly complex question to answer. Substantial costs have been associated with it, both direct resource expenditures (in product development and setting up production facilities) and indirect costs associated with the delay of introducing digital technology in the Brazilian telephone network.

Informed estimates of Tropico's total development costs range from $85 million ($55 million direct and $30 million indirect costs) to $200 million (of which $100 million would be direct costs and the other $100 million indirect), not insignificant amounts by developing country standards. To these costs should be added the continued obsolescence of a segment of the Brazilian public exchange system, which failed to be digitalized while TELEBRAS waited for the Tropico design to become operational. During five years (approximately 1980−85), TELEBRAS was directed to buy large volumes of electromechanical exchanges (crossbar and crosspoint) in spite of the availability of a clearly superior alternative in the form of foreign digital technology. Possibly the major implication of this considerable delay is that it makes more distant the goal of an integrated services digital network.

Such indirect costs of the Tropico program might have been smaller were CPqD's research program more focused on electronic switching development—as was the original intent of the institution—and if its chronogram and targets were more realistic. To put Tropico's development expenditures in perspective, suffice it to say that even if CPqD's entire budget were allocated to the Tropico program, it would have taken 3040 years to match the expenditures that major digital exchange producers incurred to bring successful systems to market. Moreover, the relatively small volume of resources ($10−$20 million per year over 10 years) allocated for Tropico's development did not allow for the exploitation of significant economies of scale in R&D activities.

Finally, unit costs for the Tropico equipment are high by international standards. By early 1988, 200,000 Tropico R (and C) lines were delivered, 250,000 more contracted and an additional 350,000 expected to be procured by 1991, totaling 800,000 lines. Development cost estimates per line range from $105 to $250, whereas domestic price is $400−$450 (including royalties of 3 percent paid to CpQD). Considering that royalties are just $12−$13 per line, the total cost of the Tropico exchange for TELEBRAS (development costs net of royalties plus price paid to manufacturer) would be in the range of $493 to $587 per line, which compares unfavorably with international digital switching prices of $120 to $180 per line (mid−1988).

These high unit costs cannot be imputed directly to the expenditures related to the acquisition digital switching technology (insofar as royalties are just over $10 per line). They cannot be separated, however, from the Tropico's program. To the extent that unit costs are driven up by the small scales practiced by Tropico's producers and a weakly competitive environment, Tropico's prices

are partly an unintended outcome of TELEBRAS attempts to attract new producers to manufacture the Brazilian design. It further crowded a market where no more than two to three producers would be justified and where all producers, except for Ericsson, are well below minimum efficient scales. Entrants' production volumes have in fact been well below 100,000 lines per year, whereas international scales are on the order of 500,000 lines per year. At the same time, TELEBRAS' policy of reserving certain market slices for individual producers and assuring them minimum demand has decreased some of the potential benefits of a more crowded and competitive market. In many ways, each producer can behave as a (regulated) monopoly, even though it is not alone in the market.

Nevertheless, a number of apparent benefits need to be taken into account when evaluating the Tropico program. The first relates to the nature of the product itself. Tropico R is argued to be a highly reliable, multifault−tolerant system, especially adapted to Brazilian environmental conditions.36 Tropico R is also fairly simple to operate, built around three types of modules and only 25 types of printed circuit boards required to handle all its operational capabilities.

Similarly, Tropico RA holds only 50 different types of PCBs, many of them the same as for Tropico R. In contrast, Ericsson's AXE requires 65 types of boards just for the central processor, in addition to other PCBs specific to its terminal, operation, and maintenance functions. The relatively small diversity of Tropico's boards also plays an important role in simplifying production engineering requirements. Finally, Tropico's standardized, compact, and modular structure, with a completely decentralized and distributed control architecture, is supposed to reduce sharply the volume of spare parts in inventory and allow for flexible growth and ease of maintenance.

