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Acquiring high-technology capability: The case of the Brazilian informatics industry

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Acquiring High-Technology Capability: The Case of the Brazilian Informatics Industry

by

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Abstract

Acquiring High-Technology Capability: The Case of the Brazilian Informatics Industry

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This dissertation examines the development of high-technology capability in a developing country, using the example of the Brazilian informatics industry. Technological capability, essentially the ability to use technology effectively, accumulates through 'learning' resulting from the technological efforts of people, firms, and regions. There are two highly interdependent components to high-technology capability: first, the positive use of foreign technology and the development of an indigenous research capability, and second, the development of supporting infrastructures. Infrastructures are based on supporting institutional structures, such as universities, firms, markets, and suppliers, and on the spatial linkages that connect these structures. Higher stages of technological capability are fostered by the development of human resources, research networks, and infrastructural spatial agglomerations.

Government policies may help stimulate these efforts through industry protection and regulation of foreign technology, and by improving the technological infrastructure. In the case of the Brazilian informatics industry, policy extends beyond the past pattern of import substitution by reserving low-end segments of the domestic computer market to nationally owned companies, effectively eliminating competition from multinational corporations. Brazil's protectionist policies can be criticized on the grounds of higher production costs and lagging technological levels, however, this research illustrates that the domestic computer industry has contributed to the development of technological capabilities; namely the intensification of the human infrastructure, the deepening of research and development capabilities in industry, government, and university centers, and the improved ability to select, adapt, and develop technologies appropriate and beneficial to the national situation.

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This dissertation was written in the memory of my father, Howard Hansen, and with the faith of my mother, Nellie Johnson.

CHAPTER 1

INTRODUCTION

Statement of Purpose

Within developing countries, especially the more advanced Newly Industrializing Countries[1], development strategies have emerged that place more emphasis on acquiring technological capability[2]. Concurrently, the dominant theme in the technological development literature during the 1980s has focused on questions and issues of how firms and nations acquire the capability to use technology more efficiently. Surprisingly absent from this literature is an adequate account of the spatial components and linkages so important for the acquisition of a technological capability and the possible options and processes available to developing countries for acquiring high-technology capability.

The conceptual lacunae motivating this dissertation, then, are twofold. First, the abundant literature on high-technology industries and technological change has a decidedly industrialized-country orientation, even though examples exist of high technology in developing countries[3]. Second, research on technological change and accumulation in developing countries has failed to touch on questions of how to acquire high-technology capability. Studies have generally focused on the capital goods industry or the agricultural sector (Katz, 1982; Katz, 1985; Lall, 1987; Watanabe, 1987).

Most developing economies, especially the NICs, are interested in capturing some market segments of the new high-technology industries; these new industries are considered as 'industrializing' and increasingly important for long-term economic growth. Yet opportunities of acquiring a viable indigenous high-technology industry are limited and hampered by seemingly overwhelming handicaps. Many argue, however, that if developing countries fail to try, their international comparative advantage will be eroded, and their asymmetrical technological relationship with industrialized economies will intensify (Blumenthal, 1987/88; Johnston and Sasson, 1986; Munasinghe, 1987). Indeed,

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[1] Lists of Newly Industrializing Countries (NICs) vary, depending on the criteria applied, but most generally include Hong Kong, South Korea, Singapore, Taiwan, Brazil, and Mexico. Argentina and India are cited occasionally.

[2] For Tanzania and Zimbabwe see Watanabe, 1987; for India see Lall, 1987; for Latin America see Katz, 1985; for South Korea see Westphal, Yung, and Pursell, 1984; for Singapore see Kng, et al, 1986.

[3] All of the NICs (Newly Industrializing Countries) are shifting into more skill- and technology-intensive areas of production, with subsequent higher demands for high technologies. Some countries, preoccupied with the challenge of new technologies, have attempted to initiate indigenous computer industries. For example, computer firms may be found in such countries as South Korea, India, Singapore, Argentina, and Mexico. See Cline (1987), Edquist and Jacobsson (1987), and Lalor (1986).

present trends suggest that knowledge inputs in the production process (including research and development, engineering, marketing, management, etc.) are not only displacing capital, land, and labor as explanations of economic change, but increasingly determining global comparative advantage, thus weakening the developing countries' base of wealth creation (Rada, 1982; Bessant and Cole, 1985; Mytelka, 1987). To compete in a global economy driven by new technologies, developing countries will be forced to support the development of these emerging factors of production.

This dissertation intends to fill theoretical and empirical voids in the literature on high technology, developing countries, and the uneven commercial relations between North and South. It provides a framework for analyzing the development of high technology in a developing country setting by focusing on the processes, structures, and spatial linkages essential to the acquisition of high-technology capability. High-technology capability is argued to be a regional phenomenon; the spatial components and linkages that build a technological capability are largely confined to specific regions or local environments.

The development of high-technology capability is analyzed by using the case of the Brazilian informatics industry. This industry is supported by policies that restrict the low-end segment of the domestic computer market to nationally owned companies, effectively eliminating competition from multinational corporations. The analysis attempts to shed light on whether or not the Brazilian pathway has truly led to technological development in the country. Empirical evidence will emphasize the strengths and weaknesses of the Brazilian pathway as a model for the development of high-technology capability.

This chapter puts Brazil's informatics strategy into a larger perspective by demonstrating the economic importance of technology, especially informatics technology. The importance of technology for Third World development, and the possible dependency-inducing trends created by the new technologies are recognized. The final sections document a growing trend in the development literature that acknowledges the necessity for countries to foster technological capabilities and concludes by outlining the methodology adopted for the analysis of the Brazilian informatics industry.

The Role of Technology

The role technology plays in our daily lives is multidimensional, in that it influences historical, social, political, and economic spheres. Technology's role is complexity in that its penetration in these various spheres is deceptively extensive and often not visible to the public or researchers. The 'mystique' of technology[1] lends itself, on the one hand, to unquestioning faith in its plentiful fruits, to the view that technology may solve the myriad of society's problems. On the other hand, many of the ills of modern society are frequently blamed on technological developments.

While the broad debate on the merits of new technology continues as the rate of change intensifies, the major role of technological progress in the competition of firms and nation-states demands recognition. Technological progress has been one of the main instruments for the creation of wealth in the industrialized countries and is now predominant as an explanatory variable for economic change (Malecki, 1981; Thomas, 1987). Researchers have demonstrated that new technology-based firms can have a beneficial impact on the economy (Bollinger *et al*, 1983). Failure of economic entities to keep pace with technological changes may seriously erode their long-run economic potential.

At the same time new technologies can be destructive. There is a real threat that new technologies promote deindustrialization, and destroy jobs, qualifications, machines, plants, or even enterprises (Markusen *et al*, 1986). Some, like Friedrichs (1982), however, argue that these painful 'deindustrialization' or 'deskilling' shifts are short-run, that in the long-run new technologies tend to create new structures and jobs.

Regardless, within nations the experience of and the fear of difficult structural adjustments resulting from technological change are outweighed by the even more painful adjustments that might occur if an economy were completely by-passed by technological change. As Thwaites and Oakey (1985) suggest from a regional perspective:

> Rapid technological advance within industrial firms in an area can give competitive advantages in local, national, and international markets which can, in turn, lead to improved prospects of output, income, employment and occupational diversity. Similarly, innovative activities in the service sectors of the local economy can support such manufacturing innovations through business or public service provision, and thus help the local area to participate effectively in new technological developments. Conversely, regions lagging in technological developments are, without protection, likely to see their economic base eroded by external competitive forces, leading to lower output, incomes and employment (p. 3).

Technology has become a central issue in economic development and the leading force for change in the global economy. Regions and countries throughout the world are

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[1] Definitions: innovation is a new or better product or process; technique is a production system (improved technique is therefore equivalent to innovation); technology is knowledge of whatever sort about technique (Pavitt,1985: 4).

viciously competing for industrial firms with technological expertise. The emergence of new informatics technologies has only made these issues more visible.

High Technology and Informatics

Industrial sectors associated with the influence of the so-called information sectors, knowledge inputs, and new technologies have experienced remarkable growth rates and technical changes. Some authors have been sufficiently encouraged to claim the recent wave of rapid technical changes as a "revolutionary age" and a radical force for change in the world economy (Bessant and Cole, 1985).

The role of new technology[1], or high technology, is perhaps best typified by the recent and rapid technological advances in microelectronics, directly affecting electronic components, computers and telecommunications. Most industrial and service sectors will be dependent to a certain degree on the informatics industry[2] (Rada, 1982b). Due to the virtually infinite number of possible applications of microelectronics in all parts of the economy, the National Academy of Sciences has labelled this era as the 'second industrial revolution' (Norman, 1980: 5). The electronics sector has been so important during the past two decades, especially in the United States and Japan, that Kaplinsky calls it the 'prime growth-pole' (Kaplinsky, 1987). Europeans have targeted microelectronics as the single most important sector of the economy for the remaining years of this century (de Vos, 1983: 11). And Servan-Schreiber (1985) considers this,

> ...the first intellectual revolution in 500 years... bound to transform every aspect of the human endeavor - agriculture, industry, the office, medicine, education. To ignore this revolution is to make oneself irrelevant (p. 571).

Government actions in Western countries clearly underscore the importance of informatics for the maintenance of their industrial base. Note the heavy government support for high-technology industry in Western Europe and Japan. The U.S. supports its industry indirectly through defence expenditures that generate a demand for new

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.[1] Conventional technologies are primarily engineering-based while new technologies are dependent on continuous scientific research and development (Bhalla and James, 1988: 29).

[2]The informatics industry, sometimes labelled as data processing industry, is defined as follows: 1) computer systems - including mainframes, minicomputers, microcomputers, personal computers, workstations, word processors, office systems, and CAD/CAM systems; 2) peripherals - including terminals. printers, plotters, disk drives, tape drives, magnetic media, and data entry devices; 3) software - including operating systems and applications programs; 4) data communications equipment - including communications processors, local area networks, digital PBXs, multiplexors, modems, and facsimile machines; 5) data services - including custom programming, systems integration, consulting, time-sharing, and remote processing; 6) maintenance and repair; 7) computer leasing; 8) point-of-sale systems; 9) automatic teller machines (Kelly, 1989:17).

technologies which then have spin-off effects in the civilian sector (Wad, 1982; Nelson, 1984). Government intervention and promotion of high-technology industries in the developed countries illustrates the important role of government policy for high-technology development. (See chapter 4 for more detail.)

The effects of present day technological trends are markedly different from those of the industrial revolution, when physical capabilities, such as the increased use of machines and energy, were dramatically improved by new industrial technologies (Norman, 1980). The contribution of high technology to the economy is not so much through particular products or techniques, but the increased knowledge of the production and organization process, which may be used to achieve greater productivity or better performance (Castells, 1985). While capital goods merely embody science and technology, a fundamental characteristic of new technologies is the centrality of knowledge and information. They enhance the ability to process, store, communicate, and ultimately generate information. As such, high-technology industries, although they may create products, are better described as knowledge or information industries. And investment in new technologies, according to Freeman (1982: 4), is really an 'intangible' investment in new knowledge - the critical element of modern day economic growth (Thomas, 1987; DeBresson, 1989; Weiss, 1988).

High-technology industries are generally defined as science-based industries, characterized by large research and development (R&D) expenditures, employment of a high proportion of scientists, engineers and technicians, and rapid technological progress. Macdonald (1987) notes that while many try to define high technology by its ingredients, such as high R&D spending or the use of scientific and technical labor, or by its output, such as new products and processes, they still fail to capture the essence of high technology. His definition of the industry focuses on information:

> The industry comprises tiny firms and huge transnationals exploiting different technologies for different purposes, and often in conjunction with established technologies; it can emerge in any part of the spectrum of existing industrial activity, and the characteristics of its individual firms may change rapidly. In practice, high technology firms have few characteristics in common except high information intensity, and that is difficult to measure rigorously and is not exclusive to high technology anyway (p. 225).

High-technology industries may contribute significantly to the regional and national economy in terms of exports, employment, taxes paid, R&D, and innovations (Bollinger *et al*, 1983). Other claimed benefits include rapid economic growth, and environmental and health advantages relative to the smokestack industries. Regionally, a high-technology industry may have important multiplier effects, particularly secondary, indirect employment effects (Hahn and Wellems, 1989). For example, many workers in high-technology firms are employed in high salaried managerial, professional and technical positions, meaning greater spending power. Manufacturers in high-technology industries also tend to develop strong links within the local economy for components, or the use of local contractors and subcontractors (Hall *et al*, 1987: 58). Spending power and industrial linkages both contribute to regional economic multiplier effects.

More broadly, high-technology industries are argued to have two important links to economic growth, as Nelson (1984:1) explains: first, they are "leading" and stimulate economic progress in most other sectors, and second, they are "strategic," in that national economic strength and competitiveness depend on these industries. In Japan, for example, the electronics industry is called "the industry of industries" reflecting its vital linkages with other industries, and its ability provide leadership for the rest of the economy (Morita and Hiraoka, 1988).

The informatics industry is in many ways the epitome of high technology, and informatics products are a key input to a broad and growing list of industrial products (Flamm, 1987). Informatics-based products and services comprise a vast industry that includes or influences:

- Consumer products such as T.V.'s, radio, video recorders, electronic games etc.
- Office equipment such as computers (mainframe, mini, micro), word processors etc.
- Telecommunications equipment for public and private voice and data networks
- Industrial equipment such as process controllers, automation equipment etc.
- Electronic instruments for medical instruments for medical, scientific purposes etc.
- Military equipment for communications and weapons systems etc. (Lalor, 1985: 6).

Outputs from the 'information' or informatics industry form critical inputs into many other industries - changing production processes, speeding up the handling of information, spawning markets for new consumer goods, and improving productivity (Norman, 1980). The development of electronics technology is likely to affect all capital goods branches, either through its incorporation in their products or through changes in their production processes. For example, conventional machine tools are being replaced by numerically controlled machine tools (NCMTs); the use of industrial robots in machine-building operations is spreading; and computers are increasingly used in the design process, and have given rise to a new market for the technology of computer-aided design (CAD) (Chudnovsky *et al*, 1983; Kaplinsky, 1984b). Freeman (1988a) estimates that computer-based capital equipment now accounts for about half of all new fixed investment in plant and equipment in the U.S..

The informatics industry, the central technology for economic growth in the coming decades, justifiably warrants its label as the most important strategic industry (Morgan and Sayer, 1988). Those countries that lack an informatics industry, or the technology, may have a reduced innovative and competitive capacity and "are liable to be disadvantaged across a wide range of other user sectors, including arms production, and to become dependent on 'leading-edge' foreign companies" (Morgan and Sayer, 1988: 3; Johnston and Sasson, 1986). Freeman (1988b) argues that it is not so much the acquisition of leading-edge industries, but that countries have the capability to adapt these technologies to the rest of the economy.

Informatics technology has become an important element in industrial organization and location. Giaoutzi (1988) contends that informatics technologies will 'drastically' reshape the spatial distribution of production and be central in the establishment of a New International Division of Labor. He argues that informatics technologies, dependent as they are on regional technological and socioeconomic structures, are likely to result in new patterns and hierarchies of production, presenting opportunities for some regions and threats to others. The fact that the microelectronics or computer industry is considered a leading and strategic industry explains why governments have been compelled to establish segments of the industry through direct or indirect policies.

These emerging issues surrounding high technology have stimulated much research among the industrialized countries, both empirical and theoretical in nature. Major English language journals commonly include articles on high technology, in particular on the economic and spatial impacts and outcomes of high technology, the conflicts arising from technological leadership (e.g., Japan vs. U.S.), and policy prescriptions to best achieve technological leadership. However, less attention has been given to the special problems faced by developing countries with the emergence of technologies that could fundamentally affect patterns of production, world trade, and international investment (Norman, 1980). In the following section, current themes on the relationship between high technology and development will be explored. Of particular importance to this dissertation are the repercussions that informatics technology will have on economic relations between industrialized and developing countries, repercussions that are critical to understanding why some developing countries are pursuing high-technology industrialization.

High Technology and the Developing Countries

The impact, both positive and negative, of informatics technology on Third World development, distinguishes an important new area of research[1]. The incorporation of informatics technologies into the economies of developing countries is viewed by some as the key to future development strategies. Servan-Schreiber (1985) speculates that an agricultural computer-based system in a developing country might increase a farmer's understanding and skills rather than, as has so often occurred in the past, introducing machinery he cannot properly apply. Morehouse (1981) offers other examples, noting the relevance of informatics technology due to,

> ...its relative flexibility and the possibilities it offers for greater product differentiation, which in principle mean that developing countries can take a basic technology and adapt it more easily to suit their own social requirements or raw-material availabilities. In a similar vein are the possibilities for decentralization of production while maintaining high levels of standardization, which may enhance the possibilities for developing more rapidly substantial, small scale, high productivity industrial sectors in the developing countries and diminishing transportation costs and urban concentrations (p. 259).

Flexible manufacturing techniques and the decentralization of production, then, could allow each region of the world relative self-sufficiency in manufacturing, or reverse the trend of a global division of labor in manufacturing (Bhalla and James, 1988). Furthermore, while informatics technologies are commonly thought to be labor saving, a more important outcome for developing countries is that they are capital saving, making the technology useful to those countries with capital shortages.

In the arena of international trade, comparative advantage is increasingly based on superior technology, the possession of which can only be kept secret for a limited time (Södersten, 1980). The diffusion of technologies may lead to shifting patterns of comparative advantage; the countries which are adaptable, willing and able to develop and learn new techniques will be successful in the world economy. Bhalla and James (1988) argue that the new technologies are science-based and require a more scientific and technical labor force, which is relatively abundant in some developing countries, especially the NICs. The diffusion of the new technologies to these countries may therefore be relatively unhindered.

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[1] For studies on high technology in Third World countries, or high technology and development see Bessant and Cole, 1985; Mattelart and Schmucler, 1985; Johnston and Sasson, 1986; Kaplinsky, 1987; Lalor, 1986; Edquist and Jacobsson, 1987; Bhalla and James, 1988; Cimoli and Dosi, 1988; Erber, 1985c; Ernst, 1985; Grieco, 1984; Jacobsen, 1987; Manasinghe, 1987; Nath, 1988; O'Connor, 1985.

What about the rural masses who generally account for the bulk of the population in developing countries? Kaplinsky (1984b) believes new information technologies will affect them indirectly by: (1) reducing costs of producer goods and agricultural capital goods; (2) enabling rural health centers to store case histories, or provide diagnostic aid; and (3) aiding the prediction of weather patterns.

On the other hand, the utilization of computers and information technology in developing countries, according to Rada (1982a), could produce both an immediate loss of jobs and a lowering of the country's job creation potential. This will be particularly true if the countries are not producers or even assemblers of equipment and thus no compensation takes place within the national economy. Or, as Lakshmanan (1981: 13) argues, since new technologies are beyond the means of the poor majority, the introduction of these technologies will only exacerbate the unequal distribution of wealth and lead to a relative worsening of the welfare of the poor.

There are, then, many contrasting views on the impact of high technology in the developing world. Arguments rest largely on speculation, due to the paucity of empirical research on the role of high technology in development. There is clearly a need for more study in areas such as the diffusion of the new innovations from industrialized to developing economies, the socioeconomic impacts of new technologies within developing countries, and what role the state should play in addressing these economic and social issues. Of particular importance to this dissertation, however, are new dependency-inducing trends that appear to be influencing international economic relations between the North and South and possible alternatives to resist these trends.

High Technology and Dependence

Although the use of information technology may be a positive step toward development, the current structure and organization of the world's information industries, centered predominantly in the industrialized countries, pose serious handicaps for the developing countries. For example, manufacturers of electronic components have used developing country plant locations for the wiring and encapsulation of chips; since about 1978, however, the trend has been to open the new generation of plants in home countries. The recent plant closures by several U.S. electronics producers in Malaysia (the largest exporter of off-shore semiconductors in the world) and the failure of transnationals to upgrade the technological make-up of their operations in Singapore have led to serious economic setbacks for these two countries[1] (Ting, 1987). According to Business Week, firms like Motorola and Fairchild Camera and Instrument Corporation have been in the process of relocating some production lines to the U.S., setting future trends (Mattelart and Schmucler, 1985). Explanations for this 'retreat to the homelands' are: increased automation of the production process, the need to be closer to end users, quality control, elimination of logistic problems, and the failure to upgrade local or national technological capabilities (Rada, 1982a). Perhaps even more significant is that similar patterns are emerging as other industries incorporate information technologies, such as the textile or the automobile component industry (Kaplinsky, 1984a; Hamilton, 1984; Rattner, 1985; Unger, 1988).

The use of information technologies in industrial applications reduces the importance of direct labor costs and increases the flexibility of the manufacturing process (in terms of size and locational requirements), thereby reducing Third World comparative advantage and the attractiveness of developing country locations for production facilities[2]. Kaplinsky (1984a: 84) argues that the use of new technologies will not only reduce the rate at which production is subcontracted to the developing countries, but might lead to a degree of trade reversal, or to the relocation of subcontracted production from low-wage developing countries sites. Indeed, Chesnais (1988) claims, as a result of information technology, a key factor for the location of new foreign investment is where exit barriers for these branches are low. Junne (1987) believes that it is not so much the retreat of firms that is a threat to developing countries, but that new production sites will more often be located in the industrialized country and that in the future more plant closures will take place in the developing world.

Retreat to the homelands and potential losses of manufacturing activities represent only one side of the bleak picture for Third World countries. As microelectronic technology gathers momentum in industrialized countries, with its promise of significant increases in labor productivity, relative comparative advantages will increasingly be determined by scientific and technological knowledge. This presents problems for developing countries intent on pursuing informatics industries.

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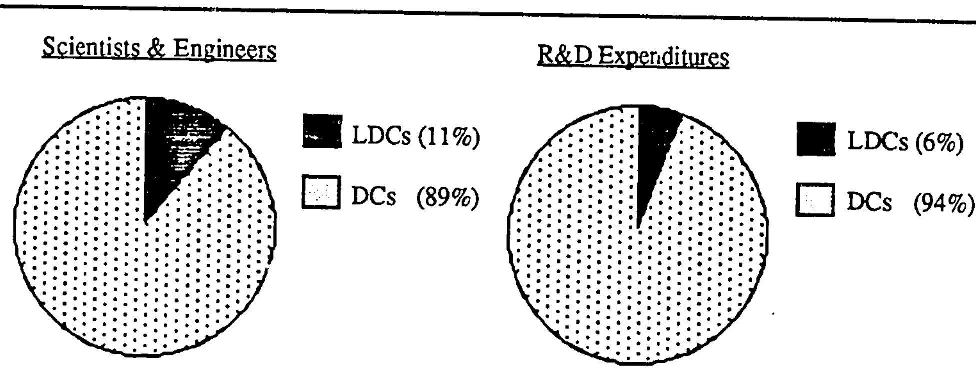
[1] Malaysia's failure to promote indigenous technological development and Singapore's over-dependence on multinationals have exacerbated the seriousness of their problems.

[2] As automatic production systems are increasingly utilized, manufacturers additionally choose developed country production sites to be closer to suppliers (for lower inventory costs and to gain savings in terms of time) and for increased total quality control (Monck *et al.*, 1988; Unger, 1988).

Developing countries are almost exclusively users of science and technology produced in advanced countries, measured by inputs (e.g., R&D expenditures, qualified scientists and engineers, see Figure 1.1) or outputs (e.g., patents, papers), and are more dependent in the arena of science and technology than, in fact, in either international trade or industrial production (Erber, 1981). Further evidence stresses this imbalance: industrialized countries account for 67% of the world's invention patents, and 92% of industrial design patents; moreover, only 20% of patents from semi-industrialized countries and 6% of patents from developing countries are issued to nationals (Stewart, 1988a).



Adapted from: Johnston and Sasson (1986), 1980 estimates.

Figure 1.1 Distribution of Scientists and Engineers, and R&D Expenditures in Less Developed Countries (LDCs) and Developed Countries (DCs).

With the present global imbalance in science and technology capabilities, developing countries face the real threat of increased dependency. The argument that developing countries should not adopt new, internationally marketed, cost-reducing technologies because they are <u>labor saving</u> and incompatible with existing comparative advantage, according to Rosenberg (1988), may be self-defeating; keeping old technologies could lead to a reduction in competitiveness in the world market and thus increased domestic unemployment.

The primary technological strategy for developing countries has been the transfer of technology and the "unpacking" of technology into its various processes and products. Two problems arise: first, technology is information specific to its application which <u>accumulates</u> in firms in the form of technological skills in research, development, and production engineering and is not easily transferred (Pavitt, 1985); second, as new automation technology increasingly moves towards systems, where components are 'black boxed' for the user, the potential for technology-importers in developing countries to unbundle these systems are likely to be substantially reduced (Kaplínsky, 1984b).

Meanwhile, large transnational corporations (TNCs) are increasingly sharing and exchanging technology among themselves (e.g., pooling patents and signing reciprocal licensing agreements) and are building up significant barriers to entry and technology gaps, putting smaller firms contemplating entry into the information industry at a disadvantage (Chesnais, 1988). Ewing (1985) argues that new technologies have greatly reinforced the dynamism and power of TNCs.

Those developing countries that have relied heavily on foreign investment and imported technology in advanced industries are becoming more vulnerable[1]. Their economies are dependent on outside decisions in relation to the type of technology, its domestic diffusion and the product-cycle of foreign investment. In other words, as the productive structures in developing countries become more dependent on these technologies their economies become more dependent on TNCs. If developing countries import on a turnkey basis, the net result could be islands of high technology within economies characterized by low productivity production systems, not to mention the pressure put on balance of payments to import these turnkey systems (Rada, 1982a). Technological dependence may also undermine government policies to strengthen their own capacity for scientific and technological development: first, by inhibiting the processes of 'learning-by-doing,' and second, by tending to devalue the efforts of local scientific and technology institutions, i.e., making their work either irrelevant or a poor copy of similar work in the developed world (UNIDO, 1984).

One cannot overstate the role played by TNCs in the industrial activity of most developing countries, especially Brazil. Compared to other advanced developing countries Brazil has relied more heavily on the use of foreign technology through direct foreign investment, and policy towards foreign investment has been one of the most open among developing countries. Transnational investment in Brazil is characteristically concentrated in high growth or advanced industrial sectors (Lall, 1983; Teubal, 1987). In high-

[1]Even in some industrialized countries foreign ownership, especially in advanced industries, is responsible for weak local R&D activities and high technological imports. According to Britton (1985), Canadian R&D performance is poor due to the low R&D expenditures of foreign-owned firms and their weak backward linkages to Canadian firms. In Canada, like Brazil, foreign-owned manufacturing firms account for about 70% of total sales in advanced sectors.

technology industries such as mechanical engineering, electrical and communication equipment, transportation equipment, plastic and pharmaceutical products, foreign investment accounts for more than 70 per cent of industrial turnover (Tigre, 1983). Technological innovations, based on research and basic design activities, continue to remain under foreign control in almost all industries (Erber, 1981). The inputs necessary for these industries are often imported capital and intermediate goods from within the transnational corporation (Evans and Gereffi, 1982). The few linkages with other sectors of the economy seriously limit the channels along which growth impulses flow to local industries. In other words, multiplier or spread effects that are expected to be generated by transnational companies in 'lead' industries are minimal (Britton, 1980; Jacobsen, 1987).

TNC investment and technological transfers are argued to limit local R&D and technology activities (Tigre, 1983; Massey, 1984; Britton, 1985; Jacobsen, 1987). This occurs because virtually all the R&D for a TNC is done in the home country with little effort to encourage local R&D (hence what Massey (1984) calls the 'headless' firm) or to reinvest profits beyond a minimum needed to run the plant. Various factors contribute to this concentration of technological activity in industrialized countries: (1) growing cost of R&D and capital equipment (Rada, 1982a), (2) increased intra-firm information flows and centralized data storage and retrieval systems that permit centralization of management and R&D functions (Schumann, 1984), (3) the increased benefits of locations near major markets and science and technology centers (Buswell *et al*, 1985), and (5) perhaps most significant, new technologies are closely guarded secrets and they are withheld to protect a TNC's competitive advantage against local firms (Kobrin, 1979; Schumann, 1984). TNCs, with their significant presence in advanced sectors in developing country economies, are unlikely transferrers of high technology.

Those TNCs that do establish R&D activities in developing countries generally perform low level tasks that do little to contribute to the advancement of science and technology in the host developing country. Typical research projects by TNCs in developing countries are limited to maintaining the production process and the quality of the product, and they rarely evolve into more sophisticated activities (Fischer, 1987). Foreign investment in developing countries is typically in industrial sectors in the later stages of product development, when more standardized products and equipment permit the separation of production from R&D, and where this relatively routinized assembly of mature products requires only low-skilled labor. As a result, TNC activities are found in geographic areas characterized by relatively low production costs (Flynn, 1988).

Recent NIC development strategies to promote more technologically advanced industries have also been criticized. Jacobsen (1987) labels this process of more sophisticated, foreign dominated production in developing countries as peripheral 'postindustrialization.' Postindustrialization represents a strategy of economic development through key industries that are science-based and research intensive. Peripheral postindustrialization signifies the diffusion of key industries to developing countries via strong policy, albeit more labor-intensive relative to developed countries, and an industrial development characterized by a lack of internal linkages and a lack of local technology-generation capabilities.

The emergence of new technologies, then, has led to a growing perception that the gap in technological capabilities between developed and developing countries is widening (Singer and Ansari, 1988), leading to what might be called the ' international division of technological capabilities.' If one agrees that the control of technology means the control of development, or less bluntly put, that comparative advantage now depends increasingly on innovation rather than purely physical factor endowment and low labor costs, then one must conclude that developing countries are in a nefarious dependency position (Ewing, 1985).

Informatics technology represents a major technological wave that developing countries will inevitably have to confront and which will have an effect on North-South relationships as well as on the patterns of development within the developing countries. However, very little is known the long- and short-term effects of high technology and development; this must not detract from the need for an objective analysis of the real implications of high-technology, and in particular informatics, for the developing countries.

It is the perspective of this dissertation that a country's position in the world economy is increasingly based on technological capabilities. The growth and 'sophistication' of technological capability will have significant long-term consequences for economic development. Economic growth relies on the acquisition of technologically advanced, skill-intensive production that raises the value-added content of products and increases the backward and forward linkages within the national economy. While many researchers have emphasized the negative impact of high technology and development, this dissertation aims to evaluate the potential of the more advanced developing countries to develop a capability to enter some high-technology market segments.

Technological Capability

A realization of the importance of developing indigenous technological capabilities is a rather recent phenomenon, commencing in the late 1970s and gaining ground in the 1980s. Technological development literature before the latter 1970s focused on the problems developing countries faced when transferring technology from more advanced countries. The technology transferred was argued to be excessively expensive, inappropriate to local conditions, and ill-utilized in the new environments.

> [Researchers] suggested that the recipient countries had to pay extremely high prices for the technology they purchased, largely as a result of their relatively weak bargaining power.... Furthermore, the technology itself was often operated in an inefficient way in the recipient countries...An assumption that was rarely made explicit in many of these studies was that Third World countries possessed extremely weak technological capabilities and that the focus ought therefore to be on the import of foreign technologies, rather than on local technological capabilities (Fransman, 1984: 4).

Focus on the implications of importing foreign technologies gave way, from the late 1970s, to analysis of to what extent the transferred technologies were adapted, modified and later improved as a result of indigenous effort. Fransman (1984) states that,

> ...a greater amount of attention began to be given to the processes involved in mastering and adoption of this technology... The process of assimilating and reproducing technology both from local firms and from abroad therefore required firms to solve numerous problems, the answers to which were not always given by the seller of the technology... The assimilation and reproduction of technology therefore involved a process of technological change, however minor. (pp. 5-6).

This research on local technological changes associated with technological imports led directly to the question of how developing countries might further substitute local for foreign technology, with the answer being the development of an indigenous technological capability (James and Watanabe, 1985; Lall, 1987; Unger, 1988; Watanabe, 1987; Bell, 1984; Dahlman, 1984). Technological capability begins and develops as a firm adapts foreign technology to the local environment and eventually builds up its know-how. National technological capability permits the option to use foreign or indigenous technologies to enhance the further growth of national technological capability (UNIDO, 1984): it includes the ability to choose, acquire, generate and apply technologies that are most advantageous to that particular firm or country.

The widespread call for indigenous capabilities is attested to by the number of international organizations (e.g., the United Nations and the Organization of American

States), government departments, and scholars writing on science and technology for developing countries (Bath and James, 1979; Wijesedera, 1979; Wionczek, 1979a; Wad, 1984; Sagasti, 1980; Morita-Lou, 1985; King, 1984; Erber, 1981a; Choi, 1988; Behrman and Fischer, 1980; Katz, 1982; Katz, 1985). These researchers refined concepts and processes of technological capability through empirical study in developing countries in both the agriculture and manufacturing sectors.

Stewart (1984) sums up the major reasons why developing countries should build indigenous technological capacities:

> 1) To use imported technologies efficiently;
>
> 2) To create technology with appropriate characteristics, in view of the inappropriate nature of much of the technology imported from developed countries;
>
> 3) To increase the learning effects of doing it yourself, which become cumulative, eventually creating a dynamic comparative advantage in more sophisticated and often more remunerative lines of production;
>
> 4) To reduce technological dependence on advanced countries. Near–complete technological dependence tends to involve loss of local control over many aspects of production (since these form part of technology contracts), and it reduces a country's ability to bargain toughly on the terms of technology transfer, as well as having adverse effects in terms of self–respect and self–reliance (pp. 81-82).

Technological capability, although "its benefits are difficult to assess quantitatively or even describe with precision," is a fundamental component of industrialization (Lall, 1980: 45). It benefits industrialization through a scientific and technical capability that can effectively regulate and reduce the cost of technology imports, lead to the development and production of more 'appropriate' technologies, stimulate the creation of vital backward linking industries, increase the use of local raw materials and the formation of new skills, and create a stronger sense of self-reliance and confidence (Lall, 1980).

Not surprisingly, a key constraint for the indigenous development of technology (as for importing and assimilating foreign technology) is the lack of requisite science and technological capabilities; or knowledge and skills embodied in people (Weiss, 1988). Only once an adequate science and technological infrastructure[1] is operational will there be a generation of new science-based firms and domestic R&D.

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[1] The term S&T infrastructure is used widely in the literature, although a more apt label is a human infrastructure for research and technological advance. This notion will be more fully developed in chapter 3.

Researchers argued that trade policy alone was not sufficient to create a technological capability (Lall, 1987; Katz, 1984). Trade policies needed to be assisted by specific S&T policies in order to promote indigenous technological development. Evidence suggests the emergence of two different S&T policy trends - one that focuses on how to best adapt and select foreign technologies and know-how, leading to an export-oriented model (South Korea), and a second that aims to achieve more technological autonomy by blocking foreign control and emphasizing the internalization of skills and institutional structures (India) (Behrman, 1980; UNIDO, 1984). Whatever direction was taken to strengthen indigenous capabilities, complete autarky was not a viable choice.

Lacking from this important research on technological capability, however, is how to acquire a capability in new high-technology industries, and equally important, an examination of the regional concentration of technological development.

High-Technology Capability

This dissertation goes beyond notions of technological capability to that of acquiring high-technology capability. Research to date concludes that high technology, and in particular informatics technology, is strategic: it affects new products and processes that contribute to economic growth, and new techniques of production and management to compete in international markets. As such, even traditional sectors in developing countries must adopt informatics technologies to survive.

The informatics industry provides new opportunities to increase and revitalize productivity and will likely be the central technology for economic growth for the coming decades. These considerable technological and market-demand spillovers may not be reflected in price, but they do highlight the importance of promoting some indigenous segments of the high-technology industry. Important is the adaptation and spread of these technologies and know-how to the rest of the economy, rather than the possession of leading-edge industries. However, while the development of a high technology industry is aimed in the short–run at intensifying indigenous technological capabilities, in the long–run those capabilities should be used to produce increasingly technologically sophisticated products for the international economy.