A more compelling view in favor of Tropico's development is that its R&D outlays act as entry costs that industrializing countries like Brazil have to incur if they want to enter an exclusive club (to which only three other developing countries—the People's Republic of China (PRC), India, and Korea—have had what amounts to a still incipient access). The country would be paying for the acquisition of a critical technology that is not available off the shelf. According to this argument, training highly−skilled teams of specialists and accumulating design and manufacturing capabilities ina critical area of digital technology would bring large positive externalities in the form of product and firm spinoffs, and would accelerate technological maturity.

The significant learning that has taken place as an outcome of the development of Tropico C and R, for example, has already allowed for a shorter development time for the next member of the family, the Tropico RA. This has been brought from design to manufacturing in 36 months at a fraction of the development cost of Tropico R ($20 million). Beyond that, however, the externalities associated with Tropico's development, although real, are hard to document and compare against the costs that Brazil has incurred in developing the Tropico family.

It should be stressed, nonetheless, that the industrial and technological strategy pursued for the telecommunications equipment sector needs to undergo significant adjustment if it is to improve its competitive standing. First, the sector would benefit from a more competitive environment stimulated by a policy regime that would not deter but promote competition among local producers (by phasing out market reservation and other anticompetitive arrangements). At the same time, producers should be induced to become more involved in the international market both as exporters and import competing manufacturers.

Second, as with the rest of the electronics industry, development and production activities should be far more specialized and selective, allowing more resources to be channeled toward products and technologies in which Brazil is competitive or highly likely soon to become (as for certain transmission equipment—PCMs with 30, 120, and 480 channels, telegraphic multiplexes, and public telephones) and shedding others that do not offer such prospects. In uncompetitive areas, Brazil would rely on imported equipment.

The sector would thus benefit from a more balanced mix of technology acquisition, adaptation, and local development. Only a limited amount of R&D can be efficiently carried out with $70−$80 million (estimate of total 1988 R&D expenditures in the sector, including CPqD's outlay of $60 million). Although these are the largest industry−specific R&D expenditures in Latin America (with the possible exception of the chemical−petrochemical complex in Brazil), they are a small fraction of the individual R&D outlays of large international equipment producers. In the highly dynamic environment of the electronics industry, these foreign firms are responsible for pushing out the technology frontier, usually by taking up small segments of the frontier at a time.

CPqD (and Brazilian firms) should have a similar approach to innovation and adaptation, with development activities even more niche−oriented in view of very limited resources. In engineering−intensive areas, where product customization is key to competitiveness, designs could possibly be locally developed, taking advantage of low engineering costs. For other products, designs might have to be imported and adapted to local conditions.

Concluding Remarks

This chapter has argued the importance of specialization for Brazilian electronics firms. It would allow them to concentrate their relatively limited technological, marketing, and financial resources on a smaller set of products.

Selectivity in the choice of what to produce and what production activities to undertake becomes particularly critical for technical change. Unless Brazilian producers are able to concentrate technical staff (and other resources) on a few promising areas, technological capabilities will remain limited to pursuing outdated development targets. Moreover, by specializing along their lines of competitive advantage and shedding others, firms would be expanding output within an increasingly focused product range. This would enable them to reap previously unexploited economies of scale. Thus, a larger volume of resources would become available for design and development, production planning and organization, quality control, and other activities critical to the competitive standing of producers.

The key issue is how to establish a structure of incentives to stimulate firms to improve their competitive standing domestically and internationally. The basic presumption is that what is currently constraining the electronics sector is a policy regime that led to excess diversification and fragmentation. Reforming this regime would be in many ways a precondition for development of the sector.

An improved structure of incentives would help firms make better use of Brazil's pool of inexpensive engineering labor and take advantage of the country's relatively large domestic market. The chapter stresses engineering labor cost differentials as a basis for specialization, although cost ratios are expressed without adjusting for differences in quality or levels of experience. The qualifications for a senior engineer (say, with 10 years of experience) in an advanced industrial country and in Brazil may be quite different. Generally, however, firms regarded the cost and the quality, versatility, adaptability, and trainability of Brazilian engineers to be a major competitive asset. Moreover, once technical labor had access to complementary factors (such as updated work stations and software), productivity differentials appeared to be substantially lower.

The domestic market is the other basic endowment that would guide resource allocation and specialization in the electronics industry. The Brazilian market, like that of other industrializing countries, is not large enough to be the sole or even the main outlet for products with large development costs, massive scale requirements, or high price elasticity (sensitivity), and that furthermore are generally regarded as commodities. Yet the experience of the segments reviewed in this chapter also emphasizes that even though an export−oriented strategy seems to be necessary to sustain product development over the longer term, the role of the domestic market is multifaceted and should not be understated.

First, the domestic market is a naturally protected space, functioning as a learning environment for technical labor. Much of this learning is derived from user−producer interaction, for which physical proximity is generally a critical variable. In addition, the domestic market is also a natural breeding ground for new firms. At early stages of product launch and often beyond, entrants often need to accumulate production and marketing experience before identifying niches and penetrating export markets.37

Second, many activities in electronics are spawned and sustained by the domestic market, for which exports are incidental. The experience of Brazil, as well as of smaller industrializing countries, points to a number of product areas, mainly in professional electronics, and office, banking, and point−of−sales automation, where domestic firms have been able to become competitive. In most cases, these are design and engineering−intensive products, with quality and performance characteristics depending to an unusual degree on user−producer interaction. Sometimes the product is a system made up of individual pieces of equipment, which are mere commodities themselves. High value is added in configuring and integrating the system so as to satisfy specific customer needs, thereby offering a unique solution to the customer problems (Banking Automation section).

Other times the product is a discrete piece of equipment (such as a printed circuit board, procured domestically or imported) modified and adapted to local conditions and needs by engineers and other technical labor. There are also examples of innovative, locally−produced, customized products (such as in−circuit testers, analyzers, special types of telecommunications equipment) for which a domestic niche market has been identified and export orders eventually secured. In sum a multiplicity of entry points exists for electronics firms in Brazil and other newly industrialized countries

without relying necessarily on the external market for growth and sustainability. In most cases, however, successful entry is predicated on the availability of minimum domestic endowments, in the form of engineering and other technical labor; a set of informed and demanding users (and, more generally, a user culture—see discussion on industrial automation at the end of the section, Banking Automation); and a strategy of avoiding dispersion of resources among an excessive number of competing activities.

The case studies indeed illustrate over a broad spectrum of industrial segments the recurrent costs of failing to specialize and the potential gains, both direct and roundabout, of greater focus of activities. They also make the point that policies focusing on the acquisition of technological capabilities should take into account the diversity of economically useful knowledge associated with developing, manufacturing, and using individual products or systems of products (Table 13.20). A broader and more balanced approach might substitute for the excessive (and sometimes exclusive) focus on product development and manufacturing (represented by cells I, II, and V).

In particular, mastering systems development and application technologies (cells III and VI), for example, should not be conditional on the acquisition of design or manufacturing capabilities for any of the system's components. The economic significance of the former often dominates the latter. This seems to be one of the main lessons drawn from the discussion of financial and retail automation (the section, Banking Automation). Yet it also appears to be equally applicable to the Brazilian experience with the Tropico design (the section, Telecommunications Equipment: The Tropicos Public Telephone Exchange System). The design, operation, and maintenance of a digitalized telephone network became (for close to five years) contingent on CPqD's success in developing an individual product family. In view of CPqD's inability to establish clear development priorities and muster the necessary resources, this ultimately proved to be a risky and costly strategy for the country to pursue.

The case studies also suggest that even though a movement toward increased specialization would bring strong economic benefits, specialization *per se* should not be regarded as the *deus ex machina* for industrial competitiveness. New organizational forms leading to interfirm cooperation, for example, might be important in enhancing the competitive position of individual segments. In only some cases would these new forms lead to increased functional specialization. Thus, in microelectronics, cooperative foundry arrangements among IC producers seem essential to the viability of the industry in Brazil (the section, Microelectronics). At the same time, temporary government support for joint mask preparation might be warranted in view of the strong externalities of having them made domestically. In color televisions, cooperative agreements and even alliances may be needed between national producers and circuit design houses if they are to break into export markets. It would be a major step to move beyond a traditionally subordinate position with respect to technology suppliers, which has led to high component prices and (tacit) contractual restrictions on external sales (the section, Color Televisions).