Implementing a high-technology industry meant to accumulate technological know-how will likely pressure developing countries to adopt protectionist measures and other supportive domestic policy adjustments, such as state support for local industries and research institutes, and indirectly, domestic policies involving taxation and education. Restrictive policies can be very costly and, moreover, vulnerable to the volatility of the new technologies. They are volatile in the sense that dynamic, high-technology industries are characterized as having short product life cycles, requiring increasing amounts of research and development expenditures, and undergoing intense competitive pressures in the market-place, all of which are subject to the 'unknown' future development that might change competitive advantages (Mytelka, 1987). Although the use of high technology appears vital for industrial performance in developing countries, formidable barriers and obstacles exist.

Studies (see Hall and Markusen, 1985; Saxenian, 1985; Haug, 1986) on the development of the computer industry in industrialized countries reveal an interesting juxtaposition of several 'ingredients' necessary for the success of a computer industry. For example, the computer industry tends to agglomerate in locations that offer economic advantages such as proximity to a skilled professional and technical labor supply, quality government or university R&D centers, venture capital markets, government markets, suppliers, efficient transportation linkages including airports, and access to the recreational and cultural amenities of metropolitan areas. The initial stage of R&D depends on much more than inter-industry, or inter-firm competition. Government policies and institutions (including military), university and academic organizations, and private (or state run) industrial development and application all contribute to the successful development of high-technology industries. The mix of these linkages and structures, perhaps best described as a 'high-technology infrastructure,' are well documented as they exist in some industrialized economies (Dorfman, 1983; Saxenian, 1984; Haug, 1986; Hall *et al*, 1987; Malecki, 1987; Thomas, 1988; Kelly and Keeble, 1988; Nijkamp, 1988). Is it possible to recreate such a sophisticated technological infrastructure in a developing country?

Certainly a high-technology industry in a developing country presupposes certain basic requirements, in addition to the high-technology infrastructure described above. The *a priori* 'building blocks' include: a domestic market of sufficient size for infant industries; appropriate policy choices relating to trade, investment, and licensing activities; a science and technological infrastructure; local research capabilities; and the ability of firms to accumulate the necessary technological know-how from local and foreign sources. Success along these lines should have measurable manifestations in the development of the human resources, the deepening of research capabilities in industry, government, and university centers, the development of a regional, spatially linked, high-technology infrastructure, and the ability of local firms to use accumulated technologies for new generations of products and eventually international competition.

The Case of the Brazilian Informatics Industry

The Brazilian informatics industry is an example of an indigenous high-technology industry that exists in spite of heavy global TNC or foreign ownership and dominance of informatics technology. According to Evans (1986), Adler (1986, 1989), Tigre (1983, 1987) and others, the creation of the Brazilian informatics industry disputes notions of technological dependence raised in development literature. In contrast, researchers critical of the Brazilian computer industry, such as Cline (1987), Piorkowski (1985), and a handful of U.S. newspaper and trade journal articles[1], argue that the industry is plagued by problems such as technological backwardness, high prices, black market imports, and lack of international competitiveness. For these researchers and journalists the Brazilian computer industry has been a cost to Brazilian society rather than a contributing factor to the country's technological development.

Brazilian informatics policies, based on the principle of reserving for nationally capitalized firms the low end of the informatics sector, such as the mini- and micro-computers, represent a significant change in attitude among Brazilian policy makers toward technological development. Brazil, from the earliest stage of its industrialization, has permitted a free inflow of technology through foreign controlled affiliates. The entry of foreign companies was considered vital to provide both capital and the required technology. TNCs have made such enormous inroads into high-technology sectors, however, that many corresponding domestic firms were eliminated, threatening Brazilian indigenous technological capabilities (Lall, 1980).

The aim of the Brazilian policy was to create a new national high-technology sector, emphasizing the indigenous acquisition of technological know-how. The policy reflects the Brazilian view that information technology is one of the key components of international competitiveness, that indigenous capacity of the new technologies is vital to future technological autonomy, and that a local informatics industry will ensure national security and sovereignty.

The informatics policy emerged in the early 1970s. With a strong domestic computer market in the industrial and financial sectors and a supply of capable scientists and engineers, the government was prompted by national security concerns to provide financial support to two Brazilian universities to design a minicomputer. The first Brazilian computer firm, COBRA (Computadores e Systemas Brasileiros S/A), was created in 1974.

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[1]Including, to name a few, the Wall Street Journal, the New York Times, MacWeek, and Datamation.

The following year policies were introduced to reduce imports and create instruments for the development of a local computer industry. In 1977, the government issued a decree that blocked imports of all mini- and micro-computers and their peripherals. In 1984 that decree became a law and will remain in effect until 1992. As a result of this "market reserved" policy the number of computer and electronic firms has greatly increased. If protection were lifted, however, transnationals would likely regain market dominance through aggressive marketing, lower prices, and state-of-the-art products, a process that would threaten local learning opportunities and limit the matching of computer products to local needs (Tigre, 1983). Brazilian policy has opted for the acquisition of technological capability.

As recently as 1975, Brazil depended almost entirely on imports to satisfy its growing needs for computing equipment, since domestic production was still at an early stage of development. Protected from imports and local manufacture by foreign computer firms, Brazilian computer firms have successfully entered the domestic market. They now supply the domestic market with a wide range of locally designed and produced products. Although more highly priced than products from developed countries, local products are more appropriate because they are designed to match local requirements for user applications, quality, and performance (Tigre, 1983). By 1989, over 300 domestic firms accounted for approximately 50% of the annual $4.5 billion Brazilian computer market (Bensimon, 1989). The domestic market for all computer products is smaller than the German, British, and French computer markets, ranking sixth or seventh in the world. However, the sale of computer products is growing faster in Brazil than in these other countries.

The Brazilian informatics industry presents fertile ground for testing conceptualizations of high-technology capability. Although a handful of studies on the Brazilian case provide good analyses of policy and industry development, they fail to conceptually clarify and empirically evaluate the industry's contribution to technological capabilities. This dissertation addresses that shortcoming. A conceptual framework is designed to examine the Brazilian informatics industry based on: (1) the industrial development and technological performance of firms, (2) the effective use of foreign technology, (3) the development of a human infrastructural base, (4) the improvement of local research capabilities through a research infrastructure, and (5) the advancement of innovative capabilities through the creation of a regional high-technology infrastructure.

Methodology

This section outlines the research process, data sources, and the methodology adopted for empirical analysis. Empirical research may not prove the validity of the conceptualization motivating the research, but , as Lloyd and Shutt (1985: 25) state, "the findings of the one should enrich the understanding of the other." The conceptualization, in this case, aims to construct a set of components, influencing factors, and articulate the process of how a developing country acquires high-technology capability.

The dissertation evaluates high-technology industrialization through technological capability. The overall research design was constructed first to evaluate the development of high-technology firms, products, markets, and industrial linkages for evidence of industrial growth in general and technological development specifically. Second it examined the spatial structures and linkages that are commonly associated with regional high-technology centers or clusters, in particular the human, research, and high-technology infrastructures.

A major part of the empirical research for this dissertation was conducted in Brazil during approximately twenty months between 1986 and 1987. Several academic institutions, some governmental organizations, and high-technology firms were visited. Field research increased the author's familiarity with the computer industry, the policies protecting that market and the emotional nature of those either for or against the country's informatics policy, and the technological infrastructure that supports the industry. Since 1987, Brazilian newspapers, journals, recently published books, and personal contacts have been utilized. Overall, information for this dissertation has been collected over a four year period from 1986 to 1990.

The initial phase of field research concentrated on gathering and analyzing existing Brazilian literature on the informatics industry. Libraries at the Federal University of Rio de Janeiro, the Pontifical Catholic University of Rio de Janeiro, the Fundação Getúlio Vargas, the Federal Data Processing Service (Serpro), the Brazilian Institute of Social and Economic Analyses (IBASE), and IUPERJ/Rio de Janeiro contained both academic and governmental publications and were continually visited during the research period in Brazil. Trade journals and newspapers, including Folho de São Paulo, Jornal do Brasil, O Globo, Dados e Idéias, INFO, and Datanews, to name a few, were also important sources of information. Contact was made with academics in the field of informatics, many of whom were employed by computer and software firms, had their own firms, or were involved in government organizations related to the industry.

A second phase of field research was based on field interviews with employees of 11 informatics firms. The 'conflict' between Brazil and the U.S. over the *reserva de mercado* has 'politicized' the nature of the dissertation topic and unfortunately limited the success of survey data collection. As Dixon and Leach (1984) warn, researchers in foreign countries must stress their 'independent' or 'academic' standing to avoid suspicion and elicit non-biased responses. While heeding this advice, interviewees often voiced nationalistic positions when interviewed by a North American, although the same individuals adopted positions more critical of policies or the industry in local published material[1]. As a result, much of the private sector empirical findings were accessed through the numerous published interviews of industry leaders in trade journals and newspapers. This also made second-sourced data collection from governmental organizations more important for the investigation.

Even with these problems, most interviews did generate useful information. Two interviews were conducted with firms located in São Paulo, and nine with firms in Rio de Janeiro. While there are over 300 informatics-related firms in Brazil, the 11 firms interviewed represent the larger and more technologically advanced firms. Eight firms were computer systems manufacturers, two were software firms, and one was a large, technologically advanced manufacturing firm that used a variety of informatics products in its production process.

A third phase of field research led the author to several 'industry and governmental organizations' such as the Special Secretary for Informatics (SEI) and the Brazilian Computer Industry Association (Abicomp). Both organizations publish studies rich with data on various aspects of the industry. SEI is the government organization that regulates the informatics industry[2]. SEI's 1987 'Panorama' was an important data source for this dissertation[3]. Data for the 1987 study were drawn from 60 national firms that account for

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[1] For example, when one prominent industrialist was interviewed, he unhesitatingly stressed that the technological capability of Brazilian computer firms was more than sufficient to successfully and effectively provide other economic sectors with viable products. Within a week after the interview, in an article published in the Jornal do Brasil, the same industrialist was quoted arguing that several economic sectors were hurt by Brazilian policy that forced them to purchase only Brazilian informatics products.

[2] Including activities in the fields of real-time control systems, microelectronics, electronic instrumentation, software and services, computer systems and peripheral equipment, banking and other terminals, data communications products (modems, teleprinters, facsimile), CAD-CAM equipment and software, advanced terminals, and numerical control equipment (including robotics).

[3] SEI divides the protected segment of the computer industry into five basic types: 1) systems - including hardware and software; 2) peripheral equipment - including printers, disk drives, etc.; 3) terminals; 4) modems; and 5) special terminals - including financial terminals, cash registers, lottery machines, etc.

about 85% of total industry revenue for the national segment of the industry. For the multinational industry, data were collected from the five largest firms, accounting for 95% of the total multinational segment of the informatics industry.

Upon returning to the U.S., a fourth research phase included continued access to trade journals and major newspapers, and Bras-net. Bras-net, a computer network of Brazilian graduate and post-doctorate students and professors in the U.S. and Europe, greatly enhanced the author's continued access to events and perspectives related to the Brazilian computer industry. In 1989, Bras-net was connected to several universities, research institutes, and firms in Brazil. Bras-net permitted the author to gain valuable insights and exposure to debates on a variety of relevant issues through general discussions and personal messages.

Hence, the empirical results in this dissertation are based on government documents, published and unpublished reports, articles and books, as well as interviews. The data are accessed and analyzed through a methodology which includes: 1) analyses of industry related publications, 2) case studies, and 3) longitudinal analyses. The latter analysis addresses the common criticism that most social science research in developing countries is based on a single cross-sectional survey without accurate representation of change (Dixon and Leach, 1984). Aggregate data are used to identify general patterns and case studies are used to indicate specific processes. Due to the homogeneity of the study, which focused on the informatics industry as opposed to a variety of industrial sectors, aggregate data and case studies are readily related to one another (Sayer and Morgan, 1985).

The problem for the researcher is how to approach the analysis of the acquisition of technological capability. To do it well, according to King (1984), requires a cross-disciplinary approach with qualitative and historical research techniques to focus on, for example, higher education policy and the scientific research environment; the history of training and technological changes by industry; the acquisition and utilization of human resource skills and knowledge; and the interaction among knowledge generators and users.

Indeed, many of the theoretical propositions and questions derived from the conceptual framework do not lend themselves to specific quantitative answers, and specific data are difficult to generate. As Stöhr and Tödtling (1986) note, economic development

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(SEI, 1983). Beginning in 1984, SEI separated general data processing and teleprocessing data (e.g., telex, facsimile, modems, multiplexers, etc.).

and problems are not necessarily related to quantitative economic changes but more often to qualitative and structural transformations. As with economic development in general, technological development is a multi-dimensional process involving both qualitative and quantitative changes, reflecting not simply changes in products, but fundamental societal changes and improvements (Wilson and Woods, 1982).

As a result, secondary indicators are used to compensate for muddled areas that are not empirically identifiable in isolation; indicators are pointers or reflections of reality that may illustrate technological conditions within a firm, industry or region. Although changes in indicators do not reveal causality, they do provide yardsticks for change (Bauer, 1966). For example, in defining the technological intensity of an industry a variety of measurements and variables exist, including R&D expenditures, S&T personnel as a percentage of total employees, the ratio of S&T personnel to net sales, etc. (Teitel, 1982; Markusen, Hall, and Glasmeier, 1986; Hall, Breheny, McQuaid and Hart, 1987; Bar-El and Felsenstein, 1989; Kraushaar, and Feldman, 1989). Equally important is monitoring the ability of firms to introduce products or to follow, or catch up to, international technological trends. For example, once Intel releases a new microprocessor, how long would it take Brazilian firms to introduce a product that utilizes this new technology?

Clearly, indicators leave much to be desired. The choice of the best indicator to measure underlying processes is a difficult one. Regarding technological change, or the potential for and effects of change, Kraushaar, and Feldman (1989), note that a single criterion is difficult to establish that applies equally well to all industries. Although technological change and capability are virtually impossible to quantify, groupings of a number of indicators have been utilized by researchers as a more comprehensive measure for technological change.

Research in developing countries indicates that such groupings of indicators, based on measurements of quality human resources (engineering and technical personnel), may adequately illustrate by proxy the technical capability of firms, industries, and regions (Teitel, 1982; Atlas, 1987a). Roman and Puett (1983) have elaborated the number of indices to include a variety of factors. In addition to a country's inventory of trained scientists and engineers and skilled technicians, they include (1) the level and availability of capital investment for plants and equipment, and (2) the general environment for technological activities, such as the extent of government support for technological endeavors, the utilization and productivity of professionals, and the amount of R&D expenditures.

These general industrial and technological indicators are primarily used at the national level and fail to account for the spatial factor, vital for high-technology industries. Hence, regional concentrations of university, industrial and government R&D facilities may be used as an important indicator of region's technological capability[1] (Malecki, 1988).

As in any undertaking in the social sciences, the character of available data helps determine how the research problem will be tested (Coulam and Smith, 1985). Because much of the data required for a study on technological capability is not available (e.g., technological learning or linkages between universities and firms), and the research was based on a small-sample size consisting of unique cases, this study of the Brazilian informatics industry precluded the use of commonly used statistical procedures, and thus general industrial statistics are supplemented by case studies.

Considering the nature of this research, there are several advantages to a case study approach. First, as King (1984) found, case study analysis of technological capability may flush out factors resistant to quantification such as culture, attitudes, knowledge systems, skill acquisition, and entrepreneurship.

Second, as Mohr (1985) notes, case study analysis has the benefit of being cheaper than large-sample research, and "it generally provides a better opportunity than large-sample research to hunt around for ideas and hypotheses in a new area - the exploratory-research function" (p. 66). Although many ideas were generated during the empirical research for this dissertation, the availability of government data made it possible to go beyond the exploratory nature of the research. A case study approach was chosen due to the cost and difficulty of gathering data from a large number of firms.

Third, the strength of a case study approach is that critical information and facts, some that may be overlooked in a rigid quantitative approach are collected. While large-sample research has the supposed advantage of allowing generalization, case study analysis permits the investigation of internal validity of theory, or to actually observe subjects and events often bypassed by large-sample studies. Case study analysis has been successfully used to show the complex interaction of causes for technological change (Bell *et al*, 1982; Katz, 1982; Stewart, 1984; Dahlman, 1984; Lall, 1987).

A common criticism of case study research is that overwhelming detail based on an insufficient number of cases might inhibit the detection of general patterns. Fothergill and Gudgin (1985) argue that case studies should be avoided because of difficulty with distinguishing general cases from unique cases. A further problem is the strong possibility

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[1] See Davelaar and Nijkamp (1989) for more discussion on indicators and innovation.

that idiosyncratic factors or observation/measurement errors may depreciate research results and conclusions (George and McKeown, 1985). In an attempt to limit this possibility, various case studies are drawn from primary and secondary interviews for comparison and generalization. Generalizations will be based on both cases and general industry data to illustrate the development of technological capability, or problems encountered in the process of attempting to acquire technological capability.

Sequential case study analyses create a learning-by-researching environment, whereby the researcher is able to engage in the dynamic process of experimentation and self-correction of original hypotheses:

> In case studies, a clear demarcation between hypothesis formation and hypothesis testing often is absent, because the research process often involves iterative cycling in which hypotheses are successively "fitted" to observations. Problems with the fit then lead to revision of the hypotheses and may incite searches for additional data. The way in which case studies generally are reported in journals and monographs does not reveal that such a process occurs (George and McKeown, 1985:24).

Such was the case for this dissertation; the actual research process led to constant revision and fine tuning of conceptual components.

Sequence of Chapters

In this dissertation theoretical concepts and empirical evidence are combined to shed light on the development of 'high-technology capability' in a Newly Industrializing Country. Chapter 2 initiates the process of conceptualization by reviewing existing literature on technological capability and identifying concepts and processes that will be integral to the framework of high-technology capability in chapter 3. Chapter 2 begins by distinguishing technological dependence from technological capability. Technological capability is subdivided into stages of sophistication for classification purposes. Processes of acquiring technological capability are explained as largely resulting from learning and accumulating technological knowledge through industrial development. Industrial development, for this dissertation, is interpreted as the growth of technological capability. Industrial development in high technology, however, is argued to occur in regional concentrations, which will be a major theme of chapter 3. The chapter stresses the importance of policy for initiating and driving technological change in Third World settings.

The objective of chapter 3 is to construct a conceptual framework for investigation the acquisition high-technology capability. High-technology industrialization is seen as a process of acquiring technological capability; firms are not only able to engage in increasingly sophisticated technological activities, but also move from foreign to more indigenously sourced technologies. Industry learns or accumulates technological know-how from foreign technology, and then acquires the ability to innovate indigenously. Regional technological infrastructures are argued to be essential in developing this capability. The spatial elements of building high-technology capability, then, require the progressive development of technological infrastructures, based first on the development of quality human resource infrastructure, followed by the development of a local research capability and innovative potential based on a research infrastructure, and culminating in the development of a high-technology infrastructure.

Chapter 4 illustrates the worldwide importance of policy for high-technology development. The chapter develops a policy framework aimed at promoting the elements of high-technology capability identified in chapters 2 and 3. Based on this framework, technological policy strategies used by the U.S., Japan, and South Korea are contrasted. These case studies help identify key policy strategies to develop a high-technology capability, which will then be used to analyze Brazilian informatics policy.

Chapter 5 outlines the general pattern of policy and industrial development in Brazil. S&T policy trends since the 1960s are identified. The creation and evolution of Brazilian informatics policy follows, with special attention on the policy instruments used to create an indigenous informatics industry.

Chapter 6 presents and analyzes empirical findings of the informatics industry. The chapter begins by a brief review of international trends in the computer industry. The evolution of the Brazilian industry is documented, market segments are identified and analyzed, and the components of high-technology capability are examined in depth.

Chapter 7 synthesizes conceptual and empirical conclusions of the dissertation and stresses the usefulness of this research for demystifying some of the complex issues surrounding high-technology and development.

CHAPTER 2

TECHNOLOGICAL CAPABILITY - CONCEPTUAL DEFINITIONS AND DYNAMIC FORCES OF CHANGE

This chapter introduces several concepts related to the process of acquiring technological capability. First, it explains how technological dependence differs from technological capability. As we shall see, the acquisition of technological capability is inextricably linked to transfers of technology. The question arises, then, as to how a dependence on foreign technology is differentiated from a transfer of technology that positively contributes to technological capability. Industrialization in developing countries has gone hand in hand with transfers of foreign technology. The nature of international technological linkages between industrialized and developing countries has often been argued to lead to technological dependency in the latter, significantly inhibiting its technological development. Foreign technology and transfers of technology, however, may have both positive and negative impacts on local technology-related structures. Imported technology can either stymie local technological activities, or contribute to local learning and the accumulation of technological know-how, thereby promoting technological capability. Sections one and two of this chapter address this apparent contradiction by conceptually distinguishing technological dependence and technological capability. Section two will also subdivide technological capability into differing 'stages' based on increasingly sophisticated capabilities. A non-deterministic stage typology allows for classification and determination of industry-firm technological development.

Section three illustrates how industry moves through these stages of technological capability towards technological frontiers. Explicit technological efforts result in learning and accumulation of knowledge and experience that increase technology capabilities and industry development. Technological learning has received little attention from most social scientists (Teubal, 1984). 'Learning' refers to the process of accumulation of skills and knowledge in individuals, and through them, organizations; it arises from any combination of education, training or experience (Bell *et al*, 1982). This is not to be confused with a classical economic definition of learning that refers specifically to changes in performance improvement (e.g., learning curves). Changes in productivity may have little to do with the accumulation of knowledge and skills. Furthermore, the accumulation of knowledge and skills may not result in productivity increases (Bell, 1984). Essential is that technical knowledge and learning are accumulated by people, firms, industries, and even regions.

Section five, however, argues that the foundation of technological capability is significantly influenced by spatial factors, in particular, the local or regional technological infrastructure. Chapter 3 will elaborate on these themes of technological capability and infrastructural development and their components.

Finally, section six depicts how policy influences most realms of technological development. For instance, policy is used to augment infrastructure development, promote industries in which a country has yet to create a comparative advantage, and ensure a beneficial impact from transfers of foreign technologies. Policy, then, is vital on many fronts for creating technological capability.

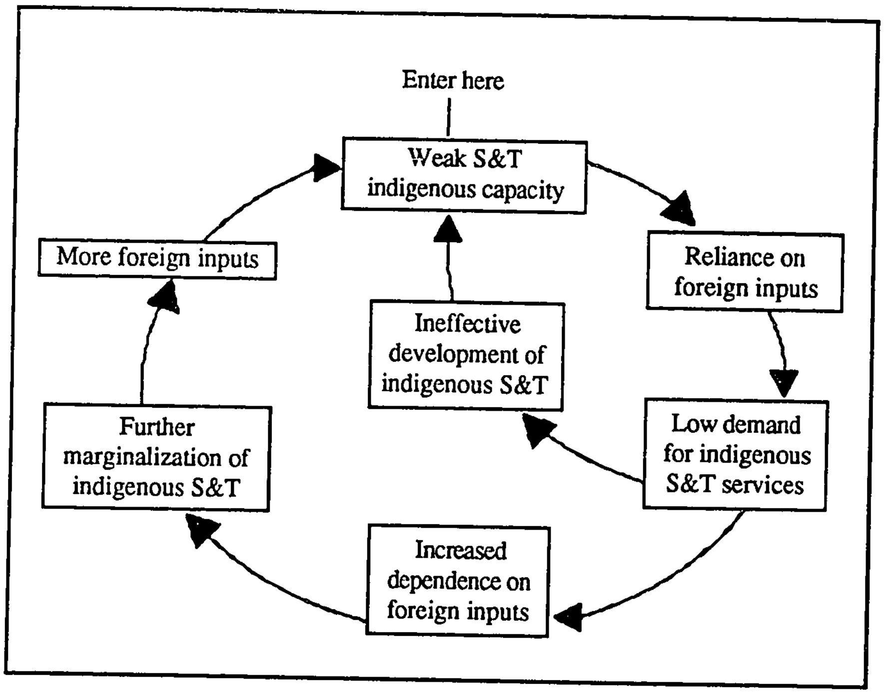
Technological Dependence

Technological dependence is generally thought to be present when most of a country's technology originates in foreign countries. Dependence can be in the form of external reliance on technical information supplied through foreign books and journals, or through the purchase of foreign machinery and capital equipment. More significant in Third World contexts, however, is dependence on technology through foreign investment, including, for example, process knowledge, product specifications, trademarks, management systems, and training. The difference between technological dependence and interdependence is in part illustrated by the balance of trade. Advanced economies tend to trade technologies among themselves, and this trade tends to be more balanced than the technological trade relationship between developing and advanced economies (Stewart, 1988a).

A more complete definition of technological dependence, however, not only emphasizes the asymmetrical flows in the direction of technology and technical knowledge, but also the impact of technological dependence on local technological capacities:

> Technological dependence results when the transfer (purchase or rental) of technology inhibits the receiver country's technological self-reliance. The ability to adapt and eventually replace imported technology by means of indigenous research and development increases local self-reliance. The often monopolistic control of technology originating in dominant countries surfaces in the staggering royalties paid by technology importers and forming part of asymmetrical exchange (Alschuler, 1988: 18).

The central indicator of technological dependence, then, is the inability to use, adapt, and create new technologies; abilities are clearly essential not only for technological development but also for more general socioeconomic progress (Ernst, 1981). The low levels of technological 'ability' in 'dependent' countries arises from a failure of the local system to demand indigenous technological changes, and is evident in the few 'incentives' that might stimulate local entrepreneurs to innovate (Halty-Carrere, 1979). This notion is graphically displayed in Figure 2.1.



Source: UNIDO, 1984.

Figure 2.1 The "Vicious Circle" of Technological Dependence.

From the starting point of little, if any, demand or pressure to stimulate innovation, a vicious circle of underdevelopment is set in motion with the following scenario: lack of demand for indigenous technological change —> low internal supply of technological knowledge —> increased orientation towards foreign technology to meet demand fluctuations —> "marginalization" of the local scientific and technological system through transfers of technology that bypass the S&T system —> lack of adequate internal supply, and so on. To reverse this process of technological underdevelopment, a higher domestic demand for technical change must be established to initiate a gradually larger and effective supply of local technology. However, technologically demanding industrial sectors in most developing countries tend to be in the hands of TNCs.

Many authors have emphasized the negative effects of technological dependence related to reliance on transnational corporation technology[1] and production (Vaitsos, 1976; Müller, 1979). Common critiques are that transnationals bring capital-intensive production techniques to labor abundant countries without design modifications or adjustments to the specific situation of the developing country (Evans, 1979; Storper, 1984; Helleiner, 1977). Perhaps most important is that the transfer of production capacity to developing countries does not imply a transfer of the capacity to innovate.

Developing countries have traditionally relied on transnational corporations (TNCs) for the transfer of more advanced technologies and in hopes of acquiring research and development (R&D) capabilities. Research suggests, however, that TNC investment in developing countries has typically yielded little transfer of high-level technology and that severe costs might be incurred as a result of the external control of technology (Frame, 1983; Kobrin, 1979). Studies have shown that the technology generally transferred is limited to simple product development and adoption to the local environment, and that R&D activities of TNCs remain concentrated in the home country (Malecki, 1981; Baranson and Roark, 1985). Tigre (1983), Massey (1984), Britton (1985) and Jacobsen (1987), among others, have forcefully shown that TNCs (either through foreign ownership or technology transfer) generate little, if not actually inhibiting indigenous R&D and technology capabilities.

Consequently, developing countries have recently begun to examine means of developing their own science and technology (S&T) capabilities (Behrman and Fisher, 1980). Furthermore, within many developing countries there is a strong perspective that to reduce dependence on imported technology they must pursue policies of self-reliance. A policy of technological self-reliance signifies not only the ability to generate, adapt and use technology to meet social needs, but also to exert some choice and control on the degree and nature of technological dependence, a dependence that will remain for many years to come (Ernst, 1981: 467).

Watanabe (1985) suggests that allowing for technological dependence to occur in the short-run may complement the long-run objective of technological self-reliance. He supports his argument by noting the heavy use of foreign technologies by Japan in the 1950s and 1960s and subsequent rapid rise of an indigenous technological capacity. Other

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[1] Several arguments from this view point have already been mentioned in Chapter 1.

examples of heavy technological importation complementing technological development lend weight to the need to conceptually distinguish technological dependence and the importation of technology:

> Technological dependence, although it presupposes technological importation, is conceptually different: it is mainly the impossibility of initiating and maintaining a self-sustained process of technological development... It is the lack of capacity to make appropriate choices between technology importation and local production, or an appropriate combination of both. Consequently, an initial approximate indicator of technological dependence is the ratio between the expenses for foreign technology royalties and licensing costs and the internal investment in local sources of technology (R&D investment) (Halty-Carrere, 1979: 22).

Thus, the reduction of technological imports may not be the best strategy to reduce technological dependence; most important is that developing countries increase the value added to imported technology. To add value to imported technology, or to follow a strategy of 'catch up' to more technologically advanced countries, presupposes an indigenous technological capacity.

Technological Capability

Technological change, which results from innovation, plays a significant role in increasing economic growth and productivity (Thomas, 1987; DeBresson, 1989). Innovation[1] is the introduction of new or better products and processes. The significance of innovation for technological change, however, is often not clearly distinguished; the innovation may result in an incremental technical change, or one of greater significance that induces a radical shift.

In industrialized countries a major part of the technological change is not brought about, as sometimes assumed, through major breakthroughs by highly trained scientists and engineers. More typical technological changes are of the incremental kind, and are found to occur in most countries; new technologies that lead to radically new ways of solving problems and unique technical solutions do tend to occur almost exclusively in industrialized countries (Fransman, 1985: 638; Thomas, 1987).

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[1]For a more complete definition:

"Scientific and technological innovation may be considered as the transformation of an idea into a new or improved saleable product or operational process in industry and commerce or into a new approach to a social service. It thus consists of all those scientific, technical, commercial and financial steps necessary for the successful development and marketing of new or improved manufactured products, the commercial use of new or improved processes and equipment or the introduction of a new approach to a social service" (Frascati Manual, 1981:15).

The study of technological change in developing countries, then, includes not only the ability to produce new innovations, products, or superior processes of production at the 'frontier' of technology, but also any technological effort to move towards the frontier of a particular technology. The technological frontier is defined as the highest possible level of technological achievement (Cimoli and Dosi, 1988; Lall, 1987). Technological change occurs when a firm, through active technological efforts, solves a technical problem far beyond its own relative technological limits, even though the technical problem may have been solved by other firms and is well within the technological frontier.

Accordingly, technological change in developing countries includes: (1) minor and incremental changes of technologies as a result of learning by doing or other informal technological efforts without, perhaps, a formal R&D effort; (2) adoption of technology by individual firms, or any other technological effort changing certain features of the technology, or even introducing innovative modifications (Lall, 1987).

The capacity to carry out these indigenous technological changes to use technology effectively is known as technological capability. Central to this capability are the knowledge and skills embodied in people. The technological capability of a firm (and by extension, of regions and countries) consists of the firm's ability to perform the following technology-related activities: (a) identify the technology required for the product and production, (b) search, select and evaluate the technology, (c) maintain the production processes, (d) modify and adapt the product and production processes, (e) integrate production through the manufacture and production of components, tools, equipment and machinery, (f) implement quality control, and (g) develop new products and production methods, (h) acquire the necessary administrative, managerial and organizational capabilities to effectively perform all the above (Watanabe, 1987: 526).

For a firm to increase technological capability, then, it must engage in efforts to move from the point at which it operates toward the given technological frontier. The firm needs to gain the knowledge required to assimilate, adapt, and improve a given technology[1]. While a technological capability refers to the necessary modifications and adaptations of technology transferred from foreign sources, a growing technological

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[1]Lyons (1987:198) provides a slightly different distinction of technological progress: "Vertical technological progress [is defined] as either: a better way to make the same thing (process innovation); or the same way of making a better thing (product augmentation, e.g. using essentially identical techniques, one is suddenly able to get more memory on the same micro-chip). Horizontal technological progress [is defined] as either: the same way of making a different thing (i.e. a new product using a well established technology); or a different way of making the same thing (e.g. a new specialist capital good which complements the existing range of processes available to make established products).

capability indicates a greater capacity to introduce indigenous technical changes, essential for long-term economic efficiency and growth (Weiss, 1988). It is the growth of technological capability that is commonly known as technological development.

Technological development arises: (a) regardless of whether or not the firm (or country) is at the international frontier of technology, and (b) even though it may be dependent on major innovations from other countries (Lall, 1987). The role of following and catching up to technological frontiers is implicit in Hayter's (1988) definition of technological capability, which is the ability of industry to solve, follow, assess, and exploit scientific and technological problems and developments.

Technological capability is discussed at the level of the firm, the industry -- as explained in Hayter's work, and the nation. At the national level, technological capability determines to what extent a country can utilize established accumulated skills and capabilities with the development of the new technologies (Cimoli and Dosi, 1988). The literature identifies technological capabilities at the national level similar to those of the firm, involving the search, selection, mastering, adaptation, further development of technology through minor innovations, and development of national R&D capabilities (Fransman, 1984: 10). Absent from such 'national' definitions is reference to regional concentrations of technological linkages and structures that significantly define the ability of firms to engage in technological efforts.

The acquisition of technological capabilities, for this dissertation, will be categorized into stages. A first stage, or the 'search stage,' is associated with the capability to search for and select the most appropriate technology at the most favorable price. A second stage, or the 'efficient-use stage,' is achieved with the capability to use technology successfully and efficiently. A third stage, or the 'adoption stage,' is reached when the technology has been indigenously mastered; it includes a reference to the capability to modify or adapt the technology according to local factor prices, government regulations, and changing market demands. A fourth stage, or the 'improvement stage,' refers to acheiving the capability to improve the design of the technology by minor innovations. Finally, a fifth stage is the 'innovative stage,' signifying the capability to create new technological knowledge and other innovative activity (new products and processes) by formal efforts in R&D. Gaining mastery over any of these varied technological activities contributes to a technological capability. Movement from stage one to stage five signifies not only a higher technological capability, but also a greater reliance on indigenous technology. For industry to move in this direction there are two key ingredients: first, the process of learning and technological accumulation by people, firms, industries, and regions; and second, policy that promotes this type of industrial development. The following section examines the former.

Learning Processes and Technological Change

As the preceding sections have illustrated, industrialization may lead to technological dependence and/or technological capability. What distinguishes dependence from capability are, in general, the technological efforts of industry to enact changes. Crucial for an industry to attain greater stages of technological capability is that it learns from these efforts and accumulates technological know-how.

On a more general level, a region's stage of technological capability may be predetermined in part by past experience with industrial activity and the role of technology in development strategies (Lall, 1980: 42). The existence of a domestic capital-goods industry is generally accepted as a pre-condition to develop and adopt innovations (Unger, 1988). Countries and regions with a more sophisticated level of technological capability will generally have a more highly developed capital goods sector, and greater experience with different forms of industrial activity, including that in assimilating technology, but also organizational and managerial experience.

Further refinement of 'technological capability' into stages of sophistication forces us to look deeper into the nature of industrial activity. Technological capacity, according to Ranis (1984), is identified through its functionality; like with entrepreneurship, it is difficult to define this capacity except by the existence of indigenous technological activity. Consequently, the varying stages of technological capability are best demonstrated by evidence of local technological activity by industry. To distinguish between different stages of technological capability in relation to different technology-related activities, several researchers have delineated technological changes based on the process of learning (Lall, 1980, 1982; Fransman, 1985; Bell, 1984).