New corporate forms also may be required in response to demand shifts or technological opportunities. Conglomeration of consumer electronics firms may be inevitable in light of the trend toward home entertainment systems. Yet offering a broader range of products does not mean enlarging the firm's manufacturing base, but rather improving its ability to access system components on an OEM basis, for example, while concentrating its production efforts on core products. Conglomerate forms would be taking shape downstream, in areas of marketing and servicing. The presence of significant technological economies of scope, however, would be a strong argument for widening the production core (as in the case of point−of−sales au−

Table 13.20
The Technology Opportunity Matrix

Function	*Product*	*Manufacturing process*	*Systems/networks*
Development	I. Individual product	II. Plant/equipment	III. Whole systems (architecture and software)
Application	IV. Operation and maintenance	V. Production engineering, planning, and organization	VI. Network operation and maintenance

Source: Based on discussions at GEICOM.

tomation), even within a strategy of downstream conglomeration with specialization.

Finally, a movement toward specialization and increased penetration of export markets would also be predicated on well−focused training programs (such as in areas of system and component design). In view of strong externalities associated with training activities, they should be supported by the Government of Brazil and should be approached as a joint undertaking between industry and education and research institutions.

Notes

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2. This is the converse of the classical proposition that vertical disintegration accompanies an enlargement of the market and increased production scales. See J. Stigler, "The Division of Labor Is Limited by the Extent of the Market," *Journal of Political Economy*, June 1951.

3. In one example, a major producer of computer sys−terns was manufacturing its own floppy disk drives because of its poor experience with suppliers. Two engineers were reassigned from the firm's major product line to do development work in this area.

4. The index of RCA for a good (or a subsector) is defined as (Xi/X)/(Xiw/Xw), where Xi is the country's exports of good i, X is the total country's exports, Xiw is the world exports of good i, and Xw is total world exports. RCA indices are quite sensitive to the competitive position of individual subsectors in the national economy, and the changes in the index are indicative of shifts with respect to the world price−performance frontier.

5. A growing lag has been observed, for example, in color televisions. Domestic products have converged to 20−inch tube technologies, whereas internationally the trend is toward larger tube sizes and higher levels of resolution (as well as an increasing degree of integration in audio, video, and computer capabilities). On the other hand, the ratio of international to domestic prices has grown from 1.3−to−1 to 2−to−1. In computer peripherals, dot matrix printers' international−domestic price differentials were in the range of 3−to−1 at their early stage of production in Brazil (and have remained so since), whereas for laser printers, this lag has grown to 5−to−1. In telecommunications equipment, a combination of overdesign (products taking five to eight years from conception to market launch) and obsolete componentry is increasingly making products and systems obsolete before they are commercially exploited. The yet−to−be−marketed Tropico RA, for instance, is taking considerable time to be developed and is not being projected in surface−mount technology or making full use of microelectronics componentry.

6. Integrated circuit design capabilities are proving to be of increasing importance for color televisions as ICs concentrate a growing array of new functions and those traditionally undertaken by discrete componentry.

7. More recent figures show that the share of ASICs in the digital IC market grew from 23 percent in 1982 to 39 percent in 1988; it is expected to reach 58 percent in 1993. Among ASICs, the highest growth rates are projected for custom ICs (20 percent per year between 1987 and 1993, versus 16 percent per year for semicustom ICs). See Integrated Circuit Engineers (ICE), "Status 1989—A Report on the Integrated Circuit Industry," mimeo, 1989.