Technical learning is gaining knowledge of the underlying technological processes and products, or the movement from know-how to know-why (Lall, 1987). 'Know-how' is the capability to implement and slightly modify imported designs, and involves 'learning' of processes; 'know-why' is the capability to substantially change product design and to introduce new products which requires applied R&D, or the knowledge of why it works the way it does and involves 'learning' of products; and the 'enhancement of know-why' is learning at the frontiers of technology, which requires basic R&D (Lall, 1987; Teubal, 1984; Weiss, 1988).

The process of 'learning' is often used to support infant industry protection (Westphal, 1982). According to Teubal (1984) the Brazilian export miracle can be explained, in part[1], by the accumulated knowledge during the import-substitution and infant industry stages. By protection, Brazilian firms were able to first acquire manufacturing capabilities, or know-how based on 'process' learning, and then acquire manufacturing design capabilities, or know-why based on 'product' learning. The acquisition of know-how allowed the firms to successfully adapt and improve technologies, the acquisition of know-why enabled firms to shift to new and more difficult products. Infant industry protection, in this case, allowed firms time to gradually engage in increasingly technology related activities and accumulate knowledge essential to becoming internationally competitive.

The type of learning treated in most economic analysis is 'learning-by-doing', which implies a passive role for the firm; by simply carrying out normal routines, it automatically and costlessly accumulates increased knowledge and skills. In other words, increased doing leads to increased learning; however, there is no satisfactory account of the causal mechanism linking 'doing' and 'learning' with technical change (Bell, 1984; Fransman, 1985).

Technical change through learning, according to Bell (1984), involves explicit effort and investment; the accumulation of knowledge only sets the stage for technical change to take place. A lamentable fact is that many policy makers associate 'learning' (based on explicit technological efforts) with 'learning-by-doing' and indiscriminately apply protectionist policies where doing-based learning processes are important sources for increased technological capacity. At some point, an infant industry will require explicit investment (e.g., a new knowledge base may need to be acquired from outside the existing industry) in technological capacity to overcome problems, and progress further in terms of maturation (Bell, 1984). For example, many firms in developing countries have gained the capacity to adapt imported technology, but mastering the detailed design skills required for adaptation does not ensure an evolutionary progression towards a capacity of introducing innovations through R&D (Erber, 1981a). Hence, protectionist policies may not be enough to promote explicit learning.

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[1]The other factor cited by Teubal for the acceleration of Brazilian capital-goods exports was a reduction in domestic demand. Both factors led firms to eventually increase exports.

While this distinction between learning and doing-based learning is important, doing-based learning is still an important initial mechanism for increasing technological capacity. With industrial development, however, there are successive phases of learning. Lall has identified a technological sequence employing various types of learning processes: (1) 'Learning by doing', (2) 'Learning by adapting', (3) 'Learning by design', (4) 'Learning by improved design', (5) 'Learning by setting up complete production systems', (6) 'Learning by designing new processes' or 'learning to innovate'.

These progressively advanced forms of learning largely parallel the process of industrial indigenization and capital deepening: Early stages of industrial development are dependent on foreign technologies that remain unchanged, but are made more efficient through the *accumulated experience* of workers. Gradually small technology changes are made by shop-floor technicians, managers and engineers that raise the productivity of technology and *adapt* the production process or the product to meet particular local needs. As knowledge of industrial processes is gained by engineers, technicians, managers, and manufacturers, some imported equipment and industrial processes may be *designed* and reproduced indigenously. With an *indigenous* capital goods sector, technological changes are increasingly based on a separate R&D department. Technological changes and learning are based on raising productivity, *designing* production to local markets, and *adapting* processes to local raw materials, conditions and skills. Accumulated experience in using and reproducing particular technologies or families of technologies for manufacturing and designing capital goods will eventually lead to the ability to *produce* equipment, and *engineer* entire factories or plants to specific needs. An advanced and diversified level of manufacturing means the ability to *develop* new processes and products. This ability requires substantial research efforts, based on high scientific skills, R&D departments or separate research institutions. Although this research may not be at technological frontiers, it may lead to processes or products quite different from those first imported into the country. (Lall, 1980: 39-40; Lall, 1982: 170).

Each of these stages generates technological capabilities through the accumulation of knowledge and skills. This may occur when the activities that generate new information translate into learning and technical change. However, the newly accumulated knowledge and skills that are embodied in people may not become immediately evident in the form of technical change, yet still contribute to the stock of a nation's or region's technological capability. For learning to have significant long-run benefits, firms or industries need to consciously raise their capacity to understand, adapt and improve the technology they are using, or, in essence, pursue active forms of learning, for which protected industries sometimes have little incentive.

An additional step might be what Teubal (1987: 196) calls a 'scanning stage,' where initial entrepreneurial skills, knowledge and capabilities are "used to search for a product on which they may base their subsequent growth and profitability." Scanning or search process suggests an active role for the firm, as well as the presence of uncertainty (Fransman, 1985). The search process, according to Dosi and Orsenigo (1988), draws upon a variety of knowledge bases. For example, searching may tap publicly available scientific knowledge, involve monitoring and imitating activities of other firms, utilize the information that results from a firm's linkages with suppliers and customers, or engage the knowledge and capabilities internal to the firm (Dosi and Orsenigo, 1988). Such a step becomes increasingly important with high technology. Entrepreneurs in developing countries must choose from a variety of sources and firms from which they must acquire technology. An appropriate choice must be made to reduce the enormous risk of the technology becoming quickly obsolete (Teubal, 1987; Nichols, 1984).

Teubal (1987), in a study on the learning process of electronic firms, found that technological knowledge gained from R&D, marketing experience and market feedback, and firm reputation are increasingly important as a firm goes through several generations of products. Accumulated technological knowledge and past experience, combined with sufficient investment in R&D and strong interaction with customers, contributed to successful innovative performance. Furthermore, the capacity of the firm to adapt to rapidly changing and available new technologies, where in the electronics sector new and old product classes have a high rate of knowledge complementarity, depends "on the pool of intangibles available from the past and on current investments in R&D, marketing, and infrastructure" (Teubal, 1987: 171).

Knowledge bases, however, are highly differentiated from industry to industry and are specific to the particular technology in question. These differentiations have significant implications for search processes. In some industries the search process is based in formal R&D; in other industries engineering of design and development is the more relevant activity; in others learning-by-doing and learning-by-using activities are sufficient (Dosi and Orsenigo, 1988). Thus, formal R&D is effective in promoting technological change in areas that are inherently progressive, and ineffectual in relatively stable areas (e.g., clay industry). The technological sophistication and evolution of the industry in question determines the relevance of R&D for the strengthening of technological innovation (Sahal, 1983). Hence, the R&D input required is influenced by the product life cycle of the product.

The product life cycle refers to the evolution of a product through three stages: R&D to growth market to mature market (Malecki, 1981b). In the early or innovative stage, product development and production processes are dependent on agglomerations of very skilled and technical labor for R&D, on product improvement, and on production engineering. The initial stage of the product is characterized by high R&D inputs and skill-intensive labor. Financially secure firms characterize this phase, to outlast early diseconomies of scale and low elasticities of demand. The second or growth stage of product development is less dependent for production on skill-intensive labor and R&D inputs. The final stage commences once product standardization has been reached. This phase, based on routine production processes, is capital-intensive and utilizes low-skilled labor. Production is performed by low-wage and unskilled workers, often under bad working conditions with limited opportunities for skill development (Tödtling, 1984). As the product cycle evolves from high-skill and high-wage inputs (including production, administrative and technical workers) to low-skill, low-wage jobs in standardized production, the opportunity for learning and the nature of technical change are also affected.

In addition to learning processes and product cycles, there are differing technical processes and stages associated with a particular technology. Different forms of technical change that take place in developing countries have been identified in the previous section. The first three technological activities listed below involve know-how knowledge, and the last two require know-why knowledge. In this sense movement from the top down requires a greater knowledge and understanding of the technological processes. However, the 'sophistication' or greater complexity of a technology may require more technological capabilities to perform step one, while a relatively simple technology may require less technological capability to perform step four. Technological activities most common in developing countries involves steps 1 to 3.

1. The search stage
2. The efficient-use stage
3. The adoption stage
4. The improvement stage
5. The innovative stage

Establishing quantifiable universal standards for technological capability is difficult and depends on the type and scope of each technology considered (Roman and Puett, 1983). The degree of technological capabilities required to produce and/or efficiently adopt innovations depends on the knowledge base specific to each technology. Each technology requires different types and levels of technological learning by the firm and different stages of industrial development in the country. Different levels of industrial activity, depending on the knowledge base of the technology in question, influence the degree of learning and the 'stage' of technological capability. For example, the successful development of a pin industry will not be comparable to that of a successful computer industry.

Regardless of these ambiquities, an understanding of the various types of learning and technological activities that comprise the development of technological capability allow us to delineate important components of technological change in developing countries. Given a single technology, for instance, movement from stage 1 to 5 is likely if technological learning is occurring. As one goes down the list, the firm relies on more indigenous factors for the development of products, and industrial development becomes more advanced. Spatially, the introduction of a new technology will be limited initially to core regions with access to skilled labor and R&D facilities. The benefits of 'learning,' likewise, will also accrue to core regions. Hence, technological capability and industrial development are significantly determined by spatial elements.

The Spatial Factor of Technological Capability

Technological capability, as alluded to in the previous section, is significantly affected by geography, although this is largely ignored by researchers of technological capability. A geographical, or spatial, perspective of technological capability stresses the importance not only of technological change within the firm, but also the elements external to the firm that influence firm technological progress. Figure 2.2 depicts elements of technological capability by differing geographical scales. Of particular importance to the conceptual framework developed in chapter 3 is the system of technology-related structures and the linkages between them that tend to concentrate in specific regions within a country, rather than equally throughout a country.

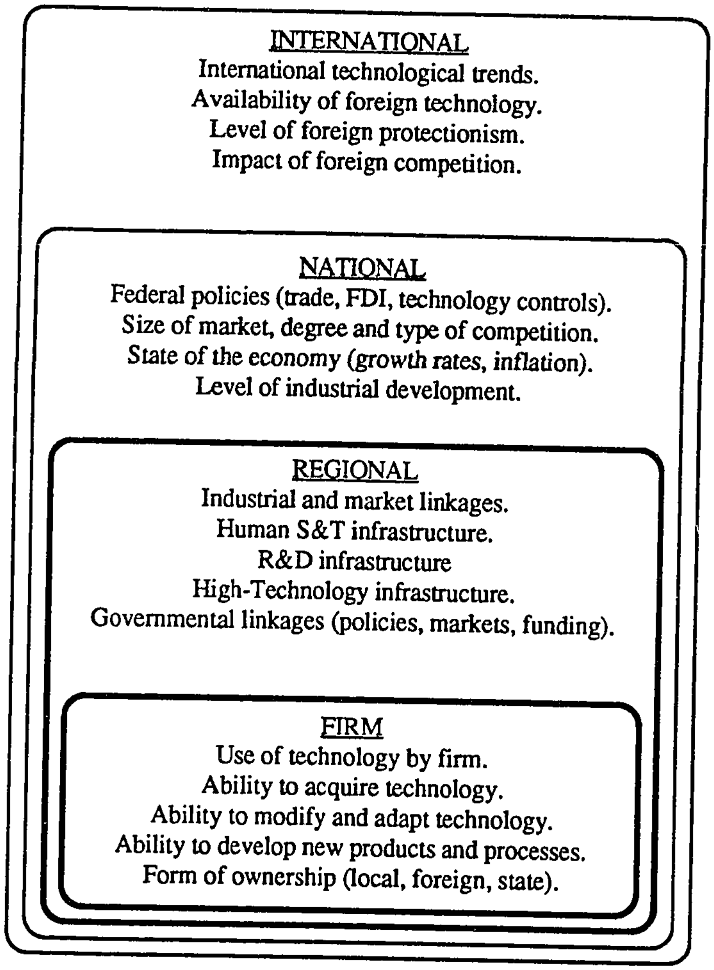

Figure 2.2 Factors Defined by Spatial Scales that Influence and Stimulate the Development of Technological Capability.

The spatial dimension of technological capability underscores that firms or regions are not isolated from international features of technology such as knowledge and ownership, and moreover, it indicates the importance of a regional factor, based on local skills, research institutes and universities, the local economic structure, and the regional culture regarding eduction and entrepreneurship. These technological features of a region are not easily transferable (Malecki, 1988). Hence, the region, or, as will be used in this dissertation, the technological infrastructure, is a key variable and dimension of technological capability.

The use of 'linkage' here goes beyond the traditional concept of industrial linkages. As Krumme (1984) suggests,

> ...conventional multiplier- or industrial linkages are only part of the entire local and inter-regional economic interdependence structure. They are the final symptoms for the workings of the local economy and tend to be rather inadequate prognosticators especially for long-term changes. Financial, corporate-organizational, political, inter-governmental, educational, or strictly personal interaction patterns may eventually provide more satisfactory explanations and predictions of local development processes since they appear to represent some of the additional crucial channels through which short- and long-term development impulses are transmitted (p. 112).

Functional and territorial linkages identify not only the inputs but also the constraints of regional technological capability. The region operates in conjunction with other factors such as foreign technology and the transfer of that technology, the health of the national economy, and technology development strategies. It is the technological infrastructure, however, that significantly defines the technological potential, and illustrate that learning and technological accumulation takes place in people, firms, and regions.

This spatial element of technological capability will be further developed in the next chapter. The following section will introduce one of the main tools for industrial and technological development in Third World contexts - policy.

Policy as a Force for Change

This dissertation has stressed that the focal point of any economic activity is the technology or knowledge about the activity, and that technological progress significantly influences industrial competitiveness, diversification, and economic growth in general[1]. The ability to access and make use of technologies, however, varies widely among countries. The poorest countries have few, if any, options. As a country's science and technological base develops, there is a corresponding change in its capability and options. A central component of creating this technological capability is a policy strategy that specifically includes the technology 'factor.' Once a national goal of indigenous technological capacity is established, policy intervention plays an important role in stimulating technological development[2]. Specifically, this section examines how external

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[1] See Cheng (1984) for a review of the literature.

[2] For developing countries, policy has been viewed as a tool to create an industrial base where none existed before. Technology-oriented policies, however, require a different kind of strategy that may include greater control of foreign enterprises, greater scrutiny over imports of technology, reform of the tax and incentive system, all of which aim to promote or protect technological capabilities (Schmitz, 1984).

policies encourage technological learning and accumulation and strengthen technological capabilities.

The debate in developing countries hinges on what mix of policies will best lead to indigenous knowledge and create technological capabilities. Will technology imports, be it foreign direct investment, licensing, or the import of high-technology goods, strengthen or undermine efforts of developing countries to initiate local technological capabilities? Or, on the other hand, will trade protectionism, with its inherent tendency for inefficiencies, and lack of sufficient economies of scale and international competitiveness, merely make investment for technological capabilities akin to throwing money down a bottomless well?

Developing countries face complex choices and risks when deciding which technological development pathway to follow. The spectrum of theoretical arguments range from technological self-reliance or the 'autarky argument' to the other extreme of 'free trade' or open–economy strategy. Theories generally lack the proper balance of internal and external prescriptions, and tend to remain on the level of either import substitution industrialization (ISI) or export orientated industrialization (EOI) strategies without clearly delineating the technology factor. Furthermore, practical experiences do not necessarily follow these extremes, and instead rely on subtle mixtures that tend to change over time[1].

Trade and Investment Policy, Industrialization, and Technological Capability

Policy aimed at the international level generally targets two components of the economy -- trade and foreign investment. Trade and investment policy may influence the regulation of imports and promotion of exports, the allocation of import licenses and entitlements to credit and exchange, and a firm's taxation and operating subsidies (Cline,

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National economic measures have external and internal components, influencing a wide range of policy instruments such as industrial or trade policy, which in turn affect, for example, tax laws or education systems. Specific policies to encourage local technological capabilities include the provision of financial assistance to citizens to set up business in competition with foreign subsidiaries, the creation of state-run firms, the government might formally discriminate in favour of indigenous firms in public procurement, and price controls. Also specific policies may promote the development of infrastructure, stimulate various forms of local R&D - both in the public and private sector, or develop an educational system - including financing the development of human science and technology skills, and other incentives to adapt and improve foreign technology. The function of these more specific policies will be more clearly illustrated in the next two chapters.

[1]NICs have often pursued a combined strategy of export promotion in some sectors and import substitution in others, for example South Korea and Brazil built up capital goods industries through protective state intervention during the 1970s (Schmitz, 1984; Evans and Alizadeh, 1984).

1987). Strategies that treat trade and foreign investment are categorized, alternatively, as more open (EOI) or closed (ISI). An open strategy emphasizes exports with relatively low protectionist barriers to imports, and encourages cooperation with TNCs for investment and technology. A closed strategy protects the domestic market from imports and restricts investment and production by foreign firms, creating opportunities for local firms to invest in indigenous technological development.

Singer and Ansari (1988) remind us that the debate between import substitution and export oriented industrialization is somewhat misleading; developmental strategies combine elements of both based in part on the size of the country's domestic market, the geographic location of the country, its relationship with foreign countries, and its resource endowments. Some form of government intervention in trade and foreign investment is often called for. Protectionism, it is argued, can increase the incentive to invent and the amount of resources devoted to innovative activity (Lyons, 1987). A protectionist policy conducive to development, according to Singer and Ansari (1988), needs to include the following characteristics:

> To begin with, the LDCs must pursue a consistent protectionist policy. This is a point that has to be stressed, because in most LDCs the system of protection has evolved in a very haphazard way. Tariffs and taxes have been imposed, modified and withdrawn at different times in response to the pressure of circumstances and of individual investors, and the effect of these sporadic measures on the different industries has been very varied...
>
> Protectionist policies must also aim at providing incentives for the growth of the technological resource potential of the poor country. It is important to realize that, unless the technological backwardness of the developing world is eliminated, the poor countries will find it impossible to tackle the problems of low productivity levels, economic inefficiency and high unemployment rates. An overriding aim of policy in developing countries should be to promote the development and use of local resources (including labour resources) and the development and import of suitable technological capacity. These considerations apply with equal force to both rich and poor developing countries (pp. 149-150).

In many instances the state has become directly involved with technological development through state ownership and control of technology-using and -generating firms and institutions (Fransman, 1985). Indeed, a notable tendency in many developing countries has been the active state participation in the economy, which, in some cases, contributes significantly to the modern, indigenous sector of the economy. While this process might seem positive in terms of indigenous technological advancement, several developing countries, according to Burnell (1986), reveal a tendency toward an unequal distribution of this newly 'indigenized' wealth and income, solidifying existing social divisions and concentrations of economic power. Questions arise, then, as to what national economic interest is being served.

If the national economic interest is aimed at fostering indigenous technology development and increasing the capacity to innovate, the ability to control foreign technology inflows are essential. Without such control indigenous policies would be continuously undermined (Halty-Carrere, 1979; UNIDO, 1984). Policies that control the flow of foreign technologies often find their expression through 'indigenization' of the local economy. Indigenization, according to Burnell (1986), is the official reservation of an economic sector exclusively to nationals, and the requirement that companies have local equity and managerial participation by private local parties or the state.

Measures that contribute to indigenization range from financial assistance to private or state-run firms to government procurement of local products. They might restrict the activities of foreign firms and protect infant industries, or regulate the allocation of import licenses and entitlements to credit and foreign exchange (Burnell, 1986: 157). Indigenization, though a costly and difficult process, may promote technological learning. Infant industries that merit protection on economic grounds will ideally, through the learning and development process, become efficient enough to be internationally competitive. Also justifying protection is the need of a guaranteed market for firms to achieve economies of scale and eventually make the targeted industry viable in terms of, efficiency and competitiveness (Burnell, 1986). Depending on the difficulty of the technology being acquired and eventually mastered, infant industries may transfer technology informally or off-the-shelf, and the government protection may be limited to the final product or the technological development process itself (Lall, 1987).

Infant protection may appear 'inefficient' and never ending, but the long-term results may well be an important investment (Kaplinsky, 1984a). Even the World Bank and IMF support short-term (with a pre-announced and credible timetable for withdrawal), specific and selective infant industry protection to protect local suppliers, especially when foreign suppliers have market power in areas with important implications for technical capability, technical change and technical 'skills' and 'mastery'.

In general, however, these international institutions favor outward-oriented trade policies for technological development, noting that they have been more successful than inward-oriented policies.

> Producers of technology often face high risks, since the outcome of innovation is uncertain and technologies can sometimes be easily copied. Purchasers of technology

> also face risks, because they often cannot know just what they have bought until they have acquired and used it. Technologies often require substantial adaptation to local circumstances; those that come in the form of machines or blueprints require a substantial complementary input of human capital. Although the process of international technology acquisition is complex, the problems are no different from those faced by firms in the normal competitive process in advanced countries. And for the same reasons it is difficult to define the best role for government in developing countries (World Bank, 1987: 64).

The World Bank argues that a preferable policy for nascent firms would be one which allows them favorable access to imported inputs, availability of below-market rate loans, and explicit and implicit subsidies in order to avoid the costs (e.g., high prices, overvalued exchange rates, etc.) of protecting an entire industry from import competition. The World Bank notes, however, that the United States and Japan became industrial leaders by copying and modifying foreign technologies (World Bank, 1987).

ISI regimes are generally characterized by high levels of protection for manufacturing, direct controls on imports and investments, and overvalued exchange rates. There are several arguments against import substitution industrialization (ISI), as the World Bank argues emphatically:

> The experience of developing countries over the past three decades suggests that when direct controls replace market mechanism, economies work less efficiently. An economy that imposes few barriers to trade and encourages domestic competition is likely to develop an industrial sector that is more efficient in its use of resources and more competitive in international markets (World Bank, 1987: 131).

By contrast, export-oriented regimes link the domestic economy to the world economy and create more competitive environments. The World Bank argues that successful technological development ultimately depends upon the desire of firms to improve efficiency; as such firms require an environment that rewards those that lower their costs and penalize those that do not. Local firms or public enterprises that license proven technologies for highly protected markets have little incentive to adapt the imported technology, resulting in little change of national technological capabilities (Segal, 1987a). Technological development policies should therefore promote competition and competitive factor markets, the freedom of firm entry and exit, allow for domestic prices to reflect the laws of supply and demand, and create conducive environments for foreign direct investment to facilitate the inflow of new technologies. Naturally, local firms, given such an environment, would have little incentive for local technological development (see Figure 2.1). The government, to counter the limitations of firms to invest in local technologies, should allow firms to register patents, subsidize technological efforts, promote specialized agents for technological development such as public supported R&D institutes, and provide education (World Bank, 1987).

World Bank-like, short-time period protection, although useful for importing technologies and rooting out X-inefficiencies (the economic cost of a quiet life), has little relevance for developing genuine indigenous capabilities, which require longer time periods (Kaplinsky, 1984a). Britton (1985) emphasizes that the 'free market' is a myth, and that all governments intervene to promote technology and R&D by heavy defense expenditures, large government procurement contracts, even outright grants or subsidies for production and export, the use of non-tariff barriers against imports, and the immense marketing power of TNCs.

The link between free trade on the one hand and technical progress and increased productivity on the other is highly questionable. Free trade is not a necessary condition for the achievement of international competitiveness (although this is not to deny that under some conditions free trade may assist such competitiveness) as seen by the fact that some infant industries under protection rapidly attained international competitiveness (Fransman, 1985). Pazos (1987) supports this argument and emphasizes that many Latin American infant industries have been able to compete with mature industries in the industrialized countries. In fact many protected infant firms have become exporters, even without any explicit policy to promote exports.

Extensive research by both Lall (1984) and Katz (1984) concluded that in some situations the protection of local knowledge-creating capabilities is justified. Lall points out that there is a difference between the protection of goods verses the protection of learning; the promotion of learning within local firms occurs by restricting the importation of technology through direct investment by TNCs, which leads to a greater propensity to export technology. Katz argues that countries like Brazil can protect infant industries since the domestic market is large enough to develop international economies of scale.

The size of a country is very important in influencing policy strategies. Not only does it affect the likely availability of human resources and physical endowments, but it also determines the importance of the domestic market relative to the international market. Protection of domestic markets will be more important in large countries, and technological activity will be broadly balanced between developing appropriate products and processes for that market; while in smaller countries the international market will have more relative importance, and international competitiveness is maintained by adapting new labor saving products and processes from abroad for the export sector (Ranis, 1984).

Not only is the strategy adopted (protection or export orientation) important, but so is the ultimate success of the strategy to induce industrial expansion and stimulant local technological activity. As Stewart (1984) points out, however, protectionism is more likely to stimulate product type innovative activities, while export oriented policies tend to lead to the importation of product designs from abroad and technological activities of the process type (that reduce costs and more labor intensive) to compete in the international market.

Based on Brazilian informatics policy, Hirschman (1987) has identified yet another strategy for those countries that have achieved industrial maturity: import-preempting industrialization. This strategy goes a step beyond import substitution industrialization and defies the laws of the product cycle and static comparative advantage. An import-preempting policy temporarily reserves the country's domestic market for the domestic manufacture of some new product currently produced abroad and not yet imported in large volumes. The success of this policy depends on a strong potential domestic market, advanced industrial engineering capability to replicate foreign prototypes, government (especially military) support and special interest in the domestic development of the industry. Hirschman adds that such a policy should be used only in restricted or exceptional cases, or in industries labelled as 'epochal' where the entrance of TNCs could not be dislodged by domestic firms by free competition, and that the policy have a time limit to ensure that domestic firms mature. While such a policy may be criticized on the grounds of wasteful reinvention, Hirschman argues that it might positively balance reinvention with local knowledge for the benefit of industrialization and creativity.

Trade policy is fundamental for technological development in Third World countries; however, it must be joined by more specific science and technological policies to ensure that firms engage in technological efforts and create an environment conducive to technological activities (see chapter 4). Policy should have long-term objectives and specific priorities, and its main purpose should be to bolster the local technological infrastructure to lead to more indigenous R&D. As learning is an important part of technological change, policy also benefits from learning. Policy strategies, instruments, and institutional arrangements continually require improvements to adapt to constraints and exploit new opportunities. These specific policies will be elaborated in the next chapter, which conceptualizes the development of a high-technology capability.

Third World Strategies for Technological Development

Country specific technology development strategies[8] may be defined in a general way by macro- and micro-economic realities that set constraints on policy options. A country's choice of particular policies, naturally, is based on factors such as: historical experience, market size, level of the technological infrastructure, the nature of the technologies targeted for development, relationship with TNCs, and the state of the world economy. Technological development in a country is limited by both the interaction of technologies with national endowments, and by the constraints of government policy (Lall, 1987).

As previously stated, openness to foreign direct investment generates a high level of technological imports that may retard the development of local supply firms in addition to the usual low levels of R&D within subsidiaries (Britton, 1985). A strategy to reverse this negative process necessitates the building of a solid infrastructure for research and technological activities, carefully choosing from foreign technologies and adapting and improving them according to local circumstances (Burnell, 1986; Lee, 1988). To implement such a process, however, is much more costly and complicated than it appears.

There are difficulties in overcoming prevailing international patterns of economic activity and technological capabilities. Core industrialized countries base their dominance and competitiveness on the development of new, sophisticated, knowledge-intensive, technology-deepening industries. These industries require highly skilled labor and have high value-added content. Poor peripheral countries engage, if at all, in mature, standardized industries that depend on cheap labor or natural resource availability. Technology and innovative capabilities are limited, and productivity growth is slow. Semi-peripheral Newly Industrializing Countries lie in-between the core and peripheral categories in terms of capital- and skill-intensive industries. Core countries still are the source for research and new productive techniques, and their national economies rely on indigenous investment for the deepening of the industrialization process (Kiljunen, 1986).

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[8] Technological development strategies are made by governments through various institutional structures. Within institutional structures, those with decision making power, and those with influence on decision makers (such as officials within government research institutes, university researchers, or industrialists) will each have their own agenda for the type of strategy adopted. Essentially what is required is a strategy to build up the local technological capability and to establish higher levels of "self-reliance" in the technological field. However, the various 'members' of government may have a different knowledge of available, or potential, technologies for possible indigenous development. Consequently, what self-reliance means in practice is difficult to state generally, each country separately identifies its pathway. In developing countries, technology decisions are not left to the market nor to private industrial companies, except for implementation (Behrman and Fischer, 1980: 85).

Table 2.1 Relationships between Technical Skills, National Technological Capabilities, Technological Development Strategies, and Industrial Product Emphasis.

Technical Skills	Technical Capability	Dev't Strategy	Emphasis & Cycle Phase	Major Characteristics
-Frontier R&D Basic Research Applied Research Development -Major Innovation	Generation of Original New Technology	Offensive	-Original Innovation -New Products	1) First in the world in introducing new products & processes. 2) "Maintain the Lead" Objective: Keep the technology gap. 3) "Frontier" Research.
-Strong R&D Capability -Design Engineering -Production Engineering	-Generation of New Technology Packages -Adaptation & Improvement of Foreign T -Opening of T Package	Defensive	-Secondary Innovation -New Growth	1) Follow the leader country as close as possible. 2) "Catch up and Overtake" objective. 3) Foreign T adaptation & improvement. 4) New T package & product differentiation.
-Adaptive Development -Consultant Services -Design Engineering (Adaptive Design) -Product and Process Engineering -Information (Patents)	-Adaptation of Foreign Technology	Imitative	-Tertiary Innovation (Diffusion of Existing T) -Growth	1) Following the leader with a short T gap. Importing proprietary T (Patents, Licenses) 2) Process Improvements (Incorporating productivity). 3) Foreign T adaptation.
-Production Engineering -Product Evaluation Techniques -Industrial Eng. and Management -Basic General Eng. Capability	-Investment Projects: Formulation & Evaluation (Including Evaluation and Selection of Foreign Technology)	Dependent	-Tertiary Innovation (Diffusion of Existing T) -Mature Growth	1) Satellite or subordinate role to T stronger countries. 2) Following them with a long T gap: Importing know-how & Technological assistance. 3) Copying (little product change).
-Lower Management Training -Technicians Training -Vocational Training -General Education	-Create gradually an industrial mentality and climate.	Traditional	-Local T -Local Products	1) No contacts with foreign technology. 2) T based on traditional skills. 3) No product changes (no demand for it).

(Adapted from Halty-Carrere, 1980).

What, then, is the potential and proper strategy for developing countries to acquire new, sophisticated, knowledge-intensive, technology-deepening industries? Table 2.1 illustrates possible relationships between stages of technological capability -- largely determined by the technological infrastructure, accumulated know-how and technical skills -- and at each stage the policy strategies for technological development.

The possible strategies for technological development are highly interdependent with the existing stage of technological capabilities, as are the probable technological changes and outcomes (see Table 2.1). As technological capabilities increase (from bottom to top), strategies may move, for instance, from an imitative strategy, based on captive markets with mature technologies, to a more defensive strategy which necessitates a rapid reaction to new products introduced internationally. A defensive strategy requires more investment in R&D for the adoption, improvement, and new generation of competitive technologies (but not the state-of-the-art technologies), and may be achieved in developing countries by the selective protection of some industries. Such a movement will likely result in substantial benefits via technological learning.

In 'follower' countries it is clear that technological developments in science-based activities, like computers, require a set of public policies involving different forms of protection and state support for local industries (Cimoli and Dosi,1988). The NICs are semi-peripheral economies that are increasingly adopting defensive strategies for the development of certain key industries and economic sectors. For these countries, which include all the NICs, a defensive strategy in some high-technology sectors has become a viable option. The growth of technological capability presents more opportunities for indigenous technological change than relying entirely on foreign technologies and TNC investment.

For those countries that are not endowed with information technology industries but anticipate to initiate such industries there are essentially three types of strategy:

> 1) To attract trans-national corporations (TNCs) to set up production facilities.
>
> 2) To build up 'national champion' companies to compete with the TNCs, particularly in the supply of home markets.
>
> 3) To identify 'niche markets' at national and international scales, which could be exploited by indigenous companies, given the existence of targeted industrial policies (Gillespie *et al*, 1988: 65).

To build a technological capability, the most plausible strategy for semi-peripheral countries is the niche market approach. The task is to guard against an indiscriminate proliferation of high-technology imports and to emphasize the selective indigenous acquisition of some strategic and lead technologies. These so called 'industrializing industries' would allow the optimum use of local resources, enhance scientific and technological capacities, create dynamic inter-industry linkages, increase technology-intensive exports, and may reduce imports by TNCs (Ernst, 1981; Britton, 1985).

Choosing a high-technology sector alone, however, is not sufficient, as Stöhr (1988) warns:

> If only a small number of 'high-technology' sectors are created whereas 'traditional' sectors remain widely untouched by it, technological disparities will increase rather than decline; the same would be the case if only a few large enterprises in specific sectors would take advantage of (or monopolise) technological innovation, whereas the medium and small enterprises would hardly be affected by it... (p. 205).

The objective of developing countries, then, is to identify leading or key sectors within their reach, design an industrially relevant science, technology and trade policy, and coordinate the educational structure with the changing occupational structure (Caporaso, 1987). Linking the new sector with other economic sectors and indigenous sources of knowledge are, of course, also important.

Conclusions

This chapter has identified technological capability as the ability to use foreign technology efficiently and to generate indigenous technological changes, including, for example: minor or incremental changes of a foreign technology that result from informal learning by doing, more sophisticated changes that result in significant modification of a technology, changes associated with the development of new products or processes that result from an indigenous research effort. The ability of a firm to enact increasingly sophisticated technological changes requires active efforts. It also requires a supporting infrastructure that provides the firm with the necessary inputs (e.g., human resources, industrial linkages). The region, then, significantly influences the capacity of firms to carry out technological changes, and thus is a vital component of technological capability.

Industrial activities and technological changes that require conscious technological efforts have a significant outcome: learning and accumulation of knowledge and experience. The varying levels of technological change have corresponding impacts on the amount of learning and technological accumulation. As with technological change, learning accumulates from slight changes of foreign technology (learning by doing), or more significant modifications of transferred technology (learning by adapting), or from developing new products and processes (learning to innovate). While this process is difficult to quantify, it is a significant dynamic force in acquiring technological capability.

In Third World countries, industrial development, technological change, and learning are all reliant to a great extent on policy. While there are many different policy pathways, historical experience indicates that in several cases selective infant industry protection has promoted technological learning, industrial development, and technological capability. Protection stimulate industrial technological efforts and thus learning, may be more productive than simply protecting an industrial sector that might have little incentive to engage in technological activities. Countries with large markets, and a greater availability of human resources and other 'technological' endowments, are more apt to follow import substitution policies since firms have the possibility of developing larger economies of scale and will face greater internal competition.

CHAPTER 3

HIGH-TECHNOLOGY CAPABILITY - AN EVOLUTIONARY FRAMEWORK

Surprisingly absent from the rich geographic literature on high-technology and technological change are considerations of high-technology in Third World contexts. Development issues such as the dependency-inducing tendencies of new technologies and possible avenues for technological development have been bypassed. Although geographers have clearly established the important role of high technology in economic development (Thomas, 1985, 1987; Oakey, 1979; Ewers and Wettmann, 1980; Thwaites and Oakey, 1985; Malecki, 1983), existing theoretical and empirical high-technology research remains concentrated in the industrialized countries. Lacking is adequate theory and empirical research not only of the 'potential' role high technology plays in developing economies, but more importantly, of the means of creating indigenous capacity in some segments of the industry.

This chapter, in an attempt to rectify this lacuna, presents an evolutionary framework for acquiring high-technology capability. Specific questions addressed are: What is the role of foreign technology verses indigenous innovation? How is a local research capability developed? What are the necessary spatial structures and linkages? To answer these questions conceptual themes are drawn from research on technological capability in developing countries, and that on the development of high-technology in industrialized countries. The framework, in general, has two themes: how industry in developing countries advances from technological dependence to stages of higher technological capability[1], and how supporting infrastructures provide industry with the tools for enacting technological changes.