8. Possibly the most successful design house is Vertice, which is now associated with SID (the informatics division of Sharp, a major Brazilian electronics group). In two years it has projected 28 ICs, five of which have been exported directly (as a project) and three embodied in other products. Vertice is small flexible, and cost efficient, while its links to the group SID/Sharp provide substantial internal demand for its projects (the group purchased $26 million annually during 1988−89 in microelectronics products, a growing proportion of which are application−specific ICs). Vertice's exports are based on extremely low engineering costs and occasional excess project capacity, the latter allowing Vertice to enter new markets at marginal costs. Vertice's and occasional experience is indicative of the potential for successful ASIC design in Brazil.

9. "Although involving a high degree of technical expertise, designing ASICs may be seen as an activity external to the semiconductor industry proper. This activity requires intensive use of sophisticated CAD tools and other kinds of complex software which perform computer simulation of the functional and physical characteristics and behavior of the component under design. Since the physical characteristics depend, to a great extent, on the process by which the component will be manufactured, the technical parameters of this process must be modeled into the simulation software. However, once this software is available, design can take place as an activity entirely independent from production . . . . From an industrial standpoint, design capability does not imply, nor is it directly linked with, the capacity to manufacture the components." See David Rosenthal, "Microelectronics and Industrial Policies in Developing Countries: the Case of the Semiconductor Industry in Brazil," University College, London, July 1987 (Ph.D. thesis).

10. Itaucom has an agreement with AMI to access their libraries of gate array and standard cell IC projects. On the basis of Itaucom's project tape, AMI prepares the mask and fabricates the wafer, which is then returned to Itaucom for encapsulation and testing.

11. The advantages of having mask preparation and physical−chemical processing done domestically include the greater control that local designers would have over

the production process, and an expected reduction in manufacturing time. Foreign foundries currently take two to three months to prepare masks and six months for physical−chemical processing. Such extended periods are the norm for smaller, nonpreferential customers.

12. Producers committed to internalizing all manufacturing steps for the production of ICs have been granted certain incentives; those unable to fulfill such a commitment will have to return double what they received from the Government of Brazil.

13. In 1987 the total inflation tax was estimated to be about 7 percent of GDP, of which some 3.5 percent was absorbed by the banking system.

14. Macroeconomic instability and an inflationary environment led to increased demand for computational resources, since the number and speed requirement of transactions grew substantially. Banco Bradesco, the largest private bank in Brazil, undertook, for example, an average of 240,000 open market operations each day before the Cruzado Plan. During the Plan period, the number of operations fell to 100,000. By the end of 1989, however, as inflation continued to accelerate and as individual investors attempted to protect themselves from its effects by moving into indexed financial assets, the number of daily open market operations increased to 440,000. See *Jornal do Brasil,* January 29, 1990. Banco Itau, the second largest private bank in Brazil, averaged in 1989 on a daily basis 634,000 open market operations daily, and processed 10.4 million documents, 7.6 million on−line transactions, 5.6 million deposits, and 4.2 million checks. The volume and intensity of transactions in 1989 required a rapid expansion of Itau's automation and communication systems, and doubling of its data processing capabilities. See *Jornal do Brasil,* February 1, 1990.

15. Between 1965 (the year of the Banking Reform Act) and 1975, the four−bank asset concentration ratio (excluding public sector banks) climbed from 17 percent to 41.1 percent, and for the 20 largest banks, the ratio climbed from 51.2 percent to 89.2 percent. During the same period, the total number of banks decreased from 320 to 106. See *"Relatorio da Comissão Especial de Automção Bancaria," Secretaria Especial de Informatica,* MCT, 1985, pp. 103 and 119.

16. See *"Relatorio da Comissão Especial de Automação Bancaria," Secretaria Especial de Informatica,* MCT, 1985, pp. 104−5.

17. According to the National Center of Banking Automation (part of the National Federation of Brazilian Banks).

18. In fact, whole systems and branch subsystems have already been exported to Latin America (Venezuela, Argentina, and Paraguay) where banking is organized within a transaction environment similar to that of Brazil. Further, a $20−$30 million contract with Hungary was waiting to be finalized by the end of 1988, which was dependent on countertrade arrangements.