The framework is used to analyze the recent development of high-technology activity in Third World contexts and, in particular, the case of the Brazilian informatics industry. The following section briefly introduces the elements and processes for acquiring a high-technology capability.

[1]Much of this theme was developed in chapter 2.

Building Blocks of High-Technology Capability in Third World Contexts

Economic growth and industrialization are common goals of most developing countries. As countries attempt to expand and increase the variety of local industrial activities, however, they encounter a number of obstacles, both local, such as limited local resource endowments, and international, such as protectionism in industrialized countries. Perhaps the most significant factor that hinders industrialization and trade in manufactured goods on world markets is the technological gap that separates them from advanced industrialized countries. Technological change, as Berry *et al*, (1987: 328) state, is one of the most dynamic elements in today's economy. It has the power to transform national "resource endowments in profound ways." Regarding developing countries, however, the technological situation is characterized as follows:

> The less-developed lands generally lack the research and development funds, the labor skills, and the professional, scientific, and engineering personnel required to invent and innovate. Instead, they must rely upon borrowed technology, which often is inappropriate for their need and obsolete before it reaches them (Berry *et al*, 1987: 329).

An analysis of high-technology industrialization in Third World countries, then, requires a conceptual framework that addresses the building process of technological capability and industry development. Industry development, for the purpose of this dissertation, is considered to be a process of technological advance or increasing technological capabilities. The development of technological capabilities in a Third World context, as identified in chapter 2, is a process of transferring technology -- selecting, efficiently using, adopting, and improving foreign technology -- and eventually developing an indigenous innovative capability.

The development of a high-technology industry, then, involves external linkages to the industrialized countries. The transfer of technology, and its local impact, represent important processes of indigenous technological capability. Important is the ability of industry to learn from the foreign technology transferred, making possible local technological changes. An effective transfer of technology and a greater ability to learn from and assimilate foreign technology will be affected in part by the existing level of industrial development, the local capacity of firms to absorb and assimilate technologies, and the complexity of each technology in question. The ability to enact sophisticated technological changes, however, rests on developing an indigenous innovative capability and local indigenous R&D activities.

While a positive use of foreign technology and the development of a research capability rest in the hands of industry, this dissertation advances the notion that both processes are explicitly linked to the development of supporting infrastructures. Infrastructures are interpreted here as the sum of external support systems including human resources, financial and research institutions, and institutional markets, and linkage systems which are at the collective disposal of firms.

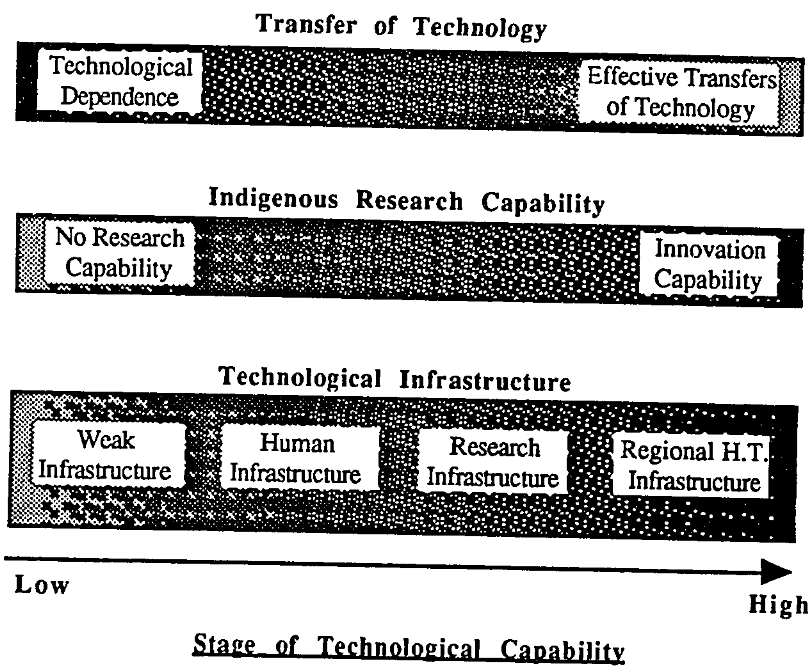

Figure 3.1 The Process of Building a High-Technology Capability.

The development of a technological infrastructure starts with the building of a high-quality human resource base. Enhancing the infrastructure for indigenous innovation capabilities requires a network of research linkages. High-technology activities necessitate the spatial agglomeration of these infrastructural elements. High-technology capability, then, is a function of infrastructural development to create a favorable regional environment for firms to engage in sophisticated technological activities and readily utilize advanced foreign knowledge and technology. These components overlap and build on one another, and linkages among the different components are vital for successful technological activities and change.

This dissertation, then, analyzes industrialization through technological capability and infrastructural development. It goes beyond more common economic analyses based on international competitiveness (e.g., pricing and exports), or the ability to produce at the technological frontier or "state-of-the-art." While attaining international competitiveness and technological leadership are important indicators of industrial development, used alone they are incomplete. For example, industrial 'success' is usually associated with the ability to compete in international markets; however, the potential to export may not actually lead to exports. Furthermore, one firm may be successful in resolving technological problems and initiate significant changes, signifying greater capability than another firm that exports without understanding the technology (Lall, 1987).

Industrial development, then, must also be examined through abilities to 'learn' and understand technology. Industrial development may be differentiated by the technological stages of industrial activity, including: (a) the search for and acquisition of new products and processes, (b) the efficient use of technology, (c) the ability to modify, adapt, and improve technology, (d) the ability to attain the 'best' technological solution, locally or abroad, implying an ability to generate new products and processes through research and development. Additionally, enabling industry to progress technologically requires a well developed technological infrastructure for local research and innovation, and high-technology activities.

The following sections of this chapter further develop these elements of technological capability; namely the ability to effectively transfer technology, acquire an indigenous research capability, and develop human resources, research linkages, and regional agglomerations of these structures.

Transfers of Technology and Acquiring Technological Capability

Technology is obtained, in general, either locally or abroad. Of course, there are many possible combinations and degrees of foreign and local participation. A technology being of 'foreign origin' signifies that there has been a transfer of technology. The transfer of technology may be defined as,

> the purposeful movement of an existing technology to a setting in which it had not been previously used. This may take the form of the same use of the technology in a different

location, a modified use of the technology in the same location, or a combination of these two conditions. The international transfer of technology adds to this definition the concept that the technology is being transferred not only to a new location but to a new location within a different political and cultural entity (Smith, 1981: 4).

Indigenous technology is less clear, but has been defined by James (1979):

> At the two ends of the poles, there can be little confusion between transferred and indigenous knowledge. If the research is financed and staffed by wealthy nations, and housed exclusively in more developed countries, any knowledge produced is a candidate for a transfer; if research is financed and staffed by nationals, and housed in LDCs, it is indigenous.
>
> Most situations, of course, do not fit these pristine categories. The basic research, for instance, may be acquired from MDCs[1] and the basic or applied, developmental, and commercial research may take place in LDCs. A research effort may be partly financed and staffed by foreign aid agencies, international organizations, foreign nonprofit nongovernmental organizations, or foreign private enterprise and combined with financing and staffing indigenous to LDCs... The phrase "more indigenous research" then really refers to a shift of resources along a whole spectrum of possibilities including acquiring the knowledge in a less developed condition and performing the later stages of research and increasing the financing and staffing of domestic research by LDCs (p. 84).

"Indigenous" technology, as the above quote suggests, is a relative concept. In developing countries perhaps the only true indigenous technologies are traditional technologies. However, those that use more local 'resources' are considered more indigenous, even though the innovation or perhaps certain components are foreign. In this sense, foreign technologies may become relatively indigenized if they are learned and improved and depend increasingly on local inputs[2].

Transfer Channels of Foreign Technology

The variety and complexity of technology is illustrated through the elements which are transferred, including: (a) physical assets, such as the setting up a plant, machinery, equipment; (b) technical and commercial information, such as the sale of blueprints, patents and similar technological 'instruments', process know-how, quality control, organization and operating methods, etc; (c) human skills, most often in the form of specialized professionals and engineers -- this component is the most crucial since all knowledge is generated and ultimately resides in human beings (Kng *et al*, 1986). Furthermore, there are

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[1]MDC = more developed country.

[2]An important distinction is whether the 'indigenous' technology is based on a product and process innovation. Products and processes are ingredients of technology that can be bought, sold and transferred. Process innovations, however, are more readily available and diffuse over space more rapidly because of the relative confidentiality of product innovations. A better indicator of a region's indigenous innovative potential, then, is its capability to develop product innovations (Oakey, Thwaites and Nash, 1982).

a number of potential suppliers of technology, including individuals, corporations, government agencies, universities, and research institutes (Smith, 1981). The ease of the technology transfer will be greatest when the recipient possesses a technological knowledge base that corresponds closely to that embraced in whatever is being transferred (Thomas, 1979a).

Not only are there a range of technology transfer elements, but many channels through which technology may be transferred, with differing levels of foreign and local participation, including:

1. Foreign direct investment
2. Joint ventures
3. Licensing
4. Franchising
5. Management contracts
6. Marketing contracts
7. Technical service, assistance contracts
8. Training and educational contracts
9. International sub-contracting
10. Architectural and engineering contract
11. Research and development contract
12. Construction supervision contract
13. Turnkey contracts (construction, plus bringing a plant or project to the point of operation
14. Turnkey plus contract (a turnkey contract plus the training of local staff to operate and maintain the plant or project)
15. Exportation of hardware (embodied technology)

(UNCTC, 1987: 2; Robinson, 1988: 5-6).

Turnkey contracts[1] are generally thought to involve the greatest foreign and least local participation. A commonly identified problem with turnkey operations is that the technology is transferred in an embodied form (e.g., the technology is embodied in the plant or in the processing and assembly; or is purchased in an off-the-shelf form), limiting the learning-by-doing effect. Foreign direct investment and internal transfers of technology within TNCs[2] may also transfer embodied technology and limit recipient know-how. Licensing, know-how contracts, and technical services and other forms of disembodied technology transfers may involve less foreign and more local participation then foreign direct investment. Disembodied technology transfers may involve substantial transfers of know-how if the recipient country has a solid science and technology capability.

---

[1]Turnkey contracts or 'systems' selling denotes, for instance, when a whole plant is built by the foreign partner and the keys are then handed over to the importer.

[2]TNCs are the principal agents of international transfers of technology (Frame, 1983).

It should be noted that there is no one best mechanism of transferring technology. The effective transfer through TNC subsidiaries is often questioned, although the role of each subsidiary varies greatly. The role of a subsidiary may range from a production-only branch plant to a quasi-autonomous operation with innovation, manufacturing, and marketing rights, the latter being more probable in an industrialized country (Young *et al*, 1988).

Passive forms of technology transfer require more active local participation and are "probably at least as important as invention as a source of technological progress" (Lyons, 1987: 177). Passive forms of technological transfer arise from nationals going abroad for education, training and work experience, the use of foreign technical journals, and reverse engineering (or imitation -- copying foreign products) (Dahlman and Westphal, 1982). Education abroad has, historically, been a very important, although costly, means of transferring technology over the long-run (Frame, 1983). Passive forms of technological transfer activity usually rely on technological know-how that is non-proprietary in nature or publicly available information. Proprietary know-how, on the other hand, is private knowledge and is only available, if at all, for a price (Kng, 1986).

'Reverse engineering' was widely used in Japan during the 1950s and 1960s, and involves the manufacture of a product that is similar to one already in the market -- the product is taken apart in order to learn how it was originally put together. Reverse engineering does not involve a formal transfer of technology. According to Freeman (1988b), reverse engineering had a significant learning effect for Japanese firms and continues to influence the Japanese system of innovation:

> [The Japanese] approach to product and process design, often originally developed through reverse engineering, created a new style of innovation management which reintegrated R&D with engineering design, procurement, production and marketing even in the largest organisations. As development, production and marketing went ahead, the whole organisation was committed to the new products and processes in a way that was relatively uncommon in other countries. Moreover, once development work began, lead times were often very short, especially in the electronics industry (p. 337).

Regardless of the form of technological transfer, the mark of a 'successful' transfer is that the technology is completely assimilated by recipient firms, adapted to local economic conditions (factor prices, input availabilities and market characteristics), and diffused throughout the wider economic system (UNCTC, 1987: 33; Smith, 1981).

Access Conditions to Foreign Technology

The transfer of technology can be costly and restrictive. It is important to distinguish between the transfer of knowledge related to the operation of the specific technology and that which allows the licensee to continue development along the technological trajectory for that industry or product (Unger, 1988). For example, licensing agreements sometimes limit the opportunity of learning by doing, leading to the underdevelopment of internal capabilities to produce technology in the borrowing countries (Mytelka, 1979: 129-35). Actually transferors of technology commonly impose a variety of restrictions or conditions regarding the use of the technology transferred, including the following:

> •Tied-buying provisions, that require the technology recipient to buy certain materials, components, machines, or continuing services from the transferring firm, not in the open market.
>
> •Technology grant-back, that requires that any innovation, new adaptation, or improvement achieved by the recipient to be granted back to the transferring firm.
>
> •Export restrictions where products manufactured with the transferred technology may not be sold in specified countries, or where the transferee needs permission before export, or other export limitations.
>
> •Application or field-of-use restrictions, which limits transferred technology to only certain specific applications or limited groups of related uses.
>
> •Exclusivity provisions that prohibit licensee from further transfers of the technology, or at least require the permission of the transferring firm.
>
> •Collateral licensing prohibitions where the technology recipient cannot obtain similar technologies from other technology sellers in the same field.
>
> •Agreement to not contest the validity or ownership of any proprietary technology transferred (Robinson, 1988: 74-76).

A successful or effective transfer of technology, then, requires not only local capability to use foreign technology efficiently, but also the ability to bargain with the transferor or donor to limit access conditions.

Conditions for Successful Transfer of Technology

The bargaining power of the firm or recipient depends on several factors, which have been summarized by Frame (1983: 86-87). First is the technological capability of the recipient. An understanding of the technology puts the recipient in a better bargaining position to force the donor to reveal more 'know-why' of the technology, eventually allowing the recipient to improve the technology transferred. If the recipient's technical skills are very good, reverse engineering might be a way to completely avoid negotiation. Second is the recipient's ability to bargain, as dictated by their knowledge of the technology itself and by the donor's sales position. Knowledge allows the recipient to better estimate demands one can place on the donor and ensures a more satisfactory deal. Third is the recipient's purchasing clout; credit standing and reserves of hard currency influence the ability to obtain concessions for significant transfers. Fourth is the recipient's market. A large local market and high demand for the product puts the recipient in a more favorable position. For licensing agreements, where royalties are based on sales, the recipient's market strength is especially important. Fifth is the position of the donor's competitors. If there are several competitors, more substantive concessions can be expected, while a monopolistic donor position limits likely concessions.

Policy may help firms benefit from the transfer of technology and acquire technological mastery through assimilating and adapting the imported technology (Dahlman and Westphal, 1982). Governments in developing countries are increasingly adopting policies along these lines by screening the imported technologies to ensure more appropriateness, buffering the bargaining power of local firms when they purchase foreign technologies, promoting the use of non-equity forms of importing technology, removing restrictive clauses from licensing agreements, limiting royalty payments and the length of contract periods, promoting the unpackaging of technology, limiting foreign capital -- especially wholly-owned foreign investment except in selective cases -- to allow local learning, providing incentives for the local assimilation and improvement of imported technologies, encouraging the utilization of local technologies, and expanding the use of local employment and indigenous materials (Behrman and Fischer, 1980; UNCTC, 1987; 69; Fransman, 1985). These policies recognize the need for transfers of technology, and the importance of avoiding dependence by learning from foreign technology.

Learning from Foreign Technology

There are various activities involved in this process of incorporating a foreign technology into the local environment. Technical change can occur because of the different environments between recipient and supplier economies. Technology when transferred is generally not applied in a completely original form but in an adapted form: changes are made to suit local scales, materials, climate, skills and market needs. In this sense, technological change is the result solving problems created by the difference in environments. It is these relatively simple technical changes from production experience that can contribute to more complex, higher stage technical change (Weiss, 1988)

The successful application of an imported technology requires learning and conscious effort by the recipient (see chapter 2). With each transfer of technology initial changes are made to commercialize and refine the technology, minor innovations of various kinds might be made to improve productivity. The technology itself can eventually be altered by importing the technological know-how and the equipment required, or by learning the know-how locally (Lall, 1987).

The processes encompassed by successful transfers of technology include adoption, absorption, assimilation, adaptation, improvement, and diffusion. Adoption involves the steps from consideration of a foreign technology to the point where it has been indigenously mastered, and includes:

> determining the needs; surveying the alternative technologies and the alternative suppliers; choosing a particular combination of technology and supplier; absorbing the techniques in their first application in the importing country; disseminating the techniques throughout the economy; improving upon them; and developing new and superior techniques through research and development in the importing country itself (Enos and Park, 1988).

Absorption is the process of imported technical knowledge being learned and embedded to the point where it can be used in its original state and improved upon (Enos and Park, 1988). Assimilation is the integration of imported techniques with the local environment, for example when an imported production system uses local suppliers for inputs (Enos and Park, 1988). Successful assimilation balances imported technology with in-house expertise, a process of establishing technological complementarities (Rothwell, 1986). When one assimilated technology is mastered, future transfers of related technologies will likely have greater indigenous participation, increasing the effectiveness of assimilation (Dahlman and Westphal, 1982). Adaptation occurs when local technical changes are applied to imported technologies during the transfer or its initial use to match the technology to local factor endowments, social customs, etc. (Enos and Park, 1988; UNIDO, 1984). When products, processes, and other firm activities are enhanced, this is refered to as improvement (Enos and Park, 1988).

Diffusion of technology may be unplanned, and refers to the "process of imitation or adoption of an innovation by potential users" (Thomas, 1975: 234). Diffusion has also been used to mean the spread of the use of a technology rather than of the technology itself (Stewart and Nikei, 1987). Unlike the transfer of technology, inventions become economically significant only when they are applied for the first time as innovations, and successful innovations lead to a process of diffusion across firms and countries, promoting productivity and economy gains. Many improvements and innovations are made by the imitating or adapting firms during the process of diffusion. User experience, competition between suppliers, and applying the innovation in a new environment stimulate recipient technological improvements and innovation (Thomas, 1975; Freeman, 1988a). These processes may be intensified by the different types of complexities associated with each technology:

> The more radical the innovation the greater the number, cost, and significance of the changes brought about in the environments of the innovator and adopting firms. Adoption usually requires adaptation and even further innovation. Some innovations also require considerable investment in infrastructure by the public sector, and often they bring about changes in technologically linked firms in the private sector. These induced changes in turn frequently generate further innovations (Thomas and Le Heron, 1975: 247).

Economic growth greatly depends on the diffusion of new technologies at the international and national level. For example, a high-technology sector will not function adequately as a development tool unless a national technological capability is in place to diffuse the new ideas to other sectors of the economy. The diffusion of new knowledge through education is often a useful means of promoting economic strength, but the spread of new products and methods of production requires that there are no artificial barriers to the diffusion of innovations across firms, sectors and countries (Heertje, 1988). The importance of diffusion is that new ideas must be transmitted between industries and universities, and through the mobility of technologically skilled personnel.

Conditions for more Indigenous Inputs in Transfers of Technology

While this section has pointed out the dangers and limitations of technology transfers and governmental policies to rectify these problems, an alternative focus is on local R&D and innovation. What is the potential for indigenous technological development? Even in the more industrialized developing countries R&D has generally been limited to the adaptation of imported technology to the local environment. R&D efforts in developing countries have been initiated,

> ...by the need to use different raw materials, scale-down to smaller plant size, diversify the product mix, use simpler, more universal, less automated, lower capacity machinery, stretch out the capacity of existing equipment and introduce improvements in its design (Teitel, 1981: 132-133).

An important factor for the low level of indigenous technological development is that locational disadvantages act to increase the cost of innovation (Perez and Soete, 1988). To a large extent the capacity to innovate, or even assimilate technology, is influenced by the technological characteristics of the region. If skills are not found locally they must be imported or people must be trained by time, practice, and mistakes, which may make innovation costly, risky, and even forbidding. Regional infrastructure variations, then, result in differential costs for firms to acquire scientific and technical knowledge for otherwise equally endowed firms (Perez and Soete, 1988: 468). Overcoming these risks and developing a local innovation capability, however, will not only increase technological capability but also result in more positive technological transfers.

The process of using more indigenous technologies may be gradual and depends in part on way technology is imported (see Table 3.1). As shown in Table 3.1, the higher the number (signifying a greater indigenous input) the greater the benefit the technology import will have in the long-run. Or, as the local component increases, the greater the learning benefits.

To obtain more indigenous innovation, or a capacity for high-technology industrialization, developing countries will be forced to developing local R&D capabilities (the R&D capability will be covered in a latter section). While some developing countries are attempting to shift the origin of technologies from foreign to indigenous, it is recognized that foreign technologies are, and will continue to be, imported either formally or informally. Foreign subsidiaries transfer technologies that result in domestically produced goods; in the long-run, however, there are significant disadvantages from an over-dependence on the import technology based on 'home-office' R&D. Technology imported in this form limits the learning-by-doing experience by the local labor force and, if the technology could have been produced locally, employment opportunities are lost and valuable hard currencies might be needlessly spent (Britton, 1985; Benson and Lloyd, 1983). As a result, technology transfer agreements that maximize the know-how transferred have become more common. Developing country governments have tried to increase their bargaining power with TNCs through threat of local market limitations (Benson and Lloyd, 1983).

Table 3.1 Engineering and Know-How Procurement Combinations for Increased Technological Acquisition.

Technological knowledge acquired through:	**Engineering executed by:** the seller or licensor of the technology	foreign engineering teams contracted by project sponsor	Local engineering teams contracted by project sponsor	Engineering teams working inside the enterprise sponsoring the project
Renting with payments proportionate to sales	1	2	3	4
Renting with advanced payments as per maximum production rates	5	6	7	8
Purchasing	9	10	11	12
Developing a special technology for the project through a contract with a foreign research team		13	14	15
Developing a special technology for the project through a contract with a local research team		16	17	18
Developing a special technology for the project by a research team working inside the enterprise sponsoring the project		19	20	21

Source: Kamenetzky (1979: 54).

The question for developing countries entering industrial, advanced technology sectors is: "what technologies will be imported and under what terms?" In science-based industries. innovation is made possible by scientific advances. Scientific knowledge is accumulated through formal search efforts, thus one may expect technical change to rely on relatively expensive search and R&D processes (Dosi and Orsenigo, 1988). If a firm has a R&D capacity, the licensing of foreign technology can be very beneficial, and also may reduce the disadvantages of R&D by spreading risks. A R&D capacity allows the firm to obtain better conditions from licensing, to reduce its disadvantages, and to profit more from the foreign technology in terms of learning and risk-reduction (Erber, 1981a). The option most favorable to developing countries, then, is to get the most from imported technology and import only when it contributes to a nation's capacity for technological development. Japan's successful relationship between the importation of technology and the accumulation of domestic potential for technological development provides an important model (Choi, 1988).

Conclusions

Transfers of technology contribute to technological capability when recipient firms learn the technology, or how to change or adapt it. The key for making the most of imported technology is to import at arms length, which is more effective for local adaptation and assimilation than relying on TNC investment for technology. Care needs to be taken when licensing technology, for transferors of technology often impose a variety of restrictions or conditions regarding the use of the technology transferred Furthermore, licensing agreements can limit the opportunity of learning by doing, leading to the underdevelopment of internal capabilities to produce technology in the borrowing countries. Government policies may guard against the negative effects of technology transfer by: 1) regulating technology imports through registries of technological transfer, import controls, foreign investment controls, joint ventures. 2) removing restrictive clauses from technology contracts, and limit royalty payments and the length of contract periods. 3) granting special licensing privileges and customs duty exemptions on imported inputs to innovating firms. 4) placing technology transfer under advising schemes of research institutions and other infrastructural elements to ensure the best search for technology and to eliminate superfluous transfers.

An efficient use of foreign technology contributes to a firm's technological capability. Evaluation of the use of foreign technology is based on the ability to assimilate, adopt and improve the technology. Indirect methods of judging the technical ability of importing firm are based on: 1) the ability of the firm to access frontier foreign technologies with international leaders, and 2) the bargaining power of the firm for 'unpackaged' technological agreements. The ability of a firm to select the best technological mix, with varying levels of local or foreign participation, is a sign of increasing technological capability -- these notions will be tested in the empirical analysis (see chapter 6).

The following section further develops the concept of technological capability and demonstrates the importance of the technological infrastructure, of which a first step is improving the human science and technical resource base.

Human Resources for Research and Technological Advance

Industrial activity and a general economic infrastructure broadly define the initial parameters of technological capability. More specific measures to increase the technological capability of firms rest on developing a technological infrastructure. Technology is embodied in products and processes, but more significantly in people. Thus, technological capability is improved through an increase of knowledge and skills embodied in human resources. This section sets out to define a human infrastructure for research and technological advance, and policies that can contribute to its development.

In developing countries there are relatively few scientists, engineers, and technicians. As a result, industry is generally capable of little if any innovation. A key constraint for the indigenous development of technology (as for importing and assimilating foreign technology) is the lack of requisite science and technological capabilities. A human infrastructure is needed to support the generation of new science-based firms and domestic R&D. Regions able to innovate are generally well endowed with an advanced human infrastructure. An increased human infrastructure means more technical R&D workers. As Malecki (1989) recently emphasized:

> National investments in people accumulate into a body of know-how, resources, strategies, and habits that represent assets complementary to innovation (p. 75).

A greater technological capability, then, is acquired through an increase of quality human resources, which involves formal education, on-the-job training, experience, and specific efforts to obtain, assimilate, adapt, improve, or create technology (Dahlman, 1984; McNamara *et al*, 1988). Structures such as research universities, institutions and organizations figure prominently in the human infrastructure. They employ and generate human resources and provide an environment to conduct pure and applied research and development activities, including physical facilities such as laboratories, research equipment, libraries, and support facilities such as consulting and engineering services, and technological information services (Thomas, 1979: 5).

The productivity of the infrastructure is dependent on educational and research facilities, and a network of information linkages among them. Linkages with the general economic environment (e.g, with the industrial or productive system) ensure that the human resources are effectively utilized. Developing countries may require specific policies to link the human infrastructure and the industrial system (Marton, 1986: 35). These linkages, although mentioned here, will be more fully illustrated in later sections.

A human technological infrastructure is proposed in Table 3.2. The infrastructure includes the number of qualified scientists, engineers, and technicians and the educational system that produces those individuals; the ability of government to support educational and research activities; and the development of a technological environment that demands qualified human resources and stimulates technological efforts. These elements are important indicators for technological capability. A quantitative assessment of a labor force for research and technological advance, however, should be joined by a qualitative assessment of their utilization, which will be covered in the next section.

Table 3.2 The Human Infrastructure for Research and Technological Advance.

1. The development of qualified human resources:
    - a) scientific and technological personnel,
    - b) administrative and entrepreneurial personnel.
2. Support of education, including:
    - a) technical schools,
    - b) industry training programs,
    - c) universities,
    - d) specialized research institutes.
3. Scholarships for graduate level study abroad and locally.
4. Financial resources available for research activities:
    - a) governmental support of R&D in industry and higher educational institutes,
    - b) governmental support of cooperative industrial research associations,
    - c) the availability and level of capital investment in industry.
5. Technological environment:
    - a) demand for technological efforts,
    - b) demand and utilization of qualified human resources,
    - c) environment for and support of entrepreneurship,
    - d) a legal framework to regulate and provide incentives that promote the development of science and technology.

As highlighted in chapter 2, policy is vital on several fronts for creating technological capabilities. This is clearly the case for human infrastructure development. Policy may support human resource development through: 1) promoting general education, either by formal education and training, or by subsidizing firms who train their workforce, 2) promoting advanced educational programs through universities and research institutes in science and engineering, 3) sending advanced students abroad to state-of-the-art research universities for graduate and post doctorate work, 4) funding for university and government research laboratories and institutes, 5) promoting of information networks and centers to diffuse knowledge, and 6) sponsoring 'prototype' projects that have commercial potential.

For developing countries, technological advance need not be based on eminent basic scientists. Although a strong capability in basic research helps to assimilate and improve important new technologies, the scientific community is characterized by an open worldwide exchange of scientific literature and ideas. In the late nineteenth century, for example, the United States exploited new technologies before its competitors without taking the lead scientifically (Freeman, 1988b: 346).

Rather, nations interested in developing high-technology industries require basic economic institutions that are essential for the performance and development of technical and science education, that support R&D, and investment in the physical infrastructure (Nelson, 1984). Developing countries cannot simply promote R&D and hope that the economy will absorb and assimilate it without a sufficient human infrastructure. The next section illustrates, however, that funding the human infrastructure alone is insufficient for developing a local research capability.

Research Linkages and the Development of an Innovative Capability

A key component of this conceptual framework is that a local research capability is crucial for indigenous technological development. Past work clearly illustrates that R&D is a key determinant for technological advances (Freeman, 1982). Certainly not all R&D will lead to technological bonanzas; the correlation exists, however, between R&D effort (measured in financial or employment terms) and innovative success (Thwaites and Oakey, (1985). Considering the increasing importance of science and engineering, innovative firms must now engage in more complex R&D activities that are extremely uncertain and risky (Dosi, 1984: 12). Development in high-technology areas, then, requires a strong inter-relationship between science, technology, production, and firm and governmental long-run planning. All of which tend to be weak in developing countries.

R&D and Developing Countries

National investment in R&D of at least 1 per cent of GNP typically results in economic growth (Choi, 1983). R&D investment among the developing countries does not even reach 0.5 per cent of GNP, while the industrialized countries invest about 1-3 per cent of GNP (see Table 3.3).

Table 3.3 Research and Development Expenditures as a Share of GDP by Country.

Country	Year	R&D/GDP (%)
United States	1983	2.6
Japan	1982	2.4
France	1979	1.8
Germany	1981	2.2
Italy	1982	1.0
UK	1981	2.3
Australia	1981	1.0
Canada	1983	1.6

Source: Stoneman, 1987

The limited resources devoted to R&D by firms in developing countries are mostly geared to the adaptation of imported designs to the local conditions (Chudnovsky *et al*, 1983). Low R&D expenditures may be explained in part by limited capital, but also important are the three types of uncertainty associated with R&D efforts:

> ...a technical uncertainty, in the strict sense, that they will be able to develop the products and/or processes with the desired characteristics; a techno-economic uncertainty that they will be able to produce the products and processes in conditions of quality, price, and time competitive vis-à-vis their competitors and purchasers; and a financial uncertainty, especially of "gambler's ruin" when the firm concentrates investment in a few projects (Erber, 1981a: 176).

With the lack of a sufficient human infrastructure in most developing countries innovating firms must internalize activities (and additional costs and risks) that in advanced countries occur in other institutions (e.g., universities). Furthermore, R&D investments require venture or risk capital, which is often lacking in developing countries; combined with the fact that their markets are small, there are significant barriers to innovation through indigenous R&D activities (Erber, 1981a).

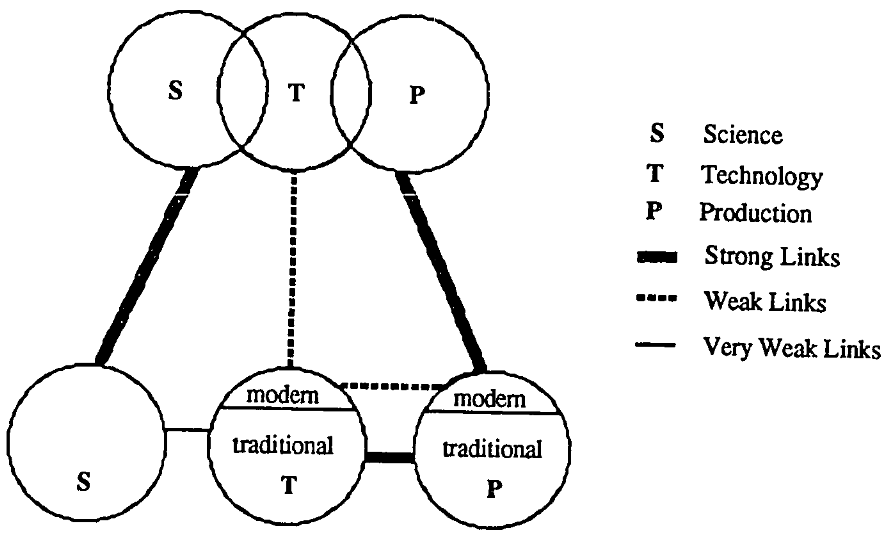
As a result, a number of governments have established publicly-supported R&D institutes to undertake scientific and technological research. Evidence suggests, however, that these expensive science institutions are often ineffective in generating technology (Stewart, 1984). Furthermore, public sector science operates often independently of the activities of private sector science and technology (Ting, 1987). Research activities, fragmented and small-scaled, and bureaucratically controlled, are criticized as wasteful, hindering creativity and of having little to do with national development goals (Choi, 1988).

An underlying assumption of many of these institutes is that technical change is viewed as a linear process which starts with R&D and proceeds by stages automatically to commercial application, with the initial stages being distinct and easily separable from production activity (Dahlman and Westphal, 1982). Gotsch and McEachron (1983) argue that the poor performance of R&D (funded and conducted by the government) in developing countries resulted when potential industrial users were not involved in the R&D process, links between the R&D establishment and users typically being minimal. They further argue that the quality research centers that do exist in developing countries are often closely linked to the scientific systems of developed countries and therefore function as isolated enclaves that have only minimal concern for the development of technology that responds to broadly based local needs. It is important to remember, as Thomas (1987: 29) warns, that there is no unidirectional deterministic sequence of 'science - technology - production.'

The scientific and technological activities that do exist in developing countries are generally not linked in any significant way to productive activities (see Figure 3.2), whereas in the industrialized countries, scientific activities are linked to advances in production technologies.

The dominant position of the advanced countries is generally attributed to their early start in science and technological development and relatively abundant economic resources available for R&D activities. Other explanations might be found in differences in culture, or the institutional and disciplinary contexts of scientific activities (Stolte-Heiskanen, 1987).

Countries with an indigenous scientific and technological base
(developed countries)



Countries with an exogenous scientific and technological base
(less developed countries)

Source: Sagasti (1980)

Figure 3.2 Relations between Science, Technology and Production in Industrialized and Developing Countries.

The technological capabilities associated with modern production in developing countries are expanded primarily through new imports, without full awareness of the cumulative processes that originated them (i.e., the intimate linkages between science, technology, and production), while indigenous technological capacities are ignored and thus weakened. This process intensifies technological dependence, and results when imported technology is neither adapted, developed or improved (Roura *et al*, 1983). Policy makers and academics alike are increasingly aware that for developing countries, long-term growth and development lie in acquiring the ability to create a more dynamic and indigenous technology structure[1] that reaches into production systems (Baranson, 1981; Singer and Ansari, 1988).

[1] The impact of foreign technology on the host country is far more limited than the impact made by indigenous technological efforts; foreign subsidiaries commit fewer resources to R&D, they are less linked to local research institutions and have less technological autonomy in manufacturing than their domestic competitors (Chudnovsky et al, 1983). This is not to argue that foreign technology has no role; the example of Japan's heavy use of imported technology in the 1950s followed by a dramatic rise in

Crane (1977) has identified the following characteristics typical of the organization of R&D in many developing countries:

> (1) Practically all R&D is funded by the government (there are few non-governmental sources of funds);
> (2) Most research, both basic and applied, is conducted by government and university laboratories;
> (3) The potential users of scientific results, industrial firms, perform relatively little technological research themselves;
> (4) Foreign technology enters these countries primarily by means of contracts between local industrial firms and firms in advanced countries (p. 378).

Crane argues that the relationship between the governmental, educational and industrial sectors significantly affects all aspects of the use and development of technology. Effective lines of communication must exist to disseminate research results, and even to determine technological priorities. These lines of communication between organizations in different sectors are weak in developing countries (Crane, 1977; Gotsch and McEachron, 1983).

Communication linkages are not found because firms fail to appreciate the usefulness of local research with the ready availability of international technology to serve what appear to be market demands. In developing countries, according to Behrman and Fisher's survey (1980), the strongest research linkages occur between universities and government institutes (though not necessarily oriented to industrial needs) since government institutions are a source of prestige employment for scientists, and also offer some degree of security for researchers. The weakest research linkages occur from universities to the industrial sector; most firms did not consider university research applicable to industrial problems.

Poznanski (1984) further argues that there is a lack of long-term commitment by a large number of governments in developing countries to support domestic R&D and to incorporate such research into wider economic programs, and that research activities, especially in university communities, become in many cases the object of political repression on the part of the state's administration. Moreover, Nichols (1984) suggests that non-governmental organizations have greater competence in R&D and production. An additional problem is determining how and where should R&D efforts be concentrated.

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indigenous R&D through a process of imitation and assimilation proves the eventual self-reliance may involve a degree of technological dependency (Watanabe, 1985). Furthermore, even though R&D activities may not have a direct link with economically applied technological activities, a research capability is an important step in the development process (Cimoli and Dosi, 1988).

Conditions for Successful R&D in Developing Countries

Although indigenous technological capacity requires a basic minimum level of scientific knowledge, development in most industries derives more from the accumulation of practical experience than from basic scientific research. The linear model of innovation presumes that more basic research leads to more innovations through a series of steps: basic research to applied research and development to production and marketing. The process of innovation, however, can be more accurately characterized as not just a new scientific breakthrough (a technological push), or the exploitation of potential new markets (market pull), but rather as a continuous process that integrates technical knowledge, market opportunities, and organizational linkages (Ballard *et al*, 1989: 5-6).

This characterization of innovation bodes well for those developing countries not leading in scientific research, but actively pursuing technological efforts through the development of a technological infrastructure, increased R&D linkages of technical knowledge with market demands, and the promotion of technological accumulation in industry in an environment that allows individuals and firms to take economic risks (Ballard *et al*, 1989).

R&D expenditure in developing countries, as such, should emphasize technological 'development' rather than focus on 'basic' and 'applied' research[1] (Bhalla and Fluitman, 1985). The optimum distribution of expenditures of basic research, applied research and technological development in industrialized countries is a ratio of 1:3:10, respectively (see Table 3.4) (Roura *et al*, 1983).

A successful R&D program, according to Choi (1988: 283), should also establish common goals and a cooperative system to link academia, industry and government; reorganize research institutions and establish major new strategic industrial research institutions with specific national R&D goals; provide adequate research facilities; train and secure qualified research personnel; develop a research support system along with policy guidelines diffuse research results to industrial uses.

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[1]Basic research is experimental or theoretical work undertaken to acquire new knowledge without any particular application in view or commercial intentions. Applied research is original work to acquire new knowledge with a specific practical objective. Development draws on existing work or knowledge that is directed to producing new (or improving) materials or products and to install new processes, systems, or services (OECD, 1981; Stoneman,1987).

Table 3.4 Research and Development Expenditures by Category.

Country	Year	% of total R&D		
		Basic Research	Applied Research	Development
United States	1983	12.5	25.5	62.0
Japan	1983	14.6	25.4	60.1
France	1979	20.9	33.0	46.1
Germany	1981	22.1	------77.9-----	
Italy	1982	15.8	39.1	45.1
Netherlands	1982	17.3	33.7	49.0
UK	1978	7.1	23.3	69.6
Australia	1981	36.2	41.0	22.8
Spain*	1979	11.8	44.2	44.0

Source: Stoneman, 1987; *Roura *et al*, 1983

Important to the successful development of governmental research institutions is a somewhat autonomous relationship with normal programs of the government. With autonomy, research institutions are better able to support private industrial sectors rather than worrying about supporting governmental programs for the purpose of getting more political support and funds (Behrman and Fischer, 1980).

A Research Network Infrastructure

The conceptualization and analysis of indigenous R&D activities must be broadened to incorporate the role of research linkages. Research activities are supported by government policies and institutions, university and academic contributions, and R&D development and application in industrial firms. Each generate different forms of R&D, as each has a distinct reason for engaging in R&D activity. As depicted in Figure 3.3, educational institutions supply qualified and skilled labor, industry provides the opportunity for people to utilize scientific and technological knowledge for specific results, and government stimulates and guides these efforts toward national goals. Essential to this research infrastructure is the existence of linkages among the government institutes, university laboratories, and public and private firms (see Figure 3.3). Indeed, in the U.S., barriers have been reduced to develop more cooperation between private and public sector R&D performers while the federal government redirects more emphasis on basic research (Ballard *et al*, 1989). A well developed human infrastructure is central in carrying out science- and technology-related activities, and diffusing or transferring that information among universities, firms, and government institutes. The R&D process in an economy cannot fail to emphasize the critical nature of human capital and of investing in people and knowledge (Nichols, 1984).

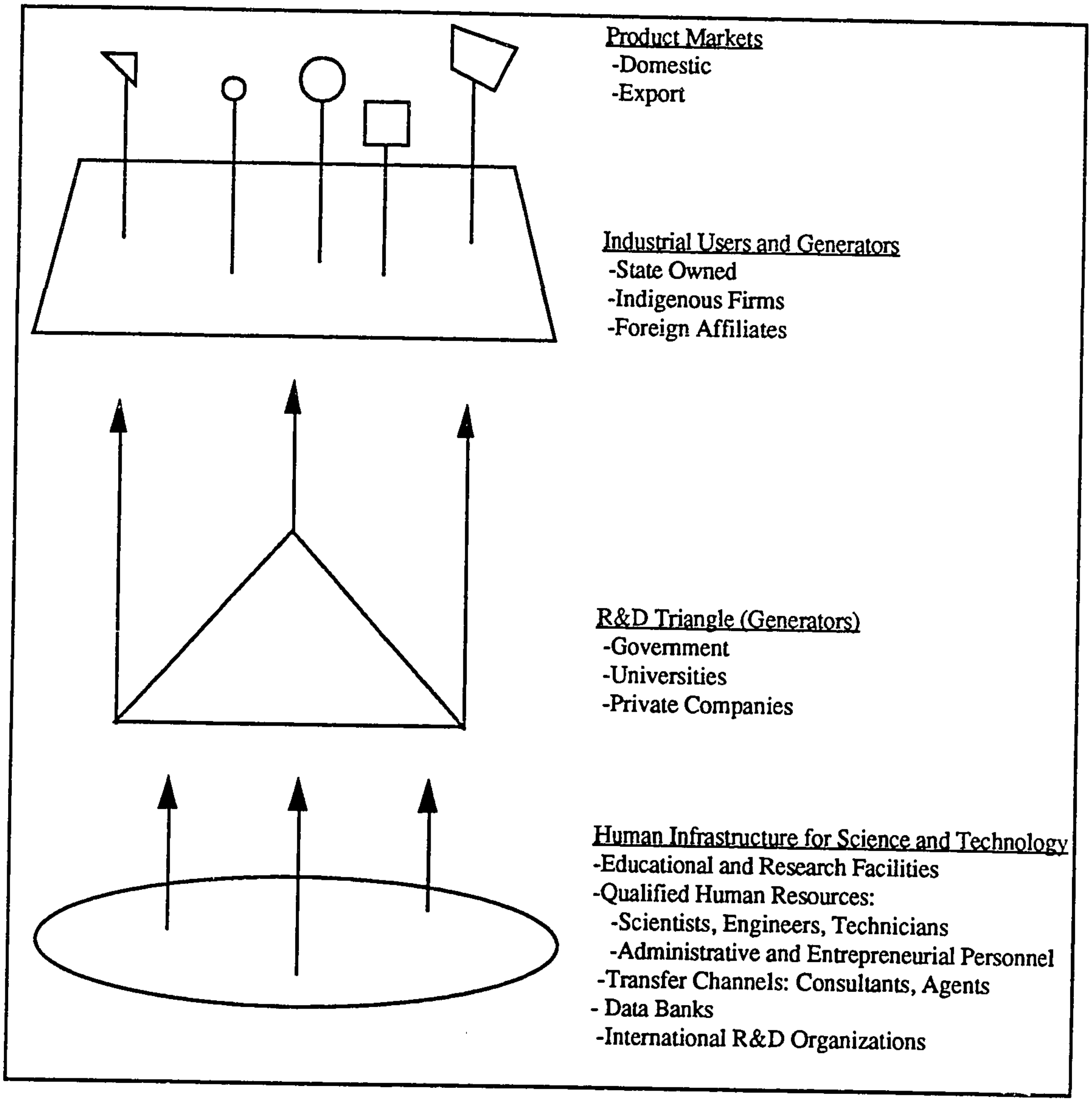

Figure 3.3 The Structures and Linkages that form a Research Infrastructure.

The research network infrastructure also includes firms that apply or commercialize the technology in new processes or products. A market that demands and utilizes research results is vital to drive the whole R&D system (see Figure 3.3). The development of a market that is sufficiently demanding and sophisticated is critical in stimulating indigenous R&D and pushing that knowledge through the research infrastructure to products on the market. The promotion of successful innovations, as witnessed by research in the U.S., depends on a strong interaction between the market and R&D performers to reduce uncertainty to a manageable level for the firm or industry (Ballard *et al*, 1989; Ting, 1987).

The government not only provides research capabilities, but, since it often constitutes a significant part of the market, is also a user of the technologies. The diversity of demand and the level of its sophistication will determine the intensity of research activities (Behrman and Fisher, 1980). The link between indigenous suppliers and the users of technology is crucial for the development of local R&D activities and technology (see Figure 3.3). Government purchasing policies can often stimulate the diversity of demand.

The interplay between these various organizations tends to reinforce the locational agglomeration of industrial technological activity (more on this in the next section). The regional agglomeration of R&D in many firms creates what Thwaites and Oakey (1985) call the 'critical mass' of a skilled and technical labor force, ensuring the retention of existing research oriented firms and the attraction and spin-off of new firms. Such a region tends to be found where local R&D and technological activities are common within local firms, universities, government facilities, and non-profit organizations, and where there is an agglomeration of a skilled technical labor force (Malecki, 1981b).

Essential to developing a research infrastructure is linking it with industry in a delivery system that will transform knowledge to product innovations (Ting, 1987). Usually there is little or no productive interaction between the two; public sector research often forms a framework almost independent of the activities of the private sector. It has been suggested that governments need to attend more closely to the structure of the research infrastructure and to its links with industry (Rothwell, 1986). Ways to offset the weak links between industry and universities may be to stimulate technological efforts within the firms that will in turn demand the help of universities, and to change the interaction between firms and institutions through different contractual arrangements (Stewart, 1984). Although it is important to establish R&D systems for the creation of research capabilities, perhaps more important is a set of policies that stimulate firm R&D[1] activities. Policies

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[1] From extensive research in developing countries, Katz (1985) found several additional factors that can facilitate technological change through R&D activity. Government policies that affect the cost of capital seem to have a significant impact upon both the rate and the nature of domestic technological efforts (e.g. low cost of capital leads to higher rate technological change). More competitive environments in

may promote indigenous technologies by ensuring sufficient demand for these efforts, such as government purchases, and regulations on the transfer of foreign technologies.

In order to promote inherently risky R&D efforts, governments may provide direct incentives, or help firms share the risks associated with R&D. Government policies of this type are often used by industrialized countries, where governments provide incentives for firms that invest in R&D activities, or reduce the cost of R&D. Policies to assist private sector R&D include subsidized credits, fiscal incentives, tax concessions, accelerated depreciation of R&D equipment, direct loans, and the availability of venture capital (Britton, 1985; Erber, 1981a). Those firms with local technological capability may be granted special licensing privileges and customs duty exemptions on imported inputs. Lall (1987) found that these R&D policies were very successful in stimulating industrial R&D in India.

The research infrastructure, as developed in this section, is comprised of a variety of structures and is dependent on linkages between them for its successful functioning. These structures and linkages agglomerate in specific regions. In developing countries, government policy has a role in stimulating the effective functioning of the infrastructure. For developing countries, however, their ability to break the substantial barriers to entry in science-based high-technology industries, will require a very strong research capability. The attractiveness of key high-technology industries is their potential effect on other economic sectors. This dissertation examines whether or not developing countries have the capability to adapt, improve, diffuse, and develop these new technologies.

What is the Research Potential in Developing Countries?

For countries whose size, level of industrialization, education system, and policy towards technology imports permits an independent assimilation of technology, there are several areas where developing countries might gain a comparative edge in high-skill activities. For example, where innovations have reached a mature phase in the product-cycle and are diffusing to other advanced countries, or in activities that rely more on skills learned from industrial activities, rather than science-intensive or technologically state-of-

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developing countries have been observed to lead to cost-reducing technological search efforts and product-differentiating strategies. Domestic economic expansion triggered favorable expectations among entrepreneurs and is more conducive to new construction and plant erections. Local technological search efforts are also affected by the cost and availability of personnel to conduct R&D and engineering activities; and by the level of government support for an individual company's engineering efforts. External factors influencing the technological behavior of a firm, are changes in the technological state-of-the-art, and the legal, economic, and technical ease of imitation.

the-art activities, or where technologies require significant re-design and adaptation for each application (Lall, 1982: 173).

Developing countries have traditionally entered industries that are further along the product life cycle. The life cycle for high-technology, however, is not only very short, but the standardization phase is virtually nonexistent and the concentration of high-technology industries will likely remain in existing locations in industrialized countries. As Oakey (1984) warns us:

> [Rapidly] changing products ensure the need for a constant input of highly skilled research and development and production workers to fuel this process of rapid innovation. Hence, both local specialist material inputs and skilled labour inhibits the mobility of high technology industrial production and contributes to strong local agglomeration economies in areas where local linkages and labour advantages accumulate. The concentration of producers in high technology industrial agglomerations is a cumulative process. A concentration of material and labour advantage creates and attracts new production of similar high technology type which, in a circular causative manner, strengthens such an area at the expense of other potential locations (pp. 157-158).

Freeman (1988a), by contrast, notes that rapid technological progress can occur without making contributions to original research and development. Technological change in the world economy results to a large extent from freely disseminated knowledge and rapid diffusion of innovations between countries, universities and firms. As such, by emphasizing the search for new appropriate technologies developing countries may be well placed to utilize 'frontier' research in the industrialized countries, especially through international linkages among universities and firms.

The commercialization of high technology is, however, slowing down, in part due to the breakdown in the worldwide patent system (Robinson, 1988). Patents are a matter of public record, and the availability of technical descriptions of patented innovations facilitates copying. Hence, individuals and firms developing new technologies are protecting their innovations by secrecy and may be hesitant to transfer relevant technologies to countries, like the NICs, where patents are ill-protected (Robinson, 1988). The NICs, as a result, may be required to place more emphasis on indigenous R&D or indirect transfers, like reverse engineering, to accumulate know-how of the new technologies. NIC investment in indigenous R&D, then, seems to be essential to gain high-technology capability, which in turn will improve the access to foreign technology.

High-technology firms are important to an economy not for their employment generation, but for the diffusion and application of their processes and products to other industries that in turn increase their competitiveness. Is it possible that developing countries can enter seemingly lucrative[1] high-technology industries? The following section demonstrates that high-technology firms have very specific locational requirements, as documented by research in industrialized countries and regions. These spatial elements will be incorporated into the framework of high-technology capability,.

Spatial Perspectives of High-Technology

The preceding sections have stressed the importance of human and research infrastructures for technological advancement and innovative capabilities. This section sets out to elevate these notions of infrastructure to one that specifically treats the development of high-technology. Geographers have been at the forefront in examining the tendency of high technology to cluster spatially and defining the regional characteristics necessary for self-sustaining its development (Dorfman, 1983; Saxenian, 1984; Haug, 1986; Hall *et al*, 1987; Malecki, 1987; Thomas, 1988; Kelly and Keeble, 1988; Nijkamp, 1988). This research, based on the experience of industrialized countries, has identified several regionally agglomerated institutional structures and linkages as crucial for the development of high-technology firms. Although many of these structures and linkages have been alluded to in previous sections, they have not been specifically applied to a spatial context, nor to developing an innovation capability in high-technology. This section will 'regionalize' the concept of infrastructure for high-technology industries. The section moves from the identification of the structures and linkages required to application of these notions to a Third World context.

Human Resources

For high-technology industrialization the availability of qualified human resources is indispensable. Influencing the location of high-technology firms, more than any other single factor, is the availability of a skilled professional and technical labor force (Nath, 1988; Christy and Ironside, 1987). High-technology firms depend on people who can

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[1]The Silicon Valley constitutes an example of such a dynamic area. Here, the growth of new firms has been rapid, including both new start-ups and spin-offs from older firms. While the focus of attention seems to be on the approximately 3,000 microelectronic manufacturing firms in the Valley, there are at least an equal number of firms that support the microelectronic manufacturers, such as in marketing, advertising, research and development, consulting, training, and providing venture capital, legal and other support services. Furthermore, of the microelectronic manufacturers located in Silicon Valley, over two-thirds employ from only one to ten people, and 85% have fewer than 50 employees. The 54 giants, such as Hewlett-Packard, Intel and Apple Computer, with over 1,000 employees, constitute only 2% of the electronics companies located in the Valley, although they account for half or more of the total local employment in microelectronic manufacturing (Larsen and Rogers, 1989).

design cleanrooms, tool intricate features, perform R&D activities, and design innovative products (Larsen and Rogers, 1989). Indeed, the innovativeness and R&D intensity of a firm may be correlated with the percentage of qualified scientists and engineers that it employs[1] (Monck *et al*, 1988).

It is the regional concentration of highly educated engineers, professionals, and entrepreneurs that sustains high-technology development. Influencing a region's supply of highly skilled labor is the presence of universities and other research establishments, including firms (Haug, 1986; Hall *et al*, 1987). Existing firms, for example, provide skilled labor to new firms as workers learn and accumulate knowledge from their past employer's technology (Kelly, 1987). Furthermore, scientists and engineers prefer to work in regions of concentrated high-technology activity as they often have high employment opportunities (Malecki, 1987). High-technology firms, however, require other forms of labor ranging from low skill (and low pay) operatives to more experienced production line workers, semiskilled machinists, metal workers, and skilled craftsmen (Dorfman, 1983; Saxenian, 1984; Kelly and Keeble, 1988). A key component of the high-technology industrialization, then, is a region's 'human' infrastructure, originating in universities and firms, that provides the medium for a successful transfer of skills and capabilities to infant firms (Thomas, 1988).

University/Industry Linkages

The locations of major research universities, especially with strong science and engineering departments, are significant in the location decisions of high-technology firms. The diffusion of university research results and scientific and technical knowledge is essential for new and existing high-technology firms, reinforcing the need of these firms to locate near universities[2] (Miller and Côté, 1987). There are several types of linkages between individual firms and universities, including consulting services, joint research projects, exchanges of personnel, private funding of university research, access to university facilities such as libraries and labs, or less formal social contacts which may lead to an important exchange of information (Monck *et al*, 1988: 167-168).

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[1]In the United Kingdom, for example, one-third of all computer firms' founders have a Ph.D. (Monck *et al*, 1988).

[2]In some fields, such as artificial intelligence, university research departments are the center of scientific activity (Glazer, 1986). In the U.S., the importance of universities as source of research is illustrated in the following figures; in 1985, universities and colleges performed 51.6% of total basic research, 10.7% of total applied research, and 0.7% of total development (Ballard *et al*, 1989). Universities attract large amounts of federal and private-sector funding, as well as key scholars and talented graduate students (Smilor *et al*, 1988).

Exchanges of personnel and social contacts are particularly important. The results of basic scientific research are typically diffused through formal written channels. Technology, however, is often hard to communicate; it is a mix of complex data and ambiguous know-how. As a result, technical knowledge is often more effectively transferred through interpersonal communication and the actual movement of people (Ballard *et al*, 1989).

The development of university research parks has been a more formal and broader attempt to generate linkages between universities and industry. Research parks are areas adjacent to universities set aside for firms that draw research-oriented companies into the university environment. Today there are over 300 research parks in the world with over half located in the U.S.. The most famous park was developed by Stanford University in 1951 and continues to serve the Silicon Valley area (Wigand, 1988). Many parks include incubators[1], i.e., multi-tenant buildings helping to nurture small firms through shared facilities and services (Glazer, 1986). Incubators provide an important setting for potential entrepreneurs to act on their ideas (Premus, 1988). Indeed, many local governments have created incubators as a mechanism to promote innovation (Nijkamp, 1988).

Universities also contribute to the generation of new firms, or spin-offs, as faculty members sometimes establish firms to exploit the fruits of their own research. Universities such as MIT and Stanford have been particularly successful in generating a number of firm spin-offs, attributed in part to their internationally renowned departments in engineering or computer science and close links with the local business environment (Malecki, 1986). Universities in general, however, are not a major source of spin-offs. Public research labs as well tend to have only a few spin-offs, due to the non-market orientation of the research, and the lack of researcher interaction with the private sector (Malecki, 1986). Spin-offs are, however, associated with spatial concentrations of R&D activities, and are important in generating new economic activity (Malecki, 1987).

Government Investments and Markets

Government expenditures and procurement have been instrumental in the development of high-technology regions (Christy and Ironside, 1987). Government research spending tends to be concentrated in specific regions and is a common denominator in most areas of concentrated R&D activity. The location of Federal

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[1]Incubators allow the potential entrepreneur to gain access to information about markets and technical opportunities and meet potential partners, clients, suppliers, distributors, and venture capitalists (Miller and Côté, 1987: 60).

institutions and research institutes attract high-technology firms wanting close proximity to agencies that provide research support and financial aid, and also represent important markets (Hahn and Wellems, 1989). Government purchases of products also tend to benefit specific regions. Electronics related firms in the Silicon Valley were initially aided by the growth of government military and aerospace contracts (Saxenian, 1984). The federal government's purchases of microprocessors fell below 50% of total output only as recently as 1976, suggesting the importance of government markets in the early stages of the computer industry (Vaughan and Pollard, 1986). See Appendix A for a more detailed discussion of the importance of government expenditures and the development of the U.S. computer industry.

R&D Linkages and Transfers of Technology

Due in part to the high cost of research and the fast pace of technological change, transfers of technology and R&D linkages have become increasingly important for high-technology firms. The increased cost of, and outlays for, R&D have been particularly noticeable in computers, electronics and components, and would also be identifiable in other areas if detailed company data were available (Chesnais, 1988: 509). Furthermore, the typical product life cycle in the high-technology field may be no more than five years (Oakey, 1984; Crawford, 1984). The high cost of R&D and volatile nature of the market have led to several types of R&D linkages and transfers of technology.

For example, joint industrial research have been used by many firms to share proprietary information and perhaps more importantly the risks of R&D ventures (Ballard *et al*, 1989). For other firms, new product technologies have been acquired through external acquisitions, and yet in others, particularly small niche firms, licensing is used to get proven ideas without spreading R&D dollars too thin (Galbraith and Kazanjian, 1983). R&D linkages and the external acquisition of technology have thus resulted in a variety of technological agreements, including joint or cooperative R&D linkages, technological agreements, and manufacturing and/or marketing agreements and partnerships[1].

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[1]Types of technological linkages may include:
1. University-based cooperative research projects.
2. Government-industry cooperative national or international research projects.
3. Research corporations or private joint-venture companies.
4. Corporate venture capital agreements by large corporations with small firms.
5. Non-equity cooperative research agreements between a small number of firms to deal with specific technical problems.
6. Technological agreements for existing 'proven technologies.'
7. Comprehensive R&D, manufacturing, and marketing joint ventures with a number of partners.
8. Customer-supplier partnerships.

These agreements highlight the necessity for effective linkages among the various R&D actors, and spatial concentration facilitates these linkages. Equally important, firms must have the ability to transfer and effectively negotiate for new technologies. A firm's technological capability, as identified in chapter 2 and an earlier section of this chapter, significantly determines its ability to acquire a beneficial transfer of technology.

Financial Linkages

A particularly important factor in the development of high-technology firms is a local supply of venture capital (Oakey, 1984). Venture capital provides the crucial service of financing the start-up of high-technology firms that otherwise have no financial collateral other than potential ideas for new products. Moreover, venture capital provides essential investment monies for costly R&D activities, vital to the continued growth of firms.

It was only in the 1960s that a professional capital market emerged in the U.S. and, according to Prakke (1988), this venture capital network played a major role in transforming the economy from stagnancy, by shifting capital from declining industrial sectors such as textiles and shoes, to growth sectors, such as those based on informatics technologies.

Of all venture capital organizations more than 50% are concentrated in either California, New York or Massachusetts (Prakke, 1988). More than a third of the largest venture capital firms in the U.S. have offices in the Silicon Valley region, while most others invest heavily in the Valley's firms (Larsen and Rogers, 1989). Venture capitalists are attracted to regions where promising entrepreneurs proliferate (Dorfman, 1983). It is capital invested, as shareholdings, to form and set up small firms with new ideas of new technologies. Venture capitalism is not only the investment of funds into a new firm, but also the provision of the skills needed to set the firm up, design its marketing strategy, organize and manage it. Profit comes not from dividends but from the capital gains at the time of divestment (Prakke, 1988). Venture-capital is especially geared to high technology in that it can adapt to very important elements of innovative activity; it may even assume responsibility for firm management and provide valuable business experience. Venture-capital firms possess experience to relatively quickly understand the market and correctly assess the potential entrepreneur, and often actively search for potential undertakings at universities and R&D institutes. The formal bank-industry, on the other hand, requires

9. Licence agreements and technology transfers forming part of a long term relationship between two firms, as in OEM agreements (Chesnais, 1988: 510-512).

relatively long-term commitments of resources (Dosi and Orsenigo, 1988). Furthermore, borrowing from banks involves short-term debt, and new products may not be introduced quickly enough to pay off the debt (Ballard *et al*, 1989).

The development of high-technology requires a special emphasis on finance. Research activities, usually the fruition of work in universities, research institutes, industrial R&D labs or firms in research parks, require financial backing to commercialize innovations as well as to identify clients or market segments and help with business support and other services.

Location Environments

There are several other 'factors' that influence a region's innovative environment. For example, early links between new high-technology firms and the existing or 'old' industrial structure of a region contribute to agglomeration economies (Gibson, 1988). This is not to say that firms will choose a location because of infrastructure availability, rather it is the lack of a basic infrastructure might deter a firm from selecting an otherwise desirable location (Wigand, 1988). Airports have been found to be important for quick access to customers and clients where work needs to be carried out on the clients' premises, consultancy or contract R&D (Kelly, 1987). High-technology industries rely more on personal face-to-face contact to exchange information to monitor new processes or activities in branch plants, to search for capital sources, and to search for clients (Mahmassani and Toft, 1985). To adequately satisfy the travel demands of high-technology professionals an important contingent is both private and commercial air service. Air freight service is also important for transporting high technology products, which have material inputs and final products that are of relatively high value, low bulk, and tend to be fragile. In general, the speed of transportation that provides close communication among supplies, clients and competitors can give the firm significant advantages (Dorfman, 1983). Support services for high-technology industries are often very specialized. Local firms are needed to supply circuit boards and other electronic components, or liquid gas daily; also required are machine shops with the capacity to measure in microns, and transportation for computers and other delicate equipment (Larsen and Rogers, 1989; Mahmassani and Toft, 1985; Dorfman, 1983). Advertising and public relations firms must have a good knowledge of the high-technology industry and its particular needs. Lawyers must be adept in legal specialties, to enforce piracy violations or to bring firms public (Larsen and Rogers, 1989).

The ability to find suitable buildings can influence the location decisions of high-technology firms. Building space at relatively low costs, however, is not the only requirement; high-technology firms often require locations that meet demanding technical specifications, such as 'clinically' clean, air-conditioned, unusual electrical requirements, a high proportion of office space, and a building appearance that emits a good image for customers (Kelly, 1987: 166).

Furthermore, in addition to highly specific building-type demands are purpose-built physical environments. For instance, the city of Sunnyvale in Silicon Valley has water and sewer line under the streets joined by miles of hydrogen mains. In the Japanese drive to create *technopolis* -- a new type of city-state linking public and private sectors to promote technological commercialization and diversification -- emphasis has been placed on the construction of large scale projects not only to support new research centers and industrial parks, but also to construct new roads, water and sewer systems, highways, bullet train terminals, airports, recreational parks, housing, telecommunications networks, community centers, and other public facilities (Tatsuno, 1988).

Accessible amenities are also important for firm location. Highly skilled workers and managers have marked preferences for residential locations (Kelly, 1987; Wigand, 1988). High-technology professionals often prefer a quality of life associated with urban areas -- an attractive physical setting and climate, relatively un-congested conditions, cultural amenities (shopping, restaurants, and the performing arts), proximity to outdoor recreation, affordable quality housing, tolerable crime rates, etc. (Mahmassani and Toft, 1985; Wigand, 1988; Malecki, 1986). The high costs of urban locations sometimes encourage expansion to small towns or rural areas (Kelly, 1987). However, the tendency for high-technology firms to agglomerate and concentrate in urban regions is persistent.

Agglomeration and Entrepreneurship

Agglomeration economies result from a clustering of economic activities that permit firms greater access to markets, inputs, and other benefits from centralized locations. Agglomeration of a regional high-technology infrastructure involves the elements described above. Dorfman (1983) has captured the importance of agglomeration for electronics firms in Massachusetts:

> Producers of electronics products are caught up in a network of mutual interdependencies, linking manufacturers of electronic components, parts and sub-assemblies, makers of computers and their peripheral along with their distributors, designers of software, manufacturer of industrial equipment and instruments that incorporate micro-processor and other computer technologies, makers of equipment for testing their performance, and so

forth. There are obvious advantages for such mutually dependent firms in locating close to each other (p. 308).

One important outcome of the agglomeration of these firms has been the stimulus of entrepreneurial activity. Entrepreneurship is a key factor in the development of high-technology clusters (Premus 1988). It is the entrepreneur that pushes new ideas toward commercialization (Ballard *et al*, 1989). According to Premus (1988: 446), entrepreneurs have: (1) the ability to spot new business opportunities before others, (2) the ability to assemble the necessary resources to develop the business opportunities, and (3) the necessary managerial and organizational skills to launch successfully new businesses or move existing corporations into new markets.

Entrepreneurs in high-technology fields come from universities and research institutes and, more generally, from established and larger high-technology firms. Large firms are known to stifle the pursuit of their research ideas, causing entrepreneurs to create their own new firms (Malecki, 1986). Rapid technical changes also creates many new market niches that are either too specialized to interest large firms or into which large firms fail to move quickly (Dorfman, 1983). Geographically, new firm spin-offs tend to be most prevalent in areas where other successful new firms are located; these regions also exhibit high levels of industrial R&D (Malecki, 1986). The agglomeration of entrepreneurship in these environments creates an 'entrepreneurial climate' that is generally found only in large cities (Malecki, 1987). Factors or conditions that aid entrepreneurship are incubator organizations, regions with excellent universities, clustering of suppliers of parts, components, and services, information networks where entrepreneurs may exchange technological knowledge and business opportunities (Miller and Côté, 1987: 68-69). Entrepreneurs and high-technology firms are thus influenced by the benefits of agglomeration economies found in specific regions that possess a high-technology infrastructure.

A Regional Infrastructure for High-Technology in Developing Countries

In developing countries, important conditions for high-technology industrialization are human resources and research linkages, and the ability to indigenously develop and effectively transfer technology. This section has demonstrated the importance of the regional concentration of institutional structures and linkages for high-technology firms. Through examples drawn from industrialized economies it is evident that spatially agglomerated support structures and linkages significantly influence the location and development of high-technology firms. Failure of high-technology industries in developing countries to stimulate and intensify these linkages bodes ill for the development of high-technology capability[1]. This notion will be tested in the case of the Brazilian informatics industry (see chapter 6). To summarize, regional high-technology infrastructures involve labor supply linkages, R&D linkages (foreign and local), industrial and market linkages, investment linkages, entrepreneurial linkages, and basic physical resource linkages. Figure 3.4 summaries each of these areas, particularly as applied to a Third World context.

Given these conceptual foci, it will be important to examine the development of qualified professionals, the interactions between university and firm research personnel, the availability of capital required to finance new high-technology firms and costly R&D activities, and the development of markets. Furthermore, the development of industrial linkages will be critical to ensure that high-technology is indeed an industrializing industry. Forward linkages are manifested through the diffusion of technologies to other economic sectors. Backward linkages are created to the sources of either local or foreign inputs. In cases of market failure, the firm itself must produce inputs, indicating internalization.

The agglomeration of these elements creates an 'entrepreneurial climate' that will likely be found only in core regions in developing countries, and particularly in areas close to university and government research institutes. In developing countries, the government will likely be forced to take a more active role to protect local high-technology firms from foreign competition and to provide venture capital for local entrepreneurs. Large local markets will be crucial for initiating industries through protection. These policy speculations will be more fully clarified in chapter 4.

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[1]The importance of infrastructural linkages may be illustrated from recent research on the Indian high-technology industry (Nash, 1988). The paternalistic organization of Indian firms with rigid authority structure stifled entrepreneurship. The basic infrastructure was deficient in areas such as transportation, and water and power availability. Financing for R&D was limited and insufficient. There was a lack of cooperation among government, industry and university R&D. From Nash's (1988) research on Indian case, it is evident that the lack of high-technology infrastructure was an important stumbling block for industrial development.

R&D LINKAGES

Traditionally weak R&D activities in LDCs must be improved by consolidating and linking all available sources of R&D.

LOCAL

-Linkages between R&D actors:
technological universities, research institutes, major R&D laboratories, and industry R&D.

-Technology-driven firms using available R&D actors.

-University spinoffs.

-Hardware and software consulting firms (faculty).

FOREIGN

-Linkages to foreign sources of technology:
Firms.

-Linkages to foreign sources of knowledge:
Universities, technical journals.

MARKETS

Need strong or potentially strong local market. Market concentrations will attract firms (e.g., industrialized regions).

-Government markets (e.g., military, state organizations, state-run firms).

-Protected markets (infant national firms).

-International markets.

CAPITAL

Capital availability is crucial for firms involved in new and risky R&D-intensive business ventures.

-Venture-type capital sources from investors, banks, financially secure firms, or government.

AGGLOMERATION ECONOMIES

Regions with all the above will benefit from agglomeration economies: enhances all the other factors; center of action, "pressure cooker" for ideas and entrepreneurship.

-Regional high-technology centers backed by government are also important.

HUMAN RESOURCES

Development of quality human resources locally and abroad: through educational and research institutes, and experience in local and foreign high-technology firms. Firm location will be significantly determined by regions with a quality labor force.

1) Scientists, engineers, and other technical personnel.
2) Managers and other administration personnel with experience in high technology.
3) Low paid operatives to more experienced production line workers and skilled craftsmen.

INDUSTRIAL LINKAGES

Industrial linkages are crucial for economic development, but may be costly during infant stage.

Backward industrial linkages:

-Suppliers of circuit boards, precision machinery and sub-assembly, electronic components.

-Access to foreign components when not produced locally.

Forward industrial linkages:

-Diffusion of computer-related equipment to other economic sectors.

PHYSICAL INFRASTRUCTURE

Well developed physical infrastructures are likely to be found in core regions.

-Physical infrastructure: air passenger and freight services (speed of transportation).