19. In 1988, there are fewer than 2,000 on−line branches (out of 15,000)—most of them in metropolitan areas and belonging to the larger banks. The banks with the largest proportion of on−line branches are those with subsidiaries in the automation business, such as Banco Itau (half of its approximately 900 branches are on−line) and Bradesco (with one−third of its nearly 2,000 branches online). The domestic market continues, therefore, to be quite large, although automation needs are now mostly concentrated in smaller branches, except in the case of Banco Real (with no agency on−line), Banco do Brasil (of nearly 3,500 branches, fewer than 100 are on line), Banorte, BCN, and some of the mid−size banks.

20. Cash dispensers are a relatively new product, first deliveries having taken place at the end of 1987. At the end of 1988, fewer than 500 units were sold, but the in−and out−branch market (on firms' premises, for example) is potentially large.

21. These figures were obtained directly from the networks and appear to be more reliable than the reported total (in Table 13.8) of 862 ATMs at the end of 1987. In either case, the ATM installed base is quite small, being less than 1 percent of the U.S. base. By mid−1987, the 100 largest U.S. networks had a total of 68,000 ATMs and 40,000 point−of−sales cash dispensers. See *Bank Network News,* September 1987.

22. Itautec is currently planning to enter into a joint venture (possibly with Sonae, a retail chain) to assemble (initially CKD and thereafter SKD) and sell its point−of−sales terminals.

23. Although estimates of minimum efficient scales tend to be imprecise, it is telling that Samsung Electronics Co. announced in 1988 that it had opened a $12 million plant with an initial capacity of 400K color television sets and the same number of chassis per year in Tijuana, and that it would invest an additional $2 million to increase its capacity to 600K sets a year in 1990, with most of its output going to the United States and Latin America. Samsung, incidentally, has other plants in Portugal, the United Kingdom, and the United States, and is planning to set up plants in Thailand, the People's Republic of China (PRC), Hungary, and Spain, to avert tariff barriers.

24. Springer National is one color television producer that has taken important steps to improve production technology. It introduced three sophisticated automatic insertion machines, and to achieve greater precision in machine processing, it instructed its subcontractors to manufacture printed circuit boards without any warps and with errors of less than 0.1 mm for the distances between insertion holes. Furthermore, the firm's testing and inspection technology is based on automatic testing systems.

25. High production costs are also due to elevated inventory expenses associated with the considerable time it takes to move parts and components from São Paulo to Manaus, and with environmental difficulties (high humidity and soil acidity) that require special packaging and additional labor for material maintenance.

26. In surface−mount assembly, electronic components are mounted directly on the surface of substrates with no leads inserted through the surface. For this mason, the technology for surface−mount assembly is ideally suited for automatic assembly. A whole new range of devices (miniature components) have been developed for surface mount: resistors, capacitors, diodes, transistors, ICs, and even chip carriers.

27. It is noteworthy that locally−produced picture tubes cost $80−$100, whereas international prices for equivalent models range from $60−$80. Two producers are en−

gaged in their manufacture: Philips and RCA—the former through a fully−integrated plant with a capacity of 1.2 million units per year, and the latter through a semi−integrated plant with 0.8 million units per year capacity.

28. Law 4117 enacted in 1962 oriented the federal government toward promoting the development of the telecommunications equipment industry by stimulating entry and growth of national firms, and establishing and approving technical norms and specifications for the equipment to be used in telecommunications services. The basic instrument to carry out these objectives was TELEBRAS procurement policy as defined by ministerial directives 661/75 and 662/78. Policy implementation was to be supported by GEICOM (the Interministerial Group for Components and Materials), created in 1975 to increase domestic content, establish programs for technology transfer and development, and to standardize the production of equipment, component, and materials, and supported by CPqD (the Research and Development Center of TELEBRAS), started in 1976 (see a brief history and description of CPqD's activities below).

29. Between 1976 and 1985, exports of telecommunications equipment averaged $26 million.

30. See the description of this early period in Helio M. Graciosa, "Telecommunications Research and Development in Brazil," mimeo, 1988. According to the author, the sponsored R&D program areas were antennas and microwave radio propagation (at Rio de Janeiro's Catholic University), fiber optic communications, semiconductor lasers, voice signal digital encoding and time−division multiplexing (at the State University of Campinas), digital switching at the University of São Paulo, and microwave radio propagation (at the Instituto Tecnologico da Aeronautica (ITA)). In 1975 one firm was contracted to develop a Cassegrain−type, 10−meter parabolic antenna for satellite communications and another to develop a push−button telephone set (pp. 4−5).

31. See TELEBRAS, "The TELEBRAS Research and Development Center," undated.

32. CPqD also offers laboratory infrastructure, specialized pilot production lines, and a data processing network, as well as a technical data bank necessary for manufacturing.

33. In this regard, CPqD's experience is broadly in line with the notion borne out of many cross−country studies of technology development and transfer that suggest that technology, instead of being regarded as public information, might be more usefully conceptualized as a quantum of knowledge retained by individual teams of specialized personnel. The key to successful absorption would therefore be the development of a skilled labor force with hands−on development experience. See N. Rosenberg and C. Frischtak, *International Technology Transfer: Concepts, Measures and Comparisons,* Praeger, 1985.

34. As a senior CPqD officer put it: "when we started everything was incipient. . .we couldn't afford to concentrate just on switching."

35. According to M. Graciosa, *op. cit.*, "R&D activities in the area of time−division electronic switching started in 1973 when a team from the University of São Paulo [w]as contracted to develop a laboratory prototype of a time−division stored program controlled (SPC) telephone switching system. Such goal was achieved by 1976 . . . . In the first half of 1977, soon after CPqD was founded, most researchers moved to the Center and started working out the development of a whole family of time−division SPC telephone switching equipment named Tropico" (p. 9).

36. An innovative degradation concept in the presence of faults makes Tropico tolerant to multiple faults in its control part, penalizing the system by decreasing the quality of service; in similar circumstances in other systems, however, it would lead to the interruption of services.

37. It is noteworthy that even export−driven economies, such as those of Japan and Korea, used their domestic markets as technological staging grounds for export penetration. There are few cases of products being internationally competitive from the time of start−up. A careful examination often shows, however, that domestic market activities were responsible for generating the needed technical base. A classic case is that of the Korean shipbuilding industry, the capabilities of which (in areas such as soldering of large metal pieces, or in production planning and organization) can be traced to the experience acquired by producers in heavy construction.

14— The Electronics Industry in India: Past Problems, Recent Progress, Future Outlook

Geoffrey Gowen and Daniel Hefler

The Indian electronics industry, established more than 25 years ago, is still a small part of the international industry, and accounted for around 0.7 percent of international electronics production in 1989. Relatively stagnant during the 1970s with a growth rate of 10 percent in real terms, the Indian electronics industry was the victim of a policy regime dating back to the early days of independence that emphasized self−sufficiency and reliance on indigenous technology. These policies began to change at the beginning of the 1990s, and the industry, as a result, has begun to catch up: its growth rate accelerated to 18 percent in the first half of the 1980s and to nearly 26 percent during the Seventh Five−Year Plan period (1984/85−1989/90).[1] Gross output reached a level of Rs 92.0 billion (US$6.2 billion) in 1990. The electronics industry now comprises 7−8 percent of manufacturing value added. Its growth has recently stagnated due largely to foreign exchange constraints on imported inputs and to decreased investor confidence; growth will no doubt resume, however, with the return of political stability. What is the outlook for this industry in the light of these changes in policy and the constraints that still exist? This chapter tries to address this question.