-Close face-to-face communication among suppliers, customers, engineers, and other technical personnel.

Figure 3.4 A Regional Infrastructure for High-Technology and Developing Countries.

Conceptual Synthesis and Empirical Propositions

Several elements, conditions, and processes are critical to high-technology capabilities, specifically: the transfer and utilization of foreign technology, its assimilation and improvement by local industry, and the development of an indigenous innovative and research ability. These activities take place through the development of supporting infrastructures based on: a) human resources, b) research networks, and c) regional agglomerations. Although these individual factors are identified as distinct, it should be remembered that their interrelationships are very important even if not well understood; the factors cumulatively build on one another and find their manifestation in areas of spatial concentration.

In a Third World context, initial stages of technological development are associated with a limited infrastructure and weak linkages among existing technological structures (e.g., few educational and research institutions and thus a small number of qualified human resources, few linkages between science, technology, and production generators, small markets, little capital available for risk-taking). A local technological infrastructure characterized by poorly developed institutions and human resources with weak linkages or dependence on MNCs should indicate a weak technological capability. Such an environment necessitates a heavy reliance on transfers of foreign technology (see Figure 3.5).

Of crucial importance in the movement from initial dependence on foreign products and technology to a more autonomous technological capacity is indigenous technological change, based on learning and technological accumulation involving people in firms and regions, strong state support and policy measures, and industrial development (see chapter 2). Movement from a weak to a strong technological capability is significantly influenced by policy. Policy may be used to develop institutional structures, encourage linkages, pressure firms to engage in real technological efforts, and stimulate local technological learning.

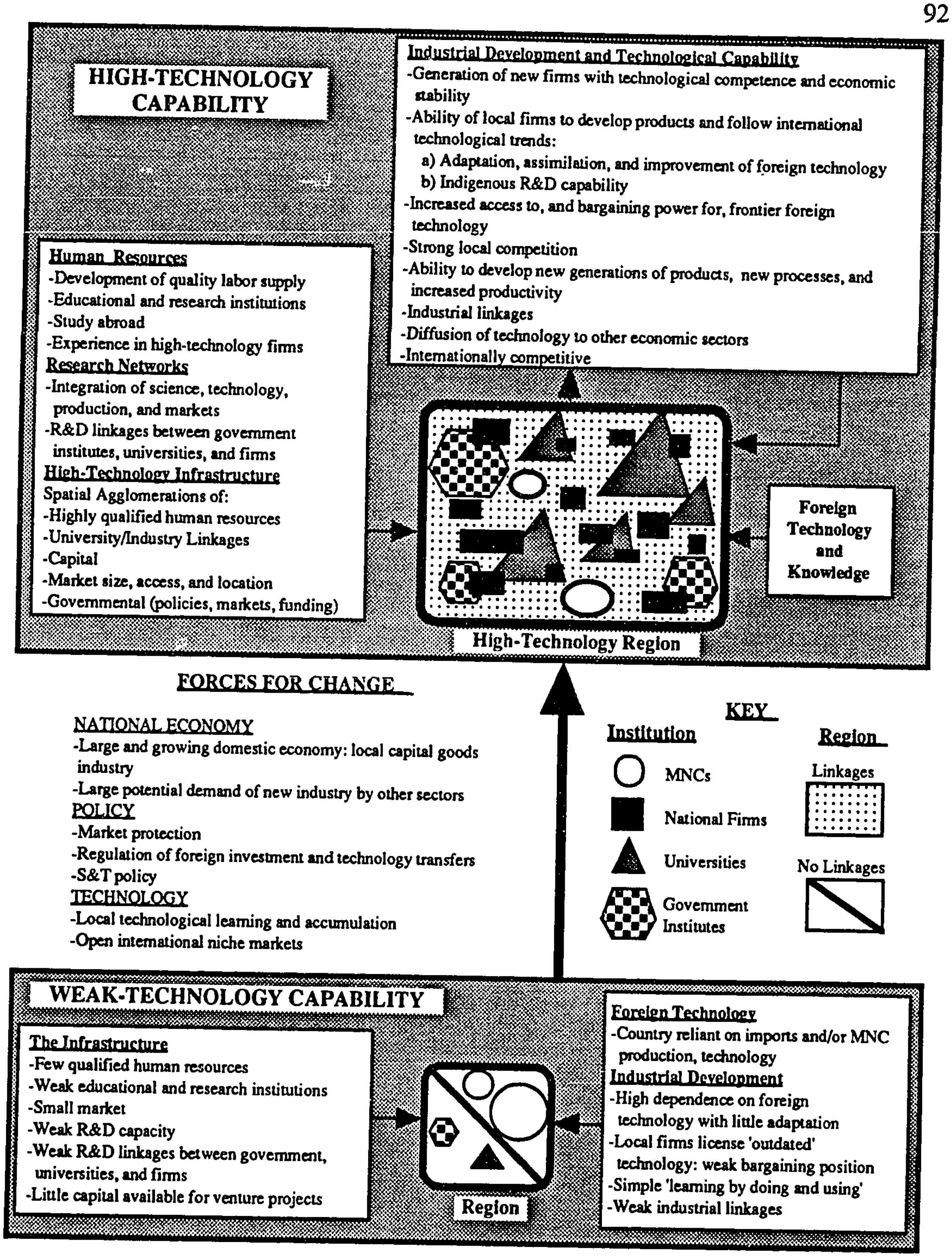

Figure 3.5 The Development of High-Technology Capability.

Furthermore, it is suggested that growth of technological capabilities (e.g., assimilation, adaptation, and improvement of foreign technology) is supported by the development of human resources. Human resource learning and technological accumulation, and moreover, the development of network of research linkages, increases local innovation capabilities, allowing for a greater use indigenous sources of technology in conjunction with foreign technologies. The successful development of high-technology relies on the agglomeration of institutions (e.g., universities, government research institutes, markets, capital markets, labor resources, etc.) and the linkages that tie them together (e.g., joint R&D projects, personnel movements between firms and universities, and market and supplier contacts, etc.). Equally important, as portrayed in Figure 3.5, are the linkages between foreign or external inputs of knowledge and technology with local structures (e.g., technology transfers, students at major universities abroad, reverse engineering, etc.). As developing countries attempt to improve industry potential in high-technology sectors, each of these infrastructural components will culminate in a high-technology capability.

High-technology capability entails the development of both industrial technological activities and the supporting infrastructures. A positive change in the technological infrastructure, and improving industrial technological activities signifies enhancement of technological capability, as will be tested from empirical evidence of the Brazilian informatics industry (see chapter 6).

The extent to which Brazil has moved towards a high-technology capability will be measured by success in using foreign technology, intensifying human resources, deepening research and development capabilities in industry, government and university centers, and the regional agglomeration of these components and linkages. Industrial development mirrors this capability through explicit technological efforts and movement towards the given technological frontier. Furthermore, as the country develops technologically, intersectoral interdependences should increase and technology will diffuse to other sectors of the economy. These developments may encourage foreign firms to locate more R&D activities in the country to tap lower cost skilled personnel and to gain favor with the government.

Industrial development in Brazil will be analyzed through the technological ability of firms (see chapter 2). 'Developing' firms are those that engage in greater technological efforts, increasingly use indigenous technologies, follow international technological trends, and develop new generations of products and processes. Increased access to, and bargaining power for, frontier foreign technology will likely accompany industrial development. As infant firms mature, however, reliance on direct transfers of technology will be supplemented by local R&D efforts and the accumulation of indigenous technological knowledge. Backward linkages will be increasingly locally derived as local supplier firms are generated by firm demand. Selective import restrictions may promote such backward linkages.

Pressures inducing firms to invest in technological efforts in general result from competition for price and product quality. In Brazil, however, opportunities to venture into high-technology activities are largely presented through government policies. Strong government assistance will be needed to cultivate infant high-technology firms (see chapter 4). Firms must show results for justification and continuation of policy. In the case of the Brazilian informatics policies, the stated goal is for firms to obtain technological autonomy. For other observers, evaluation of the industry will be based on international competitiveness. For this dissertation, technological autonomy and international competitiveness will both serve as guidelines for evaluating the capabilities of firms.

The following chapter (chapter 4) develops a general policy framework that identifies policy instruments important for the stimulation of high-technology capability and evaluates high-technology policy models in the U.S., Japan, and South Korea. Chapter 5 examines the evolution of Brazilian computer policy, a policy that is rather surprising given Brazil's traditional openness to foreign direct investment. Chapter 6 presents the empirical results of this dissertation and evaluates the Brazilian informatics industry.

CHAPTER 4

HIGH TECHNOLOGY DEVELOPMENT MODELS

The rapid growth of the high-technology industry is hardly the result of serendipity; the industry has been nurtured and supported by a variety of explicit 'high-tech' government policies. The intention of this chapter is to develop a policy framework designed to identify the different roles that government can play in acquiring a high-technology capability. Attention will be placed on policies affecting the components of high-technology capability detailed in chapters 2 and 3, namely, transfers of technology, indigenous innovation and research, and infrastructural development. The chapter then examines policy pathways of countries at different stages of technological capability to identify possible government strategies in creating high-technology industries. Specific reference will be placed on the U.S. - as a long established technological leader, Japan - as an example of a successful 'catch up' strategy, and South Korea - as a Newly Industrializing Country with an emerging set of high-technology policies. This framework will be the basis for policy analysis of the Brazilian informatics industry, presented in chapter 5.

Towards a Framework for the Analysis of High-Technology Policy

The wide-ranging and extensive impacts of the informatics industry on most economic sectors have made governments interested in acquiring this technological capability. Japan and the U.S. first recognized the importance of informatics technologies for economic development, national security, and job creation, and have promoted their development by trade and industrial policies, R&D programs, and in the U.S. case, defense policies (Kuwahara, 1985: 8). More recently, governments in other countries have adopted substantial policies that support informatics industries.

Various forms of state intervention and involvement have been incorporated to develop high-technology industries. For the informatics industry, governments have utilized a range of policy instruments directed at promoting research and innovation, ensuring sufficient demand through protectionist policies, and regulating transfers of technology. These policies, which have been alluded to in chapters 2 and 3, integrate combinations of foreign trade and domestic industrial policy. A summary of the applications of policy in the informatics industry in different countries is shown in Table

4.1. Particular policy strategies are, however, influenced by a country's relative position in that industry and reflect national economic characteristics.

Table 4.1 Trade Policy and Domestic Policy for the Informatics Industry.

Policy	Type of Intervention	Most Frequent Forms of Intervention	Countries Mainly Using the Instruments (1985-87)
Trade Policy	Import restrictions	Customs tariffs	Brazil, India, Argentina, EEC
		Import quotas	Spain, France, Brazil, Argentina, India
		Voluntary export restraints	EEC/Japan, US/Japan, EEC/South Korea*
	Export support	Export subsidies	Japan, South Korea, Taiwan
		Market access arrangements	Japan/United States, South Korea/United States*
		Government contracts	Japan, United States (military equipment)
	Responses to "unfair" trade practices	Anti-dumping actions	EEC, United States
		Countervailing actions	United States
		Restrictions due to non-respect of intellectual property rights	United States
Domestic Electronics Policy	Subsidy	Military R&D	United States, South Korea, France, United Kingdom
		Government or subsidized R&D	United States, EEC, Japan, Brazil
		General subsidies	South Korea, France, Japan, Brazil
	Public procurement	Military procurement	United States, South Korea, France, United Kingdom, Brazil
		Public sector procurement	Japan, France, South Korea, India
		Government "guidelines" for firms	Japan, South Korea, Brazil
	Regulation	Price controls	United States, Brazil, Argentina
		Restrictions on foreign investments	Brazil, Japan, South Korea
		Standards of electronics products	EEC, Japan, Brazil

Source: Kostecki, 1989
* Importing country/exporting country

A number of technological policy classification systems have been proposed elsewhere in the literature. This section sets out to establish a different framework, which is the policy extension of the concepts developed in chapters 2 and 3 that have been argued to lead to high-technology capability.

Table 4.2 Policies for Acquiring a High-Technology Capability.

Policy Area:	Policy Objectives and Instruments:
Transfers of Technology	1) Trade and foreign investment regulations to stimulate new indigenous firms. 2) Controls on transfers of technology - bolster the bargaining position of domestic firms, reduce the cost of imported technology and promote the use of licensing importing technology, remove restrictive clauses from licensing agreements, limit royalty payments and the length of contract periods, promote the unpackaging of technology, and limit direct foreign investment. 3) Technology transfer and advising schemes involving research institutions and other infrastructural elements. 4) Incentives for firms to adapt and improve foreign technology. 5) Grant firms with local technological and R&D capability special licensing privileges and customs duty exemptions on imported inputs.
Indigenous Research and Innovation	1) Financial assistance to set up private or state owned industries to develop new technologies based on local R&D. 2) Provide capital for new technology-based firms; or grants, favorable loans or loan guarantees, subsidies, export credits, venture capital. 3) Promote R&D through subsidized credits, fiscal incentives, tax concessions, accelerated depreciation of R&D equipment, direct loans, and the availability of venture capital. 4) Government purchasing in favor of indigenous firms - products or prototype purchases, R&D contracts. 5) Encourage joint research projects. 6) Establish stringent performance standards. 7) Allow for or establish competitive environments.
Infrastructural Development	1) Support Education - general and university education, technical and advanced education, apprenticeship schemes, continuing and further education, retraining. 2) Send students abroad to state-of-the-art research universities for graduate and post doctorate work. 3) Fund long-term science and technology projects - including universities and government laboratories, research and professional associations, and 'prototype' projects that have commercial potential. 4) Fund national collaborative technology research programs with industry and universities to diffuse technological know-how. 5) Create incubators or science parks near major research institutions. 6) Provide public services - transport, telecommunication.- or provision of equipment, buildings, or services.

The policy framework is presented in Table 4.2. Policy priorities and objectives for each of the elements of acquiring high-technology capability - technology transfers, indigenous innovation and research, and infrastructural development - have been identified. These are tools to stimulate new industries and technologies, improve the indigenous innovation potential, promote learning from foreign technologies, and create a technological infrastructure.

Of particular importance is the creation of an environment in which high-technology firms can transform information and ideas into products and production processes. High-technology firms must actively seek information from many channels, formal and informal, both internal and external to the firm (Macdonald, 1987). To improve the search capabilities of firms in developing countries, local scientific institutions may act to bridge pure science and new technological developments in the industrialized countries and the efforts of indigenous high-technology firms.

The following sections examine to what extent these policies have been utilized by the U.S., Japan, and South Korea. The U.S. and Japan have taken different policy pathways to attain high-technology capabilities. South Korea, one of the most technologically advanced developing countries, is an example of a country that remains at the stage of acquiring a high-technology capability. These case studies, then, will be used to identify broad strategies for applying policy framework in a development context.

The U.S. and Japan - Contrasting Policy Models of High-Technology Capability

Japanese policy has focused on building up technological capabilities since the nineteenth century (Benson and Lloyd, 1983). Imported technologies are carefully selected and adopted to the Japanese environment, often by government enterprises and laboratories. Firms with technological capabilities are given priority in importing technology, and the domestic market has been protected for these infant industries by trade regulations. Capital for technological development is supplied by the Japan Development Bank, and commercial banks that carefully follow government priorities. Laws are introduced to promote selected industries, such as allocating funds on favorable terms, the granting of tax benefits, and exemptions from cartel regulations (Benson and Lloyd, 1983).

U.S. policies for high-technology, on the other hand, have resulted as much from defense procurement policies as from government support of generic research[1]. Defense

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[1]American technology policy, in general, has been oriented, in descending order, to: (1) direct support for R&D, (2) government procurement, (3) indirect fiscal and financial incentives, and (4) policies that directly regulate the nature of competition in the marketplace (Flamm, 1987: 93).

R&D generally accounts for a major share of government funding of industrial research. This research strategy has been criticized because the technology and products that the government procures may not be suitable for and profitable in a civilian market (Nelson, 1984). Regardless, the procurement of microelectronic products by the defense department led to significant innovations by U.S. industries (Lalor, 1985). Contributing to the success of U.S. policies were the linkages between government funded research in universities and product development in firms.

While policies that resulted in American dominance in informatics have been linked to national security, the success of Japanese informatics industry has been associated with MITI's[1] policy guidance. Both programs protected the home market - in the U.S. by government procurement restrictions, and in Japan by reserving the civilian market for Japanese firms. In both cases vigorously competing firms were rewarded for technological advances by access to large public and private markets. Publicly funded R&D programs enhanced the abilities of the firms to produce advanced products (Nelson, 1984).

In the U.S., almost all of the exploratory R&D efforts that led to the first computers were financed by the armed forces and aerospace programs. The government was practically the sole market at that time and continued to be the dominant market into the early 1960s. A commercial computer market emerged from 1965 on, and direct government funding lessened. For example, the work that led to integrated circuits was not directly financed by the government, although technological efforts were undertaken with the clear understanding that there would be a massive governmental market (Nelson, 1984). More recently, the government has continued its direct role in supporting the high-end, super computer market.

Japanese policy-makers quickly recognized the key role information technology and the goal to establish a viable knowledge-intensive industry was initiated in the early 1970s. Industries were targeted and policy was shaped after carefully forecasting future directions of technical change and evaluation of the relative importance of various technologies (Freeman, 1988b).

> The Japanese system of informal and formal technological forecasting permits the formulation of technological and industrial policies not so much on the basis of particular products or of existing industrial statistics or the weight of established firms and industries, but rather on the basis of those new technologies which are likely to transform the established existing pattern (Freeman, 1988b: 333).

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[1]Ministry of International Trade and Industry.

Rather than to defense markets, policy was directed to industrial and consumer markets. A restrictive trade policy was an essential element in Japan's early efforts to develop a computer industry (Flamm, 1987). The initial impetus of the electronic industry began through a process of imitation, assimilation, and improvement of imported technologies through reverse engineering (Sayer and Morgan, 1987; Freeman, 1988b). Technological imports were only allowed on a selective basis to protect local technology developments and capabilities. Japan's successful technological development demonstrated how restrictions on transfers of technology may promote technological independence, and accelerate the learning process (Chatterji, 1988).

Policies to promote the informatics industry included tariffs, quotas placed on selected imports (including computers and integrated circuits, which required MITI's approval to import on a case by case basis), assistance for exports, and MITI funded cooperative generic research (in laboratories staffed by scientists and engineers from several companies). Foreign investments and technology licensing agreements in the informatics industry were carefully controlled to avoid technological dominance by U.S. firms. Texas Instruments, the only U.S. firm to have a production plant in Japan until the end of the 1970s, had to license its integrated circuit patents to other Japanese firms and limit production to less than 10% of the market (Dickens, 1986). Within the Japanese market, however, fierce competition existed even with protectionism. MITI also had an important role in arranging low cost financing, providing incentives to export, co-operative R&D tax credits, and most important, facilitating technology transfers between Japanese firms (Sayer and Morgan, 1987).

In 1976, the Japanese government liberalized trade and investment in the informatics industry although tariffs are still in place today which are only slightly higher than in the U.S. and lower than in Europe (Flamm, 1987). While other U.S. firms, like IBM, have set up operations in Japan, the government continues to purchase virtually all of its computers from Japanese firms.

MITI also helped domestic computer firms establish a leasing company so that, like IBM, they could offer their machines on lease. MITI attempts to not direct the commercial development of computer companies, but to see that they have the technological capabilities to compete with IBM and the other major foreign companies in designing and developing next generation computers (Nelson, 1984). MITI stimulates the introduction of new technologies by research investment (for example, the government funded 50% of VLSI research carried out by five major Japanese firms) and by recognizing the key role of externalities and infrastructure for innovative firms (Freeman, 1988b; Lalor, 1986). In Japan, R&D in new technologies is carried out without involving a university connection; MITI unites and subsidizes several firms to do generic cooperative research (Nelson, 1988).

Table 4.3 Government Entities Holding Principal Jurisdiction over Policies Affecting Competitiveness in Microelectronics.

Policy	Japan	United States
Information Industrial Policy	MITI MPT	
Trade Policy	MITI	USTR Commerce USITC State
R&D Funding	MITI MPT	DOD DOE
Tax Policy	MOF MITI	Treasury OMB
Procurement	MPT	DOD
Antitrust	MITI JFTC	DOJ FTC
Telecommunications Policy	MPT MITI	FCC Federal Courts
Technology and Science Policy	MITI	NSF Commerce DOD NASA DOE
Regional High Tech Promotion	MITI MPT Prefectures	States Municipalities

MITI Ministry of International Trade and Industry
MPT Ministry of Post and Telecommunications
MOF Ministry of Finance
JFTC Japan Fair Trade Commission
(Source: Howell *et al*, 1988).

U.S. policies affecting microelectronics have been implemented by numerous agencies with multiple, often uncoordinated and piecemeal objectives (see Table 4.3). The two Japanese ministries, MITI and MPT, have been more effective at enhancing commercial competitiveness in Japan (Howell *et al*, 1988). Not only do Japanese firms enjoy a coherent long-term strategy, but particular products are targeted and complementarities and technical standards are developed among component producers, consumer electronics producers and computer producers (Morgan and Sayer, 1988). The result is a less uncertain environment and more confidence to make long-term investments in research, development, software, equipment and training (Freeman, 1988b).

The Japanese long-term approach through MITI has been supplemented by the Japanese education and training system. Japan has a large number of students acquiring degrees in science and engineering; equally important is the training and retraining of employees in Japanese firms. According to Freeman (1988b):

> The combination of a high level of general education and scientific culture with thorough practical training and frequent up-dating in industry is the basis for flexibility and adaptability in the work-force and high-quality standards... Obviously, the availability of a large number of good-quality professional engineers, not just in R&D but in production engineering and management too, generally has played a vital part in the Japanese success in the import of technology, the redesign of processes and products, and increasingly now in autonomous innovations (pp. 339-340).

A testimonial to the Japanese technological success is a recent U.S. Defense Department report that identified Japan as the international leader in 6 of 22 key technologies[1]. The success is a tribute to MITI's policies and the sophisticated international acquisition and application of relevant technological information.

Based on successful catch up policies and industrial learning from imported technologies, the Japanese model proffers a relevant example for developing countries. The Japanese experience demonstrates that countries with the capability to absorb advanced technologies have a strong potential to 'make leaps' and generate knowledge and technology at the frontier (Abramovitz, 1986). The U.S., with its well developed technological infrastructure and wealth of innovating industries has adopted a different policy strategy, one aimed less at learning from imported technologies and more at ensuring export markets for domestic firms, scientific leadership in universities, and national security. Although probably not the most appropriate model for developing countries because of its defense orientation, the U.S. example demonstrates the importance of institutional structures such as higher education.

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[1] The report assessed that Japan held a significant lead in key niches of the following technologies: microelectronic circuitry; preparation of gallium arsenide and other compound semiconductors; robotics; integrated optics that use light instead of electricity for circuits and computers; superconductivity; and biotechnology materials and processing (NYT, 1989).

South Korea - A Developing Country High-Technology Policy Model?

Among developing countries Korea[1] is often cited as a success model with respect to the commercial electronic segment of the informatics industry (Suarez-Villa and Han, 1989). Like Japan, the role of the Korean government is strong; both as a mentor for industry and a generator of development. Korea, like the other Asian NICs, has aimed at production principally for the international market, based initially on low-cost labor advantages. Foreign participation was required for access to technology and markets. Although starting with simple technologies and mature products, based on low-skill, low-cost labor processes, the Asian NICs are now attempting to move to increasingly complex technologies, like computers. Ting (1987) draws together the main components of the Asian NICs' experience in technology development:

> 1) the promotion of market-oriented technology policies both on the national as well as on the firm level,
> 2) the choice of a technology and production system that optimizes the local technical and organizational resources and infrastructure,
> 3) the choice of technologies that are knowledge-intensive rather than capital intensive,
> 4) the adoption of a set of government policies that will stimulate the creation of a self-sustaining indigenous technological structure which can attune itself to the constantly shifting comparative advantages in the global markets (p. 154).

Korea's development strategy has, since 1962, been one of export-oriented industrialization, with import substitution shifting between different sectors as the country deepened its industrial structure. In addition to emphasizing exports, the government has attracted foreign investment for finance and as a source of technology. Korean purchases of technology have more typically been arm's length transactions, rather than direct foreign investment (Dahlman and Westphal, 1982). Unlike Brazil, the Korean government did not allow TNCs to become dominant, and foreign investment is overshadowed by investment undertaken by public and private entities. Indeed, the state banks finance local firms in risky or priority areas with subsidized interest and low taxes. Such a transfer of technology policy has had a favorable impact on local technological learning and accumulation. TNCs are, however, allowed to operate in sectors that are given priority by national development strategies. For example, there is some foreign investment in export and high-technology industries, although domestic firms at the same time are induced to

[1] All reference to Korea refers to South Korea only.

acquire and improve technology and are sometimes given protection (Singer and Ansari, 1988).

The electronics industry is an example where foreign direct investment has been a significant source of technology (Westphal *et al*, 1984). Korea has relied more extensively on direct foreign investment in the electronics industry because technologies are rapidly changing and production for (and access to) export markets is reliant on brand names (Dahlman and Westphal, 1982).

The development of consumer electronics policy in Korea (see Table 4.4) was designed to occur in three stages: first, the implementation of a production operation with little indigenous technological input, second, assimilation of foreign technologies based on limited indigenous technical know-how, and third, the gradual improvement of foreign technology (Kim, 1980). The implementation stage began in 1959 with the local assembly of radios for the domestic market. Soon thereafter, in the mid-1960s, the export market was responsible for the industry growth, with much of the production in the hands of foreign firms. Foreign firms were seeking low-labor-cost locations for assembly plants to reduce production costs; the assembled components were then shipped back home. Local firms began to take a more active role in production in the early 1970s, although foreign firms and joint ventures were significant (Edquist and Jacobsson, 1987). Local firms concentrated on simple consumer products, like black and white television sets, at the mature stage of the product life cycle and the major focus of output was on the export market. Technology was imported in a packaged form and exported under the technology supplier's own brand name (Lalor, 1986).

During the 1970s and early 1980s, although foreign firms and joint ventures were still significant, local firms were able to 'learn' from the simpler technologies and, as technological capabilities improved, to imitate and modify foreign technologies through licensing. Local firms were gradually able to produce more complex consumer products such as color television sets and cassette players (Lalor, 1986). By 1983, Korean firms were dominated by four large and diversified conglomerates, although there were some 450 firms with 41 of those with more than 1,000 employees (Tigre, 1987; Edquist and Jacobsson, 1987). Foreign participation, however, remains strong, accounting for slightly less than half of Korean electronics production (Cline, 1987).

Table 4.4 Technological Development in Korea.

	Stage 1 (Implementation)	Stage 2 (Assimilation)	Stage 3 (Improvement)
New firms established through	Transfer of foreign technology	Mobility of local technical and entre-preneurial personnel	
Technical task emphasis	Implementation of imported technology	Assimilation for product diversification	Improvement for enhancing competitiveness
Critical human resources	Foreign experts	Local technical personnel trained at supplier firms	Local scientific and engineering personnel
Production technology	Inefficient		Relatively efficient
Predominant source of technological change	Transfer of 'packaged' foreign technology		Indigenous efforts
Predominant form of international transfer of technology	'Packaged"		'Unpackaged'
Predominant sources of external influence on technological change	Supplier and government		Customer, Competitor
Market	Local (low competition)		Local and overseas (high competition)
Emphasis on research, development, engineering	Engineering	Development and Engineering	Research, Development and Engineering
Supply source of components and parts	Mostly foreign		Mostly local
Important government policies	Import substitution		Export promotion
Role of local applied R&D institutions	Consultative	Adaptive development	Research and Development

Source: Kim, 1980.

As the cost of Korean labor rose, competition from other Asian countries with cheaper labor led to the sourcing of more routine assembly tasks to those countries (Dickens, 1986). This forced the four larger firms to move away from simple electronics and focus more on product diversification and R&D.

This move toward advanced technologies, such as telecommunications and computer-related products, has met strong barriers. Foreign firms are not licensing relevant technologies to Korea for fear of direct competition (Lalor, 1986). And since production of electronic products was often undertaken by firms acting as subcontractors for foreign firms, and in other cases by license agreements, the indigenous technological know-how is not very deep (Edquist and Jacobsson, 1987). The government has responded by imposing import restrictions in 1982 on personal computers.

Korean computer policy has the objective of promoting a mini- and micro-computer and peripheral industry by protecting the infant domestic industry from direct competition of TNCs. Government purchases are limited to national products, and private imports require permits (Tigre, 1987; Cline,1987). The industry also benefits from government credit policies and government investment in public research (such as the Korea Institute of Electronics Technology - KIET), although the technological capabilities of the large conglomerates exceeds that of the institutes (Edquist and Jacobsson, 1987). The government has encouraged private R&D activities by various types of incentives including tax write-offs, subsidies, and fiscal incentives for R&D investment. As a result, R&D expenditures have increased rapidly in the last few years. At the moment, the local market drives the demand for these locally produced products.

Korea has concentrated almost exclusively on the low end of the computer industry; personal computers and terminals dominate local production. Domestic production of mini-computers, printers, storage devices, other peripherals, and software are either at low levels or non-existent (Cline, 1987). Between 1980 and 1985 Korea attempted to restrict the importation of peripherals and microcomputers compatible with the IBM/PC. However, due to pressure from the U.S., with whom Korea has a trade surplus, the government decided to change this strategy (Ferreira, 1986).

Assimilation in the Korean case is a result of indigenous technological efforts over time, mainly by local firms, to gain technological mastery and accomplish minor technological changes (Dahlman and Westphal, 1982). Many of these firms are actually large conglomerates and, in advanced technologies, enjoy either explicit or implicit market protection. Korea has managed to minimize technological dependence because of the benefits of technological learning (Alschuler, 1988), a process assisted by an arms length relationship with foreign technologies and joint ventures limited to a maximum 40% foreign participation of risk capital. Korea's export dependence, and the resultant ability of the U.S. to influence development strategies has, however, limited the scope of computer policies and thus high-technology capabilities.

The Role of Government and High-Technology Capability

This review of high-technology development models demonstrates that policy is vital for promoting the development of infrastructure, selecting, initiating, and supporting the industry, and orienting technological change and learning based on balancing the support of foreign technology and indigenous research. Overall, the Japanese informatics policy model supports many of the policy notions designed at the beginning of this chapter. As the example of Japan indicates, infant industry protection may allow firms to enter market segments dominated by foreign firms[1]. Much of the technology used by local firms was obtained either through reverse engineering or through licensing agreements from abroad. The technology was carefully selected and regulated by the government; and local learning of that technology was fundamental. When necessary infrastructural components were lacking, such as capital, the government may have to step in and fill the gap. The government, as illustrated in the case of Japan, has an important role in providing venture capital and direct loans for infant high technology firms (or other arrangements such as grants, subsidies, financial sharing arrangements, loan guarantees, and export or import credits). The country experiences indicate that policy may stimulate industrial R&D by providing incentives for innovation and R&D, or by reducing the cost of R&D (e.g., subsidized credits and special credit lines, grants, fiscal incentives, tax concessions, accelerated depreciation of R&D equipment). Equally important is the encouragement of joint R&D projects to consolidate limited resources, as demonstrated by MITI and Japanese firms.

The example of the U.S. highlights the importance of higher education, R&D expenditures, government procurement. That the state constitutes a significant market is clearly indicated by both Japan and the U.S., and emphasizes the importance of public purchases and large governmental markets to assist the development of infant high-technology firms.

South Korean technological development policies, although generally regarded as successful in consumer electronics, accentuate the difficulties of acquiring a high-technology capability. In particular, dependence on foreign investment and technology combined with trade 'vulnerabilities' that have acted to moderate computer policies have each limited high-technology capabilities. Korea has been successful, however, in learning

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[1] Based on these policy examples, it appears that at the infant stage, local markets are more important than the export market, although the development of export markets becomes important.

from foreign technologies, stimulating indigenous R&D, and encouraging infrastructure development .

Policy influences a range of activities: the protection of infant industries, the sending of students abroad for advanced education, the funding of research activities, and the regulation of foreign technology licensing agreements. Furthermore, national policies may be supplemented by directives from state and local governments, especially in the area of local technology infrastructural development. While policy may have gallant objectives, often unintended results impede or override original objectives. Hence, a careful balance of protection and openness needs to be achieved. These policy notions will be examined for the Brazilian informatics industry in chapter 5.

CHAPTER 5

BRAZILIAN POLICY AND THE DRIVE FOR HIGH-TECHNOLOGY CAPABILITY

Chapter 5 provides historical perspective on Brazilian development policy. It stresses the historical trend of industrialization through import protection, the openness of national production to foreign investment and technology, and the regional concentrations of industrial activity. The relatively recent interest in incorporating science and technology policies into broader development strategies is documented. These policies attempt to build technological capabilities by solidifying the technological infrastructure, regulating transfers of technology, and developing an indigenous research capability.

The latter sections of this chapter will trace the evolution of informatics policy, specifically emphasizing the broad range of technology policy instruments[1] used to support the industry. Informatics policies reserve the low-end segments of the domestic informatics market to nationally owned companies, eliminating competition from foreign corporations. The informatics development strategy represents, for the first time in its history, a break with Brazil's traditional openness to foreign investment. As will be shown, policy objectives illuminate the Brazilian intention to develop a high-technology capability in informatics.

Post World War II Industrialization - Import Substitution, Technological Dependence, and Regional Concentrations

Brazil's drive to industrialize is largely a post World War II phenomena. Previously, exports were confined to a limited number of primary products, depicting the agrarian orientation of the economy: coffee, cocoa, sugar, cotton, and tobacco. Brazilian policy makers became increasingly convinced that the future of primary product export dependence was at best dim. World trade in manufactured goods was expanding at twice the rate of the type of products Brazil was exporting. As Brazil's exports steadily lost their share of world trade, the incentives for policy makers to change the structure of the economy by import substitution policies became unavoidable.

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[1]See chapter 4 for explanation of the various high-technology policy instruments.

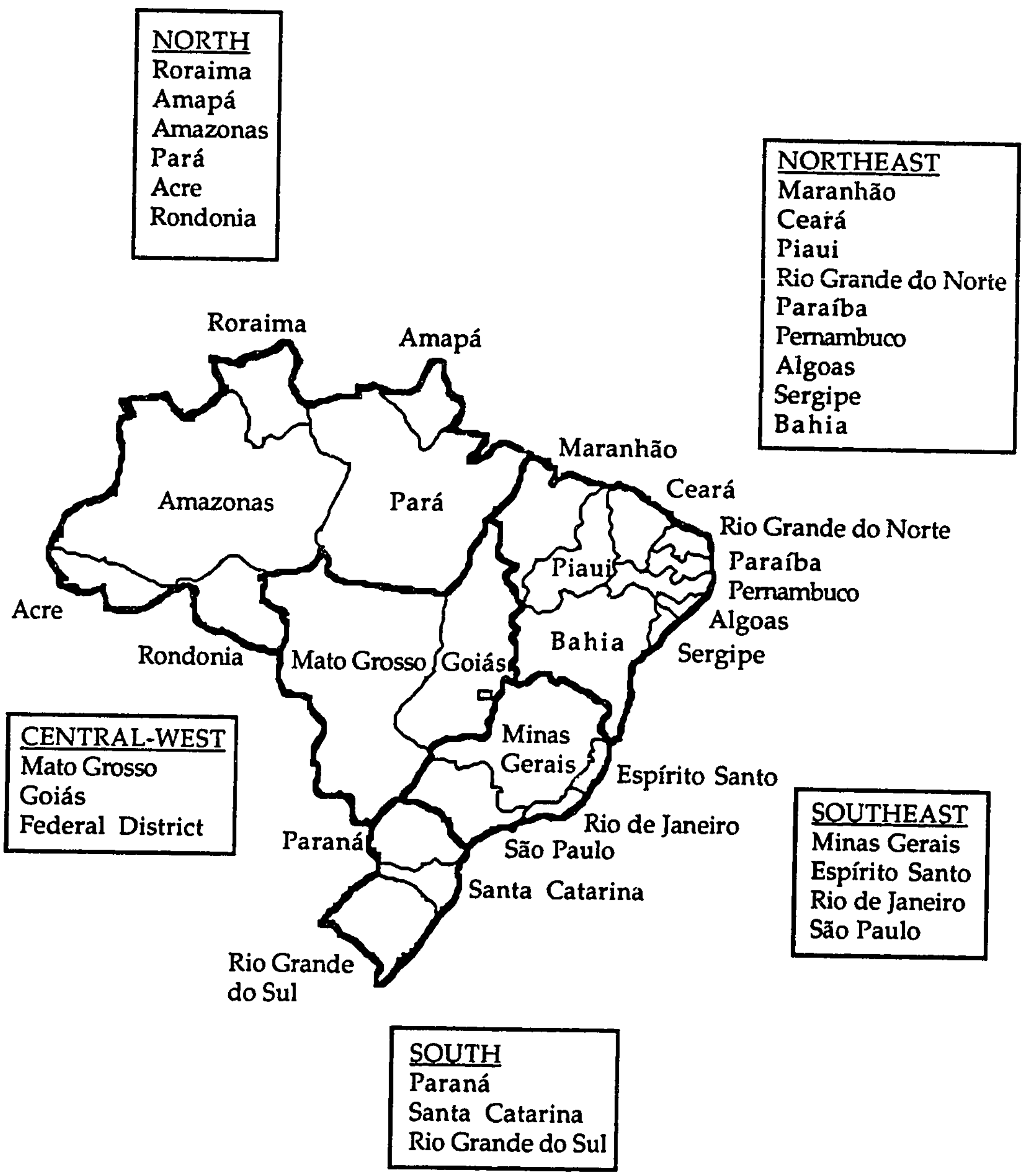

Figure 5.1 States and Regions of Brazil.

Import substitution policies continued until the mid-1960s. During the late 1960s and early 1970s industrialization became more export-oriented, and since 1973 there has been a combination of the two. Throughout these policy cycles foreign investment has been encouraged not only for capital but more importantly for technological know-how

(Smith, 1981). Much of this technology was acquired through foreign direct investment rather than licensing, limiting the actual diffusion of know-how. The rationale of these policies was to promote and diversify the industrial base of the country. Brazil has rapidly industrialized, as evidenced by increasing exports and a growing percent of the population employed in manufacturing activities. However, the positive effects -- in terms of industry creation -- were most significant in the Rio-São Paulo axis (the core Southeast region) where agricultural wealth, transportation networks, and some light industries were concentrated.

Initial import substituting industries were designed to serve markets which had already emerged; their logical location was in the core area where income was highly concentrated. Since the core region was the node of the transportation network, other markets could easily be supplied from this location. The capital deepening stage of import substitution requires the replacement of intermediate goods and producer and consumer durables by local industries, such as petrochemical and steel (intermediate goods) or automobiles and refrigerators (producer and consumer durables). Industrial and political linkages became very important in this stage, augmenting the advantages of locating in the core area. Because import substitution industrialization was closely controlled by the government, industrialists needed a continuous link with government in order to gain official support (or protection) for projects, or at least to have immediate access to relevant policy changes. Since the later, capital-deepening stages of import substitution industrialization required a variety of inputs, parts and components were easier to access (and cheaper) at locations in the core area - this applied to the many imported inputs as well. Other offerings or inducements for locating in the core region were access to markets, a skilled labor force and financing. The development of an industrial infrastructure was thus concentrated in the São Paulo- Rio region.

After the military takeover in 1964 the government became increasingly centralized. The style of government that emerged can be best described as bureaucratic-authoritarian, with goals that were less concerned with inequalities (social or geographic) than with economic efficiency and growth (Baer, 1983). The bureaucratic-authoritarian regime sought to achieve a "deepening" of industrial production by promoting policies grounded on rational economic thought. This led to the Brazilian export phase, the suppression of unions and the working class, and an increasing reliance on TNCs for production and technology and state enterprises. Since conflicts between the objectives and goals of the various policies could not be resolved between social groups and regions without threat to the new political regime, it was necessary to make decisions on what the stability of the economic system would be in the long-run; the benefits were again felt mostly in the core Southeast region (Clements, 1988). After 1973, the end of the "Brazilian miracle", state planners opted for a mixture of import-substitution and export promotion policies that continue today, yet growth arguments dominated the social and regional distortions resulting from these market processes.

Brazil's success during the export phase of the late 60s and early 70s was something of a "double edged sword." In order to compete in export markets, Brazilian firms required advanced technologies and imported technology via foreign direct investment. Foreign direct investment rose over 250 percent between 1969 to 1974. The significant imports of technology drained scarce foreign exchange, but more important, according to Smith (1981), led to a technological dependence probably not experienced to such a degree by any other developing country.

Brazil, from the earliest stage of its industrialization, has permitted a free inflow of technology by means of foreign controlled affiliates. The entry of foreign companies was considered vital to provide both capital and the required technology. Multinationals have made enormous inroads into the economy in general (tables 5.1 and 5.2) and especially in high-technology sectors.

Table 5.1 Participation of the 1,000 Largest Firms in the Brazilian Economy.

Largest 1,000 Firms in Brazil	1979	1985
State Firms	31%	36%
Private National Firms	44%	41%
Multinational Firms	26%	23%

Source: Jornal do Brasil, 1987e.

Table 5.2 Participation of MNCs in the Brazilian Economy.

Industrial Production	26%
Employment	18.5%
Taxes	35%
GDP	26%
Exports	18%
Trade Surplus	10%

Source: Jornal do Brasil, 1987e.

The Brazilian economic picture in the 1980s has not been positive. The second oil shock in 1979 and rising interest rates on external debt have exacerbated balance of payments problems, increased inflation, restricted government spending, all of which has severely impacted the industrial sector. Brazil's GDP, between 1980 and 1983, actually declined by 6.1%, and as a result of decreasing government expenditures and high interest rates, capital investment fell from 25% of GDP in the mid 70s, to 16% in the mid 80s (Tyler, 1986).

Policy in the 1980s has been largely influenced by the need to generate foreign exchange through export growth and import restrictions to make the formidable debt-service payments. From 1980 to 1987, Brazil paid out $50.4 billion more in debt payments than it received in new loans (New York Times, July 26, 1989). Austerity measures dictated by the international community have forced Brazil to eliminate traditional export subsidies; hence exchange rate devaluations are the primary tool to promote exports. Devaluations, however, have raised the price of imports and the rate of inflation (Clements, 1988). As a result, pressures to restrict imports have greatly increased. The Brazilian economy, the world's eighth largest in terms of GDP, entered 1990 battling inflation rates of over 50% per month and the risk of economic chaos.

Brazilian industrialization, then, has been characterized by extreme regional concentration, a significant dependence on foreign investment and technology transfers, and balance of payments problems that have put pressure on limiting imports. Each of these factors, in different ways, have contributed to the development of Brazil's high-technology development strategy. Industrial concentrations and the associated well-developed regional infrastructures have determined the location of high-technology industries. Pressures to restrict imports and an awareness of dependence on foreign technology and investment stimulated national yearnings for a 'Brazilian' high-tech industry. Before we examine Brazilian high-technology policies, however, the following section traces the development of a policy 'consciousness' regarding the importance of technology.

Brazil's Recent Experience with Technology Policy

For a majority of developing countries, including Brazil, it was only in the mid 1970s that 'technology' first appeared in development strategies[1] (UNIDO, 1984). Brazilian industrialization up to that point was characterized by several large firms that were foreign owned and controlled, but lacked autonomous capacity for research, development, or even product or process innovation. The industrial sector developed during the 1960s had its demand for more complex technologies increasingly satisfied from foreign sources, elevating significantly the value of royalty payments sent abroad (Rattner, 1983). TNCs in Brazil often transferred only those aspects of technology required for local assembly, characteristic of typical technological dependence reflected by high payments for technology, little indigenous technological capabilities, and little control over the direction and pace of industrial and technological development. As a result of this technological dependence, the federal government instituted policies in the early 1970s in an attempt to control this indiscriminate importation of technology (Rattner, 1983). Prior to this more explicit response, however, were government policies that bolstered the technological infrastructure.

Building a Human Infrastructure

Initial technological policies focused on institution building and human resource development. For example, in 1951 the National Research Council (CNPq) and the Campaign for the Improvement of the Higher Educational Staff (Capes) were created. The objective of these two institutions was to finance the development of human resources through higher education, in particular by increased funding for universities and research institutions. Both organizations helped modernize Brazilian universities and create a human infrastructure, although their research efforts had little industrial application.

In 1965 the Agency for Financing Studies and Projects (Finep) was created to fund engineering firms in key areas of development policy. And in 1963, with the creation of the National Fund for Science and Technology (Funtec) to finance national technological projects under the Brazilian National Development Bank (BNDE), a view clearly emerged of the crucial importance of science and technology for development.

The government backed this view by supporting higher education, and academic research. In the 60s, BNDES, Capes and CNPq helped place graduate-level studies in the

[1]Other countries beginning to adopt technology policies at this time include, for example, India, Mexico, Pakistan and Venezuela.

principal Brazilian universities[1]. A National Fund for Scientific and Technological Development (FNDCT) was created in 1969 to finance S&T policy and in particular to modernize university laboratories and promote university applied research. Later, in 1971, Finep was reorganized to administer FNDCT funds, and essentially operated as a bank to promote S&T development. Finep also, in 1974, took over Funtec's responsibilities (Dantas, 1988).

For the first time at the federal level, explicit policies for S&T began to be included in the development plans. In 1972, a National System of Scientific and Technological Development (SNDCT) was set up to coordinate the role of government in S&T planning, although the CNPq, in 1974, became the central organization of the SNDCT and was made responsible for overall S&T planning. These plans led to policy guidelines as stated in the Basic Plan for Scientific and Technological Development (PBDCT). Real efforts to promote and coordinate science and technology in Brazil began with the combination of the SNDCT and CNPq, and the approval of the First Basic Plan for Scientific and Technological Development (Nunes, 1985).

Regulating Transfers of Technology to Increase Technological Capabilities

The first S&T development plan focused on funding institutions and sought to establish policies to efficiently select and learn from transfers of technology. Transfers of technology were to be targeted for priority development sectors. Policies were to be implemented to reduce the cost of imported technology, improve local knowledge of the availability of foreign technologies, and eliminate restrictions in technological agreements (Smith, 1981). Since this first S&T plan there have been two more covering the periods 1975-79, and 1980-85.

The second plan (1975-79) continued the drive to strengthen the technological infrastructure, and also focused on promoting the development of the technological capabilities of national firms. Legislation concerned with technological transfers was enacted in 1975; a result of the new Medici Government that was committed to increase local industrial and technological capabilities in key sectors (Naim, 1987). Technology transfer agreements were to be registered with the government with differing regulations on terms and payments authorized, periods of validity, requirements on the degree of local participation, depending on the type of technology and contract. Technology imports now

[1]Segal (1987b) notes that in Brazil the CNPq has funded university centers of excellence in fields such as solid-state physics and aerospace and these centers have worked closely with the private sector and state enterprises.

were to be evaluated to see if they should be imported. Furthermore, the government: 1) strengthened the bargaining position of the recipient to reduce the cost of imported technology; 2) eliminated clauses that restricted the local absorption and diffusion of imported technology, as well as clauses that limited on the export of products manufactured with the technology; 3) implemented a bias to favor the importation of technology rather than importing capital or goods; and 4) required full disclosure of technical knowledge to ensure the absorption of the technology and for training of local labor (Baranson, 1981). These measures clearly mark a new perspective regarding past indiscriminate imports of technology. The new objective was to learn from transfers of technology.

Problems with Creating a Research Infrastructure

Although several prerequisites for technological development were in place, Brazil still lacked an effective research capability. The orientation of Brazilian research was more towards pure research and science, rather than applied research and industrial technology [although officially, in 1979, the distribution of research expenditures was similar to advanced countries -- basic research (16%), applied research (32%), and development (52%) (Erber, 1985a)]. Unfortunately, these research activities failed to link with industry and did not materialize into product development (Telles, 1986).

Additionally, R&D activities and investment by local firms remained, and continues to remain, extremely slight. During the period 1975-1979 only 0.2% of all firms legally established in Brazil had some type of R&D activity, representing only about 0.25% GDP. Although in recent years those figures have slightly increased, Brazil still imports much of its technology and has a significant deficit in its technology balance of trade[1].

Industrial policy has further hampered R&D activity by promoting the development of products, rather than the development of process and product technology. The result has been a continued high dependence on foreign technology, and a lack of demand for the technological research from universities and government institutes. The high degree of uncertainty in the Brazilian economy and short-run tendency of policies only exacerbated the fear of investing in R&D.

Aiming to remedy the poor showing of local R&D, the third technology plan (1980-85) sought to stimulate public and private sector innovation. New measures, adopted in the 1981-1983 period, were introduced for the development of indigenous technology. In

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[1]Between 1974 - 1984, the technology deficit is estimated to have accumulated to about US$ 1 billion (Telles, 1986).

particular, policies stated that: 1) national engineering firms must participate in engineering services contracts; 2) technology contracts were to be approved on the condition that the recipient implement a program to invest in technological infrastructure and in R&D, either in-house or through a national research institute; 3) firms must justify the need for technological imports and the selection of the supplier; and 4) engineering, capital goods, and chemical/petrochemical contracts were to be reviewed in greater depth (UNCTC, 1987). In addition, in order to lessen balance of payments problems, several policies were adopted that indirectly impacted technology: taxes on purchases of foreign exchange (1980), ceilings on public sector imports (1980), an import license system (1981), and a comprehensive foreign exchange system (1983) (Pochet and Praet, 1988). Foreign capital remained important, although more in the form of joint ventures to prevent full foreign control yet facilitate technological transfers (Franco, 1988).

Achievements of Brazilian S&T Policies

In spite of the low R&D expenditures by local firms and the high dependence on foreign capital and technology, there have been rewards for Brazilian S&T policy efforts. Since 1974, the beginning of explicit S&T policy in Brazil, a handful of positive changes may be noted. Brazilian expenditures in S&T have steadily increased over the years, in absolute amounts and as a percentage of GDP (Table 5.3).

Table 5.3 Brazilian Expenditures in Science and Technology and GDP.

Year	GDP*	S&T Expenditures**	S&T/GDP (%)
1973	483.3	.95	.20
1974	708.0	1.5	.21
1975	1,009.7	3.5	.35
1976	1,625.1	6.4	.39
1977	2,486.8	12.7	.51
1978	3,763.9	18.7	.50
1979	6,311.8	33.9	.54
1980	13,163.8	71.0	.54
1981	25,631.8	153.0	.60
1982	50,815.3	334.1	.66
1983	121,055.4	850.0	.70
1984	391,251.0	2,272.0	.70

*In billions of cruzeiros - real.
**Includes: R&D, engineering in innovative activities, science and technical activities.
Source: Telles, 1986.

By 1984, S&T expenditures as a percentage of GDP reached 0.7%. In 1987, the total budget for S&T was $1,640 million, approximately 0.7% of GDP (Anderson, 1987). While this figure is low relative to the industrialized countries, it compares favorably with other industrializing countries (Table 5.4). For cross country comparisons, in 1982, S&T/GDP in Mexico was 0.5%, and in 1981, S&T/GDP in India was 0.6% (Telles, 1986). Furthermore, Brazil increased the number of active researchers to over 30,000 (Erber, 1985a).

Table 5.4 Research and Development in the Western Hemisphere (1980).

Country	Researchers (full-time equivalent)	R&D Expenditures (US $ millions)	R&D (% of GDP)	Technology Exports as % of Total Exports
USA	600,000	$65,000	2.5	60
Canada	35,000	$1.200	1.1	30
Brazil	12,000	$800	0.8	25
Mexico	8,000	$600	0.7	15
Argentina	7,000	$400	0.6	20
Venezuela	3,000	$250	0.4	5
Colombia	2,000	$90	0.3	15
Chile	2,000	$75	0.2	15
Cuba	1,500	$50	0.25	5

Note: This table represents very crude estimates based on data from national science and technology plans, OECD, UNESCO, and National Science Foundation sources. There is little data on "shop-floor" industrial R&D in Latin America and it is probable that private sector R&D has been underestimated.
Source: (adapted from Segal, 1987a: 3).

Brazil, in comparison to other Latin American countries, is the most developed in science and technology. There are calculations that over 25% of all Brazilian economic growth over a fifty year period may be attributed to science and technology[1] (Segal, 1987b). Brazil, in the 1980s, was generating more than one third of its total export earnings from domestic or adapted foreign technologies, selling telecommunications systems, passenger jets, and processed orange juice to the rest of the world (Segal, 1987b). Technological capability has been strengthened by the regulation of technology transfers, indirectly aided by Brazilian efforts to reduce imports and to manage external

[1]According to Teubal (1987), the export performance and continued sophistication of the capital goods sector, which emerged in the late 1960 and 1970s, has benefitted from: skill acquisition and technological learning, government policies of protection and subsidies, and increased government purchases of locally produced capital goods. The accumulation of capabilities during the import-substitution and infant industry phase - physical capital, technological knowledge, experience, and skills - and the subsequent reduction in domestic demand prompted firms to export.

debts (Segal, 1987b). Science and technology policies have produced, relative to other Latin American countries, a human infrastructure for science and research, domestic linkages, and a technological development strategy based on national priorities. Policy priorities[1] include an aerospace industry, military technologies for export, hydropower, gasohol, telecommunications, computer science, and development of the Amazon region (Segal, 1987b).

Brazil has been successful at instituting comprehensive policies geared to controlling imports of technology and simultaneously building up local capabilities. Domestic capabilities have been enhanced by a build up of the physical and human infrastructure through the development of capital goods industries and the procurement policies of state firms and by subsidizing financing of technological activities of private firms -- giving local firms preference in purchases by state owned companies (UNCTC, 1987). Steel production is frequently cited as a successful example of indigenous technical change. From initial dependence on imported technology in the 1960s to a point, by 1975, where production and expansion was based on internal technology (Weiss, 1988).

A significant political step came with the creation of a new Ministry of Science and Technology (MCT) in 1985. The MCT had two objectives, first, to amplify the role of science and technology in the country, and second, to mobilize more resources for technological development. Designating a new ministry for these tasks emphasized the government's apparent interest in strengthening S&T capabilities. 'Apparent' because during the early 1980s, several technology-oriented agencies suffered governmental funding cuts, like Finep, CNPq, and Capes. Although overall S&T expenditures remained constant at .7% of GDP, from 1979 to 1984, funding for five principle science and technology agencies (CNPq, Finep, STI, Capes and Fapesp) fell in real terms by 42.5%. The MCT, however, has ambitious plans to invest 2% of GDP in science and technology by 1990. Furthermore, the MCT plans to increase the number of researchers in the country by increasing the number of graduate level researchers per year to 18,000 from 5,000 in 1987 (Dados e Idéias, 1988b).

Considering the state of the Brazilian economy, these plans are ambitious. Monies for S&T investment are limited and expenditures that do occur need to be carefully targeted for maximum benefit and with obvious results to assure continued backing from policy

[1]Rejected priorities, after costly failures, include commercial nuclear reactors through transfers technology, and Amazon pulp and paper industries (Segal, 1987b).

makers. Brazil remains limited on the number of national level research areas that it can pursue and must choose them carefully.

Informatics Policy in Brazil

Brazilian industrial development, shaped by import substitution policies, has traditionally relied heavily on the technological help of multinational corporations in the form of wholly owned subsidiaries and later joint ventures. Foreign technological know-how via foreign direct investment was considered vital for the growth of new industrial sectors, even though multinational efforts to develop new technologies through research and development were relatively small (Baer, 1983). The development of the informatics sector represents a break from this traditional reliance on foreign assistance; it is Brazil's first industrial sector reserved exclusively for national companies. This section traces the roots and evolution of that informatics policy.

The Origins of Informatics Policy

The first computer in Brazil was acquired by the state of São Paulo in 1957; thereafter, the demand for computers has grown faster than in any other Latin American nation. By as early as the late 1950s the government began to recognize the potential and importance of computers for national development. In 1959, a governmental group was organized[1] to improve the benefits from computer acquisition, principally by reducing tariffs on imports (Dantas, 1988).

Demand for computer equipment was met largely through imports from transnational corporations, although Burroughs and IBM served this growing market through wholly-owned subsidiaries and each had assembly plants in Brazil for local and export markets. Their manufacturing plants assembled some mainframe computers and peripherals and employed personnel mainly for production, sales, and service (Ramamurti, 1987).

As demand increased for minicomputers during the early 1970s, foreign companies, like Data General, DEC, Fujitsu, and others, were attracted to the Brazilian market; however these companies did not manufacture computers in Brazil. And none, including IBM and Burroughs, established R&D facilities or performed any significant

[1]This government organ was called the Executive Group for Application of Electronic Computers (Geace). In its short life it approved the importation of computers to PUC-RJ, the Brazilian Institute of Geography and Statistics (IBGE), and the firm Listas Telefônicas Brasileiras (Dantas, 1988).

R&D. Indeed, capable Brazilian engineers and technicians that had previously been involved in prototype computer research were retrained as salespeople for MNCs.

The first serious[1] attempt to develop a national technological capability in computers was prompted by the Navy for the purpose of servicing and modernizing the sophisticated computer equipment that controlled six frigates purchased from Britain in 1970 (Katz, 1988; Viegas, 1987a). The Navy has historically been the most nationalistic of the three armed services, influencing its interest to have local suppliers and maintenance for the computers on the new ships (Machado, 1985). The Navy's military strategy included industrialization as a key component to military power, and it was natural that industrialization should concentrate on specific industries crucial to the nation's military strength, such as producing computer equipment (Katz, 1988).

In addition to national security, there existed an interest in modernizing public administration, in particular upgrading work methods in the public service sector. For example, the Federal Data Processing Service (SERPRO), a state firm under the Ministry of Finance and responsible data processing services, the largest computer user in Latin America, sought to increase its efficiency and effectiveness with new data processing technologies (Tigre, 1983). SERPRO hired the best engineers available in Brazil during the end of the 1960s and throughout the early 1970s; their services were used to solve several software problems, and for some computer related design and manufacturing activities (Machado, 1985). Since the 1970s, some universities had strong R&D efforts in the area of computers with master's and doctoral programs in computer science and electronic engineering. These efforts eventually provided a national capacity required by the new industry (Machado, 1985). The availability of human resources, without which the computer industry could not have been initiated, lent support to the idea of developing a local industry. As early as 1976, there were over 20,000 technicians employed in data-processing activities, including operators, programmers and systems analysts (SEI, 1983).

Joining the Navy's interest in local computer production was the National Economic Development Bank (BNDE), that, as early as 1968, had an interest in stimulating the production of a prototype computer project in universities. In fact, BNDE was in

[1]University researchers and students had previously constructed computers. For example, in 1961 the Zezinho (the first Brazilian computer which had the capability to execute 20 operations) was developed by researchers and students from the Institute of Aeronautic Technology (ITA), however, this was for the benefit of student experience rather than industrial application. Graduates from the ITA later significantly influenced computer policy and technology (Dantas, 1988). For a good review of the significant initial academic research devoted to computers in Brazil, see Langer (1989) and Dantas (1988).

negotiation with universities for their computer project when the Navy proposal landed on their doorstep (Dantas, 1988). As a result, a special task group (Grupo de Trabalho Especial -- GTE[1]), was organized by the Minister of Navy and the Minister of Planning in 1971 to formulate a plan to satisfy the Navy's computer needs, and later, to orient the development of a Brazilian computer industry. Representing the GTE from the Navy was Commander Guaranys, with Ricardo Saur representing the BNDE. Negotiations between Saur and Guaranys led to the following three proposals. First, a local industry should target the lower-end minicomputer market. Minicomputers were considered to be within Brazil's technological capability; they would enjoy high growth rates within the Brazilian economy; and most importantly, multinationals had not yet begun local minicomputer production. Second, while recognizing that Brazil needed to import technology to launch an computer industry, steps would be taken to develop indigenous technologies. Thus, a major research project was funded to develop a Brazilian minicomputer[2]. Third, ownership would be shared equally by three parties -- the state, a local private firm, and a foreign enterprise[3] (Ramamurti, 1987: 51-52).

Early Conceptions - An Industry Based on Joint Ventures

The GTE sought a foreign joint venture partner to produce computers locally for both the military and civilian market (although the Navy felt the military market should have priority). Eight foreign firms were originally investigated; AEC/Telefunken, Phillips, Hewlett-Packard, Digital Equipment Corporation, Varian, IBM, CII/Honeywell Bull, Ferranti, and after Saur and Guaranys visited Japan, Fujitsu. Given the strict nature of the conditions (no restrictions on the export of computers manufactured, full transfer of technology with free updates and eventual ownership, and minority participation) the only firms that remained interested were Ferranti and Fujitsu. Fujitsu was the most willing to negotiate and even offered to transfer their semiconductor technology (Dantas, 1988). The

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[1]Financial support for the GTE came from the FNDCT/Finep and Funtec (BNDE) (Helena, 1984).

[2]The design and construction of this prototype minicomputer was carried out by two Brazilian universities: the University of São Paulo (responsible for the hardware) and the Catholic University of Rio de Janeiro (PUC) responsible for software). The minicomputer became known as the G-10. Approximately $10 million was spent on this project over a period of four years. About 200 technician and professionals were expected to work on it, further strengthening Brazil's human infrastructure.
University research in informatics was not confined to just these two universities, for example, the NCE at UFRJ developed prototypes of data-entry terminals that were later transferred to Cobra (Fleury, 1988) and the Universidade Estadual de Campinas (UNICAMP) also developed a prototype computer (Langer, 1989). Many of these researchers later became involved in Brazilian firms, often as entrepreneurs.

[3] This ownership structure appealed to Brazilian policymakers, being two-thirds private and two-thirds Brazilian. It was used successfully in the petrochemical industry in the 1960s (Ramamurti, 1987: 51-52).

Navy preferred Ferranti, an English company which was a traditional supplier to the Navy. The Ministry of Planning selected Fujitsu as the best proposal, hence in 1973 two distinct companies using the technology of Fujitsu and Ferranti, respectively, were established to reconcile opposing forces.

The first computer firm, composed of the state (BNDE), Ferranti, and a local company, EE Equipamentos Eletrônicos[1], was originally targeted to supply the needs of the Navy, to manufacture process control equipment and engage in R&D activity. This Ferranti, EE, BNDE joint venture was initially called Digibrás -- the name of the governmental holding company, but during the following year it officially became Cobra (Computadores e Systemas Brasileiros S/A)[2].

The second firm, an association of Fujitsu, EE, and BNDE, known as Brascomp, was to produce general purpose computers and develop computer peripherals. Fujitsu did not agree to the final terms, leaving only Cobra, which was formally incorporated in 1974 and took on the additional tasks of manufacturing general purpose mini-computers (Helena, 1983; Dantas, 1988).

Cobra's initial capital was comprised of three equal partners: Digibrás, Equipamentos Electrônicos, and Ferranti. This arrangement was not to last and the structure of Cobra quickly changed. By 1977 EE's participation fell to .5%[3] but other national investors eventually joined in, including: Serpro, the Bank of Brazil, and Caixa Econômica Federal with 39%, another grouping of banks called Empresa Digital Brasileira (EDB) with 39%, BNDE with 12%, Digibrás with 5%, and Ferranti with 4.5% (Dantas, 1988).

While Brazil's computer policy was initiated by the Navy, the Ministry of Planning took an active role in informatics. In 1972, a new agency, the Commission for the Coordination of Data-Processing Activities -- (Capre) -- Comissão de Cordenação dos Atividades de Processamento Electrônico -- was created, initially directed to; 1) gather information on the Brazilian computer complex (which consisted of a widely varied base of equipment with different origins, brands, languages, and standards), 2) organize and

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[1]EE Equipamentos Eletrônicos was started in the early 1970s as a result of the Navy's drive to nationalize the production of electronic equipment used by ships and planes, such as communications equipment or navigation radars (Dantas, 1988).

[2]By 1975 a group of 30 of engineers from Cobra were sent to England to absorb the technology of the Argus 700, acquiring valuable know-how on the development and manufacture of computers (Dantas, 1988).

[3]EE's position was complicated in part by the sudden death of one of its partners in an airplane crash (Dantas, 1988).

rationalize government computer purchases, 3) propose government funding policies for data processing activities, and 4) orient and coordinate computer science instruction in Brazil.

When GTE's mandate expired in 1975, Capre assumed many of its responsibilities, and much more, including the control over imports of computers, parts and components. Capre's additional power had the objective of controlling balance-of-payments problems. However, according to Fleury (1988), it also gave the agency effective control over which companies and products were to be manufactured in Brazil. Capre also was to review applications by public and private organizations to import data-processing equipment, and to distribute annual quotas among the competing organizations (Ramamurti, 1987).

According to Evans (1986), although Capre did not initially have the nationalistic perspective of GTE, it eventually became instrumental in setting up Brazil's 'nationalistic' computer policy. No doubt the oil crisis of 1974 influenced Brazilian policy for computers; the resultant serious foreign exchange problems led the government to restrict importation of many products, including computers[1], at that time the third largest and rapidly growing manufactured import (Cline, 1987). (Table 5.5 indicates the fast rate of computerization; most were imported.)

Table 5.5 Total Number of Computers Installed in Brazil (1974-75).
(in physical units and percentage increase)

TYPE OF COMPUTER	1974	1975	% increase
Minicomputers	1573	2271	44.4
Small	781	1046	33.9
Medium-sized	289	327	13.1
Large	71	82	15.5
Very Large	42	61	45.2
TOTAL	2756	3787	37.4

Source: Marques, 1984.

[1]Importers were required to deposit the full value of imports in the central bank, and in the case of machines and equipment, imports were to be financed by the supplier or a foreign institution with a minimum loan of 5 years to avoid immediate payback (Helena, 1984).

Although controlling computer imports would help rectify balance-of-payments problems, a more important reason for protectionism was the belief that an informatics[1] industry was strategically important to the nation and that Brazil needed a policy to reduce technological dependence and acquire indigenous technical capabilities (UNCTC, 1984). It was argued that IBM had the power to stop the country if it so decided[2],.

In February 1976, the Minister of Planning issued a decree that explicitly gave Capre[3] the power to design an industrial policy for informatics. Capre's overriding goal was to develop indigenous technological capabilities and reduce the country's dependence on imported technology. To meet this end it would integrate industrial policy, human resource development, and federal government activities in the area of data processing (SEI, 1983). Policy was to be based on the following five objectives:

1) To obtain the technological capacity that would enable hardware and software to be designed, developed and produced in Brazil;
2) To ensure that national corporations play a predominant role in the national informatics market;
3) To obtain a favourable balance of payments in products and services related to informatics;
4) To create jobs for Brazilians and more professional employment opportunities for Brazilian engineers and technicians;
5) To create the opportunity for the development of a parts and components industry for computers (Barbosa, 1985; UNCTC, 1984).

Capre's new role to design Brazilian policy meant tough decisions would have to be made regarding the role of international capital and technology. Challenges came from many different fronts.

As the minicomputer projects at USP and PUC/RJ were finalized, the technology was transferred to Cobra for production and commercialization[4]. The project's success

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[1]Informatics is used in Brazil to cover the whole field of computing, including computers and their peripherals used in data processing to instrumentation, microelectronics, process control, teleinformatics, automation (CAD/CAM systems, robotics, etc.), and software.

[2]Fregni (1985) argues that IBM could potentially stop the Brazilian financial sector (including the Bank of Brazil, the Central Bank, Itaú, Bradesco, etc.), the generation of electricity (Eletrobrás is completely controlled by IBM equipment), and the telephone system (due to the dependence of Telebrás on IBM equipment).

[3]Capre was composed of representatives from the Ministry of Planning, the National Research Council (CNPq), the General Command of the Armed Forces, the Ministries of Communication, Education and Culture, Industry and Commerce, and the Treasury.

[4]The G-10 technology from USP and PUC/RJ led to the first completely national computer introduced in 1979, the model 530 produced by Cobra. Several other research projects in universities and institutes led to, or motivated commercial projects, some recipient firms included: Scopus, Embracomp, Digiponto, Parks, OZ Eletrônica, Elebra, Exata, Prológica, and Polymax (Marques, 1984).

encouraged academics and local computer associations to support an industry based on Brazilian designed equipment rather than rely on technology via joint ventures with foreign firms (Fleury, 1988). While the academic community and the professional associations supported a mini-computer industry controlled by local capital and technology, industrialists were more interested in cheap prices for internationally available data processing technology (Evans, 1986).

On the other hand transnationals that had existing operations in Brazil, with IBM at the forefront, began aggressive marketing campaigns to set up manufacturing operations for their own minicomputers. In 1976, Brazil was already classified among the world's top ten markets for computers, and the threat of protection initiated TNC action[1]. At this time only England and Japan had adopted informatics policies to protect the local development of a national computer industry (Piragibe, 1985a). TNCs did not want to lose the Brazilian market.

In 1976, IBM decided to build a factory in Brazil for the production of its system 32 minicomputer. Armed with powerful arguments that their locally produced computers would offer price advantages and proven quality IBM took its case directly its customers, the press, and even the Minister of Planning[2]. As Evans (1986: 795) notes, IBM's proposal would easily fit into an ISI (import substitution industrialization) strategy, palatable to most 'reasonable nationalists.' Coupled with the economical and technological problems of Cobra, with expected loses of US $5.1 million in 1976, Capre's denial of IBM's project was something of a surprise (Fluery, 1988).

Capre, however, did invite firms to submit projects to manufacture minicomputers. All firms, including transnationals, were allowed to participate, with Capre making the final selections. Approval by Capre meant that those firms would be granted import licenses to import component parts. Capre's selection was based on five criteria, as Tigre (1983) elaborates:

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[1]Other international firms showing interest in manufacturing minicomputers in Brazil included: Burroughs, Hewlett-Packard, Olivetti, Digital, Nixdorf, Phillips, Bata General, Datapoint, Wang, Logabaz. and Cougar (Helena, 1984).

[2]IBM's ad ran as follows:

In our list of exports, one more very special item:
TODAY WE ARE INTRODUCING THE SYSTEM/32 IBM

IBM do Brasil gives one more proof of its perfect identification with the objectives of the Brazilian government in minimizing imports and maximizing exports and improving even more the balance of payments, by introducing the System/32 IBM, to be manufactured in Sumaré - Brazilian with great honour! (Dantas, 1988: 116) Note: Sumaré is located in Campinas, São Paulo.

1. Priority would be given to firms which intended to utilize local technological resources to design and develop computer products. Technology transfer agreements with foreign firms would be allowed. But recipient firms should display a capacity to learn foreign know-how and not become dependent on foreign partners in the long term for technology, management and other skills.
2. Degree of incorporation of locally manufactured components. This was justified not only on economic terms (foreign currency savings), but also by the fact that intensive utilization of local components represented a technical capacity to adapt designs to local conditions.
3. Firms' market shares. Capre wanted to avoid excessive market concentration such as that prevailing in the large and very large computer market where a single firm held about 70 per cent of the total installed base.
4. Local partnership -- firms incorporating a majority of local capital would be given priority.
5. Foreign trade balance. Subsidiaries of MNCs usually showed better export performance than locally owned firms. But MNCs tended to import most components needed in a computer system and to incur higher deficits on service bills (royalties and technical assistance), and capital remittance (profits, interest rates) (pp. 67-68; also Barbosa, 1985: 58).