The subsector is relatively domestically oriented. Total exports in 1990 reached only Rs 9.3 billion (US$531 million), averaging about 9 percent of output, of which 35 percent originated from free trade zones. Except for the People's Republic of China (PRC), this share is lower than for other developing countries that have significant electronics subsectors. Imports meet only 25−30 percent of the demand for final products. However, except for such traditional consumer goods as radio receivers and black−and−white television sets, whose inputs are mostly produced locally, the subsector imports at least half the required materials and components.

Public sector enterprises (PSEs) account for about 35 percent of the subsector's output, ranging from 10 percent in consumer goods to nearly 100 percent in communications, aerospace, and defense. Most of the 3,000 or so electronics firms are small−scale industries (SSIs), which produce about 30 percent of total output and are especially important in consumer electronics. Medium−sized and large private enterprises account for about 35 percent of total output; many of the large private firms have had long−standing associations with multinationals.2

Expansion in consumer electronics, particularly in color television, has helped to accelerate the subsector's recent growth. This segment now accounts for about 34 percent of total electronics output. Although the production of data processing equipment has grown rapidly because of government−sponsored modernization programs in industry and in banking, output in this segment only reached about 96,000 units in 1990 (mostly microcomputers), representing about 9 percent of India's electronics subsector compared with a more than 20 percent share in other countries. The industrial, telecommunications, and components segments each command 15−17 percent of the subsector's total output. In telecommunications, two large PSEs dominate: Indian Telephone Industries (ITI) and Hindustan Cables Limited (HCL). Industrial electronics, which includes several large PSEs, is concentrated in industrial process controls and power electronics. In this segment, several firms with international ties have been able to export worldwide.

The structure of the components segment is highly fragmented, with a few large firms at one end and many small producers at the other. Production is largely for use in radio and television sets. Semiconductors (mostly discrete devices) account for only 12 percent of India's components output compared with 30−50 percent in developed countries. SSI and medium−scale industry (MSI) integrated circuits (ICs) are produced by a single PSE, Bharat Electronics Ltd. A second PSE, Semiconductor Complex Ltd., was producing large−scale integrated (LSI) ICs partly from imported wafers until the factory burned down in February 1989, but very large−scale integration (VLSI) ICs have always been imported. In total, locally produced ICs meet less than 10 percent of demand and account for 3 percent of component production compared with a larger share worldwide.

Assessment of Competitiveness

India's electronics subsector developed in an environment that protected it from both domestic and international competition and insulated it from technological progress. Process technologies are generally outmoded (8 to 20 years behind). Product technologies, on the other hand, lag behind in international standards in some areas by only a few months (e.g., some models of microcomputers), but in others are five or more years behind. Regarding prices, a 1986 study showed factory prices (before excise taxes) of the products of 10 major electronics firms exceeded world prices by 20−170 percent and many products were of inferior quality. Though increased domestic competition since then has narrowed the gap somewhat, prices remain high by world standards.

Several important factors account for the high production costs and prices. Production scales are substantially smaller than minimum economic scales (MESs) of leading multinationals by factors of 20 to 100 in some product lines, which affects raw material prices, capacity utilization, and other costs. Indian electronics industries also bear high customs duties on imported components inputs and several other indirect taxes, so that total indirect taxes comprise 20−40 percent of sales prices. Since scales are small, most firms pay 15−40 percent above world prices obtainable through bulk purchases of materials and components. Profit margins for well−operated Indian firms are high by international standards for electronics industries (from 18−40 percent of factory prices), reflecting lower competitive pressures in India. Other factors that hurt competitiveness include the following: (a) India's relative isolation from world markets, which limits exposure to product trends and changing technologies; (b) the related problem of supply uncertainties stemming from reliance on imported raw materials, components, and other needs, as well as delays due to customs administration (all of which result in costly inventories); (c) the lack of suppliers, precision services, and other industrial and service infrastructure of adequate technological capability and reliability; (d) limited and unreliable communications services; and (e) government regulation and controls. In addition, Indian electronics firms face shortages and interruptions of power, communications, and input supply, and they face labor regulations that lead to inflexibility and encourage overstaffing.