Capre received 15 project proposals: seven national firms using foreign technology, two national/foreign joint ventures, and six[1] from transnationals (Helena, 1984). In December 1977, Capre accepted three new proposals from locally owned firms: Sid (Sistemas de Informação Distribuida S.A.) with a proposed technology agreement with Logabax of France, Labo Electronica S.A. with technology from Nixdorf of Germany, and Edisa (Electronica Digital S.A.) with technology from Fujitsu of Japan. (These new proposals were in addition to Cobra's). Another firm, Sisco (J. C Melo), opted to 'reverse engineer' of 'copy' foreign products without the purchase of a project contract abroad. Although TNCs, for example IBM and Burroughs, were willing to transfer technology (Helena, 1984), their proposals were rejected by Capre because they would have been wholly-owned ventures.

The selected companies were allowed to import foreign technology but were required to gradually nationalize, or to reach 80% local content by 1982 and complete the technology transfers by 1983 (Piorkowski, 1985; Marcelino, 1983). They were also allowed to import capital equipment duty free, to import components and new parts, and to remit royalties not to exceed 3% of net sales. They could not, however, diversify away from manufacturing CPUs as that would be left for other firms (Ramamurti, 1987). These four firms along with Cobra, which had licensed minicomputer technology from SYCOR[2],

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[1]Brabosa (1985) notes that seven multinationals submitted proposals.
[2]SYCOR is a relatively small mini-computer manufacturer based in Ann Arbor, Michigan.

were to enjoy a protected minicomputer market[1] in Brazil with the expectation that they would develop indigenous technology for future products (Fleury, 1988).

Foreign technology was allowed only to speed up the process of initiating the industry. The new Brazilian firms, in exchange for market protection from foreign competition, had to make the necessary investments to nationalize product manufacturing, and to support and maintain R&D teams, both with the aim of increasing the country's technological capability (Marques, 1984). The manufacture of other types of computers remained open to foreign firms, with the understanding, however, that their production would be progressively nationalized (Venturini, 1984).

Actual Results - An Industry Created through Technology Transfers, Local Innovation and Import Protection

Capre's decision reflects the view that for Brazil to develop a minicomputer industry, the market should be reserved exclusively for domestic firms. More specifically, Capre decided that the

> domestic industry could not compete with the prices or the technology of the large foreign vendors, and that Brazil as a country could do without their "superfluous" or state-of-the-art technology. Hence, Capre decided to create national Brazilian oligopolies with fully protected positions in specified conventional Brazilian markets. The minicomputer and small business systems groups were reserved exclusively for domestic firms with international companies denied access (Katz, 1988: 102).

The exclusion of international capital represented an abandonment of the joint venture strategy. The market would be served by Brazilian capital-based firms using licensed and local technology, with permission to acquire foreign parts, accessories and components while progressively nationalizing the products. The strategy, in the long-run, was to force local firms to use local know-how and suppliers for future products.

Similar criteria and procedures were used in later years to select firms to produce other data processing equipment such as printers, disk and tape drives, microcomputers, electronic accounting machines, modems and terminals (Tigre, 1983; Barbosa, 1985). This process of selection of firms for specific market segments became known as the 'market reserve policy,' or the *reserva de mercado*. The policy envisions varying degrees of protection and incentives based on the technological complexity of product segments

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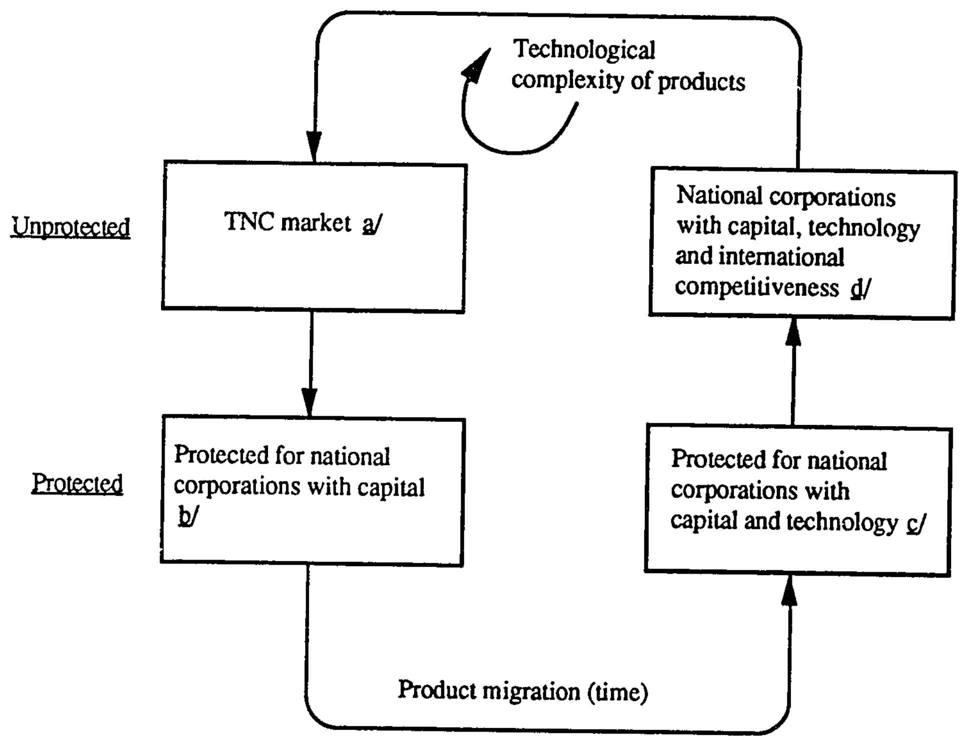
[1]In 1977, IBM, Burroughs, DEC, Control Data, and Hewlett Packard requested the Carter administration to press Brazil to curtail the market reserve policy. Since this date, the diplomatic battle over the market reserve between Brazil and the US has continued to taint relations between the two countries.

(see Figure 5.2). Sophisticated products, beyond the technological capability of local firms, are open to TNCs. As foreign technologies become available, and local firms have the capital to license the technology, market reserve protection is granted. Local firms must learn from the licensed technology and innovate locally to improve the product. Protection ceases once these local firms attain international competitiveness.



a/ Not protected (transnational corporations are welcome if they export and use state-of -the-art technology) because national corporation are not yet able to enter production.
b/ Protected for national corporations (which can use foreign technologies) because they are able to invest but do not yet have their own technology.
c/ Protected for those national corporations that have their own capital and technology but are not yet fully competitive in the international market.
d/ Protected barriers are lowered because national corporations are competitive in the international market. Local technology is still required, and preventive measures are being taken to maintain control of the national industry.

Source: SEI, 1983: 66.

Figure 5.2 Brazil's Industrial Informatics Strategy.

The goal of the 'reserva' aimed to create a genuine national computer industry, one which would constantly seek autonomy (not autarky) and decreasing dependence on foreign technology. Though not capable of employing the latest technology, policy makers felt the country would in the long-run benefit from this type of 'indigenous' industrialization.

One common argument against a traditional ISI strategy uses the example of the domestic car industry, based on international capital and subsidiaries, which has not brought about the expected technological development; automotive MNCs still lag behind other countries in technological sophistication (Machado, 1985). As Guimarães (1987), president of Finep, adds, even though the automotive industry exports, the profits end up in the home country.

The initial stage of the computer industry, then, was based on domestic capital and human resources, with the option for technology to be purchased abroad, hence eliminating MNC profit repatriation but maintaining the remission of royalty payments. The 'model' for the reserved segment, however, was to be based on Brazilian labor, capital, and technology, with the importation[1] of only parts and components not manufactured in the country. The goal of the market reserve is to develop Brazilian technology by restricting the market to national firms with their own technology (Fregni, 1984). When international competitiveness is reached, liberalization in the domestic market occurs, although capital and technology must remain in national hands. Furthermore, as technologies, markets, and Brazilian know-how evolve, products reserved will be periodically reclassified to permit Brazilian participation in more technologically sophisticated segments (SEI, 1983).

The vital factor that influenced the adoption of the market reserve policy was a large group of motivated scientists and engineers that had been engaged in informatics related research since the 1950s (Dantas, 1988; Langer, 1989). Certainly other factors contributed to policy development, including: the favorable economic/entrepreneurial environment, the existence of a solid industrial base, the lack of foreign firms producing minicomputers in Brazil, and easy access to computer chips that simplified the production of Brazilian final products.

By the end of 1979 a new government came to power and reorganized the government agencies in control of computer policy. Capre and DIGIBRAS were shut

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[1]The importation of components permitted national firms to achieve a final product closer to international levels (Venturini, 1984).

down and replaced by a new agency -- the Special Informatics Secretariat (Secretaria Especial de Informática -- SEI). SEI, in spite of the fact that several top and middle rank officials were removed from Capre, retained a similar, if not more nationalistic defense of the reserva. Instead of being attached to the Planning Ministry like Capre, SEI was responsible to the National Security Council (Conselho de Segurança Nacional -- CSN) and reported directly to the president.

The origins of SEI reflect the strategic value placed on a domestic computer industry and the need to have a more coherent policy originating with one powerful central agency. A study, known as the 'Cotrin Report', conducted by the National Intelligence Service (SNI) in conjunction with the Ministry of External Relations and CNPq, stated that Capre lacked a policy aimed at reducing technological dependency (Adler, 1986; Piragibe, 1985a). The government used this threat of technological dependence, with its strategic and economic implications, to justify the change in informatics policy. The Cotrin commission conceptualized SEI in light of these threats (Rocha, 1987).

Hence, the strategic importance of informatics to national development necessitated a reorganization of the institutional framework that governed the industry. The transition marks the move of computer policy from the more technically oriented Capre to the intelligence and security oriented SEI. Where Capre and DIGIBRAS formed decisions by consensus, mobilizing political, academic, industrialist, and professional forces, SEI's power was centralized and concentrated.

SEI had complete power for designing and planning a national policy on informatics (excluding telecommunications which was under the control of the Ministry of Communications -- Minicom[1]) and was assigned to coordinate new activities in the field of real-time control systems, microelectronics, electronic instrumentation, and software and services (Piragibe, 1985a). Additionally, it was able to issue 'normative acts' that became law without congressional approval. Each act reinforced the market reserve policy, which, in 1981 was expanded to include microcomputers, small computer systems, peripheral equipment for computers in the reserved area, banking and other terminals, data communications products (modems, teleprinters, facsimile), CAD-CAM equipment and software, advanced terminals, and numerical control equipment (including robotics)[2].

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[1]After 1983, SEI controlled imports of telecommunications equipment and systems. In the area of telecommunications joint ventures are allowed, and the technology is generally supplied by the foreign partner. The different strategy has led to tensions between Minicom and SEI.

[2]SEI divides the computer market into six somewhat arbitrary classes, based on 1980 prices and technical parameters (CPU speed, memory capacity, input/output capacity): class 1 represents

SEI also had the power to: 1) approve new projects and control the entry and expansion of firms, 2) stimulate and assist the development of technology, components, equipment, programs, and services, 3) control imports of all products, components and parts which make use of semiconductor devices, 4) protect the technical and commercial viability of domestic companies producing systems and components, 5) produce statistics on the development of the informatics industry in Brazil, 6) control government procurement, 7) control technology licenses, 8) direct research and development, and 9) formulate legal and technical instruments (Cline, 1987; Fleury, 1988; UNCTC, 1984; SEI, 1983).

Although SEI's powers to mold and manipulate industrial policy for informatics are broad, the basis of its power lies in its ability to control the importation of parts, components, and final products; its ability to cede manufacturing licenses to firms; and its ability to control acquisitions of informatics goods and services by the Federal Government (the principal informatics market in Brazil at that time).

As can be seen, SEI has the power to determine every aspect of the informatics industry in Brazil. Its primary objective of controlling the market is to promote the birth and development of a truly indigenous informatics industry. SEI plays the role of national policy advisor in the field of informatics; consequently, consultation with SEI is mandatory when a firm, either public or private, wishes to purchase and set up an informatics-dependent system (Machado, 1985). The outgrowth of this policy is not surprising considering the "Law of Similars" tradition of Brazilian industrialization, the exception in this case is the fact that foreign firms are not allowed to import or produce in Brazil those segments that are reserved. Previous experiences with import substitution aimed at producing Brazilian made products, rather than Brazilian companies (exceptions include oil and telecommunications sectors that are state controlled, and informatics) (Schwartzman, 1987).

Dytz (1987) argues that Brazil chose the only possible path to develop informatics by committing the Brazilian entrepreneur to the development of the country via the *reserva*

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microcomputers, word processors, electronic accounting machines, desktop models or a mean value of $20,000; class 2 represents minicomputers or $90,000; class 3 represents small computers or $180,000; class 4 represent medium sized computers or $670,000; class 5 represent large computers or $1,900,000; class 6 represent very large computers or $3,000,000. The last two classes, 5 and 6, by todays international standards are true mainframes. Classes 3 and 4 are superminis or contemporary minis by international standards.

de mercado; without a market reserve policy Brazil's national industry would be non-existent. As Edson Fregni puts it:

> We do not care if we are not state-of-the-art right now. What counts is that Brazilian engineers are learning how to design Brazilian computers. If we do not figure out how to do it ourselves, we will lose control of our destiny and be condemned forever as IBM salesmen (Schuster, 1985).

TNCs did challenge SEI. In August 1980, SEI approved the local production of smaller computers in Brazil by IBM and Hewlett-Packard. Hewlett-Packard was allowed to manufacture its microcomputer 85 for exclusive use in technical and scientific applications. IBM was allowed to manufacture its 4331 MG-2 model, a small mainframe, with the understanding that three units would be exported for every unit sold in the domestic market and then only to existing IBM customers. Burroughs had a similar deal with one of its larger computers. Both IBM and Burroughs, as a result, ended up exporting more computers than they imported (Ramamurti, 1987).

Overall, however, the early 1980s was a period of strong support for the infant industry backed by SEI[1]. The Brazilian informatics industry was increasingly viewed as essential to technological capability, controlling all aspects of the production process, governing office and plant administration, touching all sectors of the economy including the service sector and public firms. In Brazil minicomputers were increasingly utilized in business management applications in small- and medium-size firms and large government owned companies. Minicomputers have also been used as intelligent terminals in larger systems, and in data communication applications. A major user is the banking sector, where minicomputers systems are utilized as stand-alone machines and as preprocessors, data-input devices and intelligent terminals (Tigre,1983).

Through legislative acts SEI's controls were extended to include peripherals and superminis, the establishment of a software registry, and the development of a informatics research center.

The Informatics Law - 1984

In 1983, with the return to democratic rule in sight (1985), SEI started pressing for the enactment of its informatics policy as a law. With normative acts being part of military rule, and the power concentration of SEI likely to prove incompatible with a democratic

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[1]Two international 'events' were to strengthen Brazil's resolve for an indigenous computer industry. The US government, in the 1980s, extended jurisdiction over US computer firms abroad, and the use of high technology in the 1982 war between Argentina and the United Kingdom (Domínguez, 1989).

regime, a legal mandate by congress would assure the continuation of the policy. After more than twenty versions it was approved by congress by a large majority (with wide public support due to its nationalistic character) from government and opposition parties (Schwartzman, 1988). The bill was sent to the President who exercised his veto powers in connection with certain provisions. For instance, congress included a clause to designate financial support for academic informatics research, but the clause was vetoed by the President. The fund would have allocated approximately 0.8% to 1.0% of Brazil's GDP to academic research in informatics. According to Machado (1985) this signifies that the government expected industry to assume more financial responsibility for informatics R&D.

The final text of the Law (law 7.232) enacted on October 29th, however, reaffirmed the existing policies of protection until 1992. For eight years SEI was granted the power to examine, in advance, all import requests for goods and services related to informatics, and it also kept its role of analyzing and approving projects of development and production of computer goods. Additionally SEI will administer a special Fund for Informatics Activities (FAI), create an Informatics Technology Center Foundation, be authorized to set up Information Export Districts, enjoy financial and administrative autonomy, and be staffed by a strong executive secretariat with supporting staff and five subsecretaries of; Industrial, Strategic Activities, Services, Studies and Planning, and Administration and Finance (Dytz, 1985; Schwartzman, 1987).

The new Law did introduce several modifications. A new National Council for Informatics and Automation (CONIN) was created that would control SEI's policies and have the last say on National Informatics Policy (Política Nacional de Informática -- PNI[1]). Every three years CONIN was to propose, based on SEI's recommendations, a National Plan for Informatics and Automation (Plano Nacional de Informática e Automação -- Planin) and submit for congressional approval. CONIN, like the NSC, was attached to the presidency, but rather than be staffed by military personnel with strategic perspectives, it was to be staffed by 16 ministers from the government, and eight representatives from private industries, consumers, professionals and members of the scientific and technical

[1]The instruments of the National Informatics Policy are: 1) institutionalizing norms and standards for informatics products and services; 2) apply public financial resources for the development of informatics activities; 3) promote international cooperation to enhance Brazilian capability in informatics; 4) educate and train human resources for informatics; 5) grant financial and tax incentives to allow Brazilian firms to expand their activities in informatics; 6) impose penalties for non-compliance with the law; 7) control imports of informatics goods and services for eight years; 8) standardize communication protocols; 9) foster informatics activities of state-owned financial institutions (ABICOMP, 1986/7).

community -- and hence adopt a more economic development perspective and reflect the views different interest groups. The final step towards regulating the informatics law of 1984 was the approval, by congress, of the first National Information Technology Plan (Planin) in April of 1986.

CONIN's mandate, aside from elaborating informatics policy, includes the:

> ... establishment of technical norms, control of international data transfers, evaluation of teaching programs for professional training, creation of research centers in the country and abroad, and approval of projects of technological transfer and of capital increases in companies. It also has a say in matters of import and export policies (Schwartzman, 1987: 77).

The Informatics Technology Center Foundation, established in 1982 as part of SEI, was transformed into the main sponsoring agency to foster scientific and technological R&D in informatics by the 1984 Law. The CTI[1], linked to CONIN, is a state-owned institution located in the outskirts of Campinas with a variety of objectives including:

> -to promote the implementation of research, plans and projects through agreements, conventions and contracts with public and private institutions;
> -to issue technical reports;
> -to monitor nationalization programs, together with the pertinent agencies, in accordance to the guidelines of the National Council on Informatics and Automation -- CONIN;
> -to give support to national informatics companies;
> -to implement the policy of integration of the Brazilian Universities with the national endeavor for the development of informatics, through agreements, conventions and contracts (Abicomp, 1986/7: 150).

The Center for Informatics (CTI) is one means to meet the growing demand for informatics technology. It is funded by the federal government (80%) and self-financing (20%), the self-financing coming from service contracts with industry. Aside from conducting pure research it sells services to firms, provides technical services, and develops joint projects with other universities and firms. It also has the task of making sure IBM fulfills its nationalization targets on a nearby assembly plant, establishes standards and provides certifications for the national computer industry (Schwartzman, 1987).

The foundation is divided into four institutes: automation (including CAM, Computer Aided Manufacturing), computation (including computer architecture development and software), electronic instrumentation, and microelectronics.

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[1]The Technological Center for Informatics (CTI) was officially inaugurated on May 8, 1984.

The Computation Institute works in the following areas: development of interphases to link Brazilian peripherals with imported mainframe machines; software development for specific sectors like compilers, operating systems, editors, tools for facilitating and automating software development; development of standards and certification for programs and equipment; the certification of integration plans of industries and new areas of opportunities for manufacture of new products; technical assistance on import permits; and laboratories to study the performance of equipment (Garza, 1985).

The Automation Institute works on process control, manufacturing automation, and advanced engineering, that with industry researches projects like control systems for aluminum furnaces, and CAD-CAM systems for manufacturing (Garza, 1985).

The Instrumentation Institute focuses on sensors and actuators, instrument maintenance, and standards and certification procedures. Their work includes the certification of exports, developing measuring systems for quality control, the support of manufacturing of components and devices, and new areas to replace imports (Garza, 1985).

The Microelectronics Institute performs a broad array of R&D activities and defines objectives and priorities for R&D projects. The institute also coordinates research between industry, research groups, universities and the different governmental organizations. Its main objectives are to allow Brazil the minimum capacity required to be independent of the importation of strategic materials and components and to improve competitiveness of Brazil's microelectronic industries (Garza, 1985). The following list defines high priority projects of the Institute:

> 1. Capacity to design integrated circuits, considering semi and full custom; design strategies and techniques; design for testability; design tools including lay-out testing and simulation; models of devices.
>
> 2. Scientific and technological capacity required for manufacturing process of integrated circuits, including: preparation of substrates and their physical properties; thermal oxidation; thermal deposit of dopants; ionic implantation; standardization or nitrates; masks; lithography; materials corrosion; chemical cleaning processes; encapsulation process equipment methods and devices for the characterization of processes; models for processes; etc.
>
> 3. Applications for new materials; processes and new structures in microelectronics.
>
> 4. Basic inputs for microelectronics; semi-conductor materials; chemical products; photolithography and encapsulating materials; metals; gases, etc.
>
> 5. Measuring techniques for microelectronics; characterization of materials for sustrates and conducting films; characterization of different process stages and devices; integrated circuit characteristics; electrical testing, etc. (Garza, 1985: 15-16).

Aside from the research and development activities of the Institute, it trains scientists, engineers and technicians and gives strong support to technical schools and universities, including ample infrastructure resources and better salaries for its researchers. In 1986 about 3,000 students graduated from the institute (Beck, 1987b). The institute has also taken a role in organizing and linking university research with industry demands for technology (Rímoli, 1987b).

The informatics law also took steps to encourage national firms and local R&D activities. Policy incentives, for those firms investing a certain percentage[1] of their quarterly income in R&D, included: exemptions from import taxes on imports that are not produced domestically; exemptions from export, excise, and financial taxes; accelerated depreciation of fixed assets; and, for programs and projects with SEI's prior approval, firms were allowed to double deduct income taxes for expenses on R&D and manpower training; reduced income taxes for income generated from the sale of high-technology parts and components; reductions of income taxes for the sale of locally developed relevant software; and income tax reductions for those firms that invest in stock shares of informatics firms (Piorkowski, 1985; Viegas,1987a).

While foreign firms may export products to Brazil that are not manufactured locally, foreign investment in the informatics industry continues to be carefully regulated. An exception is the area of consumer electronics, with policy predominantly guided by the Ministry of Interior and SUFAMA, where foreign capital dominates, particularly in the free trade zones. In the computer sector, a foreign company is allowed to operate in Brazil only under several conditions. Firms with activities in Brazil prior to the law are allowed to continue operations. And firms that locate within one of the Informatics Export Districts in the north and northeastern economically depressed areas, know as SUDENE[2] and SUDAM, are not only allowed manufacturing activities but given special policy incentives to locate there. Foreign firms that export only are allowed to have manufacturing activities in Brazil (Viegas, 1987a).

In other situations the requirements are more rigid. For example, a foreign firm may export to Brazil if the products in question are not manufactured locally. A foreign firm may own up to 30% of the non-voting stock of a Brazilian informatics firm granted that the technology and decision-making remain under control of the Brazilian firm.

[1] In 1987 R&D investment to gain these incentives was 10% of firm income.
[2] Superintendencia de Desenvolvimento de Nordeste

Hence, the foreign firm may participate only as an investor and not as an active partner. Foreign firms, producing goods or services of interest or relevance to local scientific and manufacturing activities, may have manufacturing plants in Brazil in areas where no local Brazilian firms exist with enough capability to supply the market. Those firms, however, must have development plans approved by CONIN, invest a certain percentage of their yearly gross income in local R&D, present export plans, and develop local suppliers. And those foreign firms that license patents or transfer technology and know-how to a Brazilian firm are allowed royalty payments up to 5% of net sales of the Brazilian products (Viegas, 1987a).

With the change in government in 1985, SEI was transferred to a newly created Ministry of Science and Technology (Ministério da Ciência e Tecnologia -- MCT). The MCT was composed, in addition to SEI, of the FINEP (Financiadora de Estudos e Projetos[1]) -- an agency to finance firms, institutions, and projects that attempt to evolve technological capacity and national solutions for informatics; the National Council of Scientific and Technological Development (Conselho Nacional de Desenvolvimento Científico e Tecnológico -- CNPq), responsible for the coordination of scientific and technological activities (CNPq[2] also funds research and fellowships); the Institute of Space Research (INPE); and the Cartographic Commission (Cocar). The national computer firm, Cobra, was also transferred to the MCT.

In 1983, SEI decided to encourage the development of the superminicomputer in Brazil to be compatible with the national minicomputers already in the market. The supermini, based on 32-bit microprocessors (instead of 8 and 16 bits like traditional minis), and considered the next level on computers in Brazil offers roughly the same capacity of mainframes with a slightly larger price than minis and was considered a 'grey zone' of the reserva. Superminis, at that time, supported from 16 to 128 terminals, and had from 1 to 16 megabytes of memory (Tigre, 1987). The reason for SEI's interest was that by 1983 the number of micros sold was increasing rapidly while the market for minis was stagnant or decreasing. Mini technology was still based on technology acquired in 1977, although adapted and improved (with the exception of Cobra which was using indigenous

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[1]FINEP was originally established in 1965 to support technological development and to liaison between the technological infrastructure and industry.

[2]The CNPq's basic objectives are to provide scholarships, support for visiting researchers, and to promote international and regional cooperation. Research projects are approved based on the petition institution and researchers, the objectives of the project, and the potential contribution to technological development. This funding is very important for university research, 95% of university money goes to university personnel, leaving little for research.

technology comparable to licensed technology). Since the local mini producers were unable to develop 32-bit architectures, and IBM's smallest machine, model 4341, was selling rapidly, SEI opted for another round of licensing (Evans, 1986).

Under conditions similar to the minicomputer bids in 1977, SEI invited firms to submit projects. For this round there were more safeguards for foreign licensors, and confidentiality of transferred knowledge was to be assured for five years from the end of the transfer process. Again, local ownership was to be preferred, although TNCs could submit bids (Ramamurti, 1987). Of the eight firms that responded, three initially opted to use technology indigenously developed (Cobra, Sid and Labo) while Elebra (associated with Bradesco and Medidata) and Itautec argued that the only viable path was to license technology from abroad. SEI weighed significant arguments from both sides of the debates and finally decided that foreign technology was necessary to stay abreast of developments abroad. Tigre (1987) argues that while importing technology allowed the firm to introduce products more rapidly on the market and with lower costs, it does, however, limit their possibility to develop technology. Adler (1986) felt that SEI made the right choice because they ruled out joint ventures but yet let domestic companies develop the supermini computer with technology the will be transferred. Evans (1986) is even more optimistic:

> Even the super-mini licensing agreements are as much evidence of the success of Brazil's policy as they are of continuing dependence on foreign technology. In 1984, in sharp contrast to 1977, it was possible to bring in the principal international players in the industry. Brazil succeeded in licensing the technology to make the DEC VAX 11/750, long the standard in the industry, which had never before been licensed to a firm in which DEC had no equity. Data General, which had been so adamant in its opposition to Brazil's nationalism in 1977, agreed to license the technology for the MV4000 and 8000, which were the VAX's closest competitors, to none other than Cobra. To be sure, these machines represent a technological level that has been surpassed in the United States, but they are still in widespread use and there are vast amounts of industrial and business software available for both of them.
>
> The lessons of the super-mini licensing can well be extended to Brazil's policy overall. Without the political victory of the nationalist policy, it would have been impossible to convince US firms that licensing was in their interest. Yet, without acceptance of the necessity of continued reliance on international technology the policy would have floundered. The more sophisticated among those involved in the implementation of the policy are quite conscious of the disjunction between discourse and practice and see it as necessary. As one of them put it, "Without radical rhetoric the possibility of pragmatic negotiation dies." (Evans, 1986: 800).

Cline (1987) argues that SEI's decision to allow TNC participation represented an important shift in Brazilian informatics policy, even though foreign technology was limited to licensing and not joint ventures (see Table 5.6). It was the size of the Brazilian market, according to Botelho (1987), that gave the Brazilian firms more bargaining power vis-à-vis the TNCs. TNCs came to realize that the protected structure of the Brazilian industry was a reality and, not wanting to be left out of an important market, tempered earlier positions against technological participation. American firms were, however, granted concessions; in particular, the Brazilian government agreed that at the end of the licensing agreements a five year period of confidentiality for transferred knowledge would begin (Botelho, 1987). According to the Minister of Science and Technology, Luiz Henrique Silveiro (1987), informatics policies are to achieve first technological capability, and then technological autonomy, with foreign technology being an important component of former.

Table 5.6 Technology Transfer Contracts for the Production of Superminis in Brazil (1984).

Firm	Technology	Equipment	Year introduced on the international market
ABC Sistemas	Honeywell Bull	DPS 6/96	1980
Cobra	Data General	MV-4000	1982
		MV-8000	1983
Edisa	Hewlett-Packard	HP-3000/48	1983
		HP-3000/68	1983
Elebra	Digital (DEC)	VAX 11/750	1980
Itautec	Formation	F-4000/200	1980
Labo	Nixdorf	8890/72	1981
Sisco	IPL	4460	1982

Source: Datanews, cited from Tigre, 1987: 93.

Industry complained that too much power was concentrated in SEI (from total control over imports to the treatment of foreign capital), and that SEI's bureaucracy delayed release of new products through time consuming evaluations (Moad, 1988). These criticisms, combined with pressure from the U.S. government, threatening retaliatory trade sanctions, led to several changes. These aimed to liberalize, deregulate, and de-bureaucratize the industry (Michaels and Cohen, 1989). Joint ventures with foreign companies have recently been increasing, at least in the area of services. And import concessions have been granted to large non-informatics firms with significant exports, and to multinationals with options to relocate in other countries (Moad, 1988).

SEI began to decentralize geographically from Brasilia and created regional secretaries. SEI no longer defined the segments or priorities of production -- Planin now has this role -- although SEI continues to approve or deny new projects. SEI also changed import policies to reduce the bureaucratic hurdles for importers. No longer are small quantities of imports of electronic or digital components controlled. Also eliminated were import restrictions on parts and pieces to maintenance and repair or reposition for users. Firms, which once had to describe to SEI each part they intended to import, now are allocated a dollar amount that the firm can import each year, divided into four equal parts. For each of these quantities to be imported the firm must present a generic list of the products they generally import. These lists are approved by SEI and give the firm more flexibility (Paula, 1987).

SEI also recently announced it would not inspect microcomputers brought by Brazilian students or professionals that have been living outside the country for over one year, or foreigners moving to Brazil, or members of diplomatic corps that present a document stating that they will leave the country with their computer. Free entry was also given to equipment for scientific research, exhibitions, sporting events, commercial and industrial fairs, or equipment brought by foreigners for work (Bras-net).

The year 1989 marked the near end of the MCT, which, along with SEI, was proposed to be absorbed by the Ministry of Industry and Trade (MIC). The proposed consolidation is a result of the government attempting to cut public spending. The MIC is traditionally more open to less protectionist policies, hence there are some fears that there might be some significant changes in the informatics model adopted by Brazil. The recent election of Collor as the new president of Brazil, who has strong free market beliefs, might also mean changes for informatics policy. His initial policy statements suggest a gradual opening of the market to foreign competition over the next five years.

The Software Law - 1988

The position of software had not, until recently, been clearly defined from the 1984 informatics law. In 1982, SEI began registering software programs commercialized in Brazil, giving preference to products developed locally. However, software was not patentable, nor permitted software copyright protection (Piragibe, 1985a). The need for a software law was readily apparent.

In Article 43 of the 1984 informatics law, it was stated that a specific law for software would be defined and established in the future. Until this was accomplished, Normative Act 22 guided the software industry, requiring that software be registered to legally enter the market. Programs were to be re-registed every two years, with the possibility of refusal if a similar national software was available. Normative Act 27, October 1983, went as far as demanding that projects for microcomputers would be approved only under the condition that operating systems would be developed as well. The intent of this act was to create a critical mass of human resources with the capability to develop basic software.

The road to a definition of Brazilian software law has been a long and difficult one. Looming in the back of all discussions was the threat of U.S. reprisals, while computer manufacturers, software producers and users each defended their own special interests. Nationalists continued to push for complete protection, along the lines of the reserved market for mini- and micro-computers. At the other extreme were software users, wanting complete access to foreign programs.

Foreign software, however, has been admitted quite freely (with low import taxes and with technological superiority) with rare cases of refusal. Those cases, however, have been quite explosive and led to direct conflicts with the U.S.[1]. U.S. diplomatic pressure and the threat of trade retaliation has forced Brazil to clarify or change policy in the following areas: the formation of joint ventures, a reduction of SEI's control, a copyright software law, a list of informatics products not included in the *reserva* (INFO, 1987a).

National firms were also interested in software regulation. The lack of a software law, and of adequate governmental control over the functioning of the industry, led to illicit commercial practices and a de-stimulation for software R&D in Brazil. A software law that would 'moralize' the Brazilian market in terms of flagrant software pirating, most Brazilian software firms felt, would increase the value of software and interest in development.

As a result, in August 1986, CONIN voted to recommend a software law based on author's rights. In December of 1986 President Sarney sent to Congress the law to protect the intellectual property of the computer programs, and regulate its commercialization. Furthermore, joint-ventures in software would be allowed as long as 70% of the control and 100% of the voting power remained in the hands of Brazilians.

The software law that was finally passed placed software under the protection of a copyright legislation, or more precisely, author's right legislation, which protects the expression of ideas. To determine what exactly constitutes an illegal copy is to be determined in court. The court, then, determines whether a copy is based on source code

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[1]The conflict began in September 1985, when Reagan ordered an investigation on whether the 1984 informatics law represented an 'unfair trade practice' and therefore subject to trade reprisals. Later, on November 13, 1987, Ronald Reagan announced that the US would prohibit the importation of Brazilian informatics products and, more damaging, erect extra taxes on traditional Brazilian exports amounting to what would be a loss of over 100 million dollars to Brazil, unless Brazil licensed MS/DOS. Also in the picture was a Brazilian Macintosh clone waiting for licensing from SEI. As a result of American pressure the clone was not licensed. And in January 1988, MS/DOS 3.3 was licensed by SEI.

or, if the source code is different but the idea is borrowed. The new software law regulates the judicial protection of software and commercialization of foreign programs, both of which should help reduce the pirating problem. The individual user will be able to import a copy for his personal, exclusive use. The law regulates that equivalent national programs will be given preference for licensing. The question remains whether those will be clones and if there will be a real incentive for national production of software.

Software is divided into three categories: software developed by Brazilian individuals or firms, software programs of national economic interest where no national alternative exists and the software's technology and proprietary rights are transferred to national firm, and all other software programs (Sauvant, 1986). Foreign software is allowed to be imported through three channels: local representatives, single copies for the exclusive use by an individual, and foreign firms. Software for microcomputers is only to be distributed by national firms. Software for mainframes can be commercialized by foreign firms, although the price of the software must not exceed the average international price. There are no restrictions on the number of copies foreign firms may sell in Brazil.

The commercialization of national and foreign software depends on enrollment (cadastramento), and in the case of foreign software, enrollment by SEI will only be granted if a national similar software[1] does not exist and the software is assigned or licensed to a Brazilian party. Software will be automatically re-registered after three years if SEI determines (in 120 days) that there is no similar national program. The determination of a national similar software is a grey area, to be based on the memory and storage of the programs, processing time, the capacity to transact between users and systems, the appearance and data entry (INFO, 1988c).

While the law still protects Brazilian software, the actual law is considered by many Brazilians as a U.S. victory. The law does not stimulate the production of software in markets where foreign programs are already established as an international standard. Furthermore, while the original text of the law included an import tax on all foreign programs to be reinvested in university research, the clause was vetoed by President Sarney. The veto of the tax on foreign software was, according to the government, to not overwhelm the user with high software prices (Nogueira, 1988). Clearly the real reason was to avoid trade sanctions threatened by the U.S..

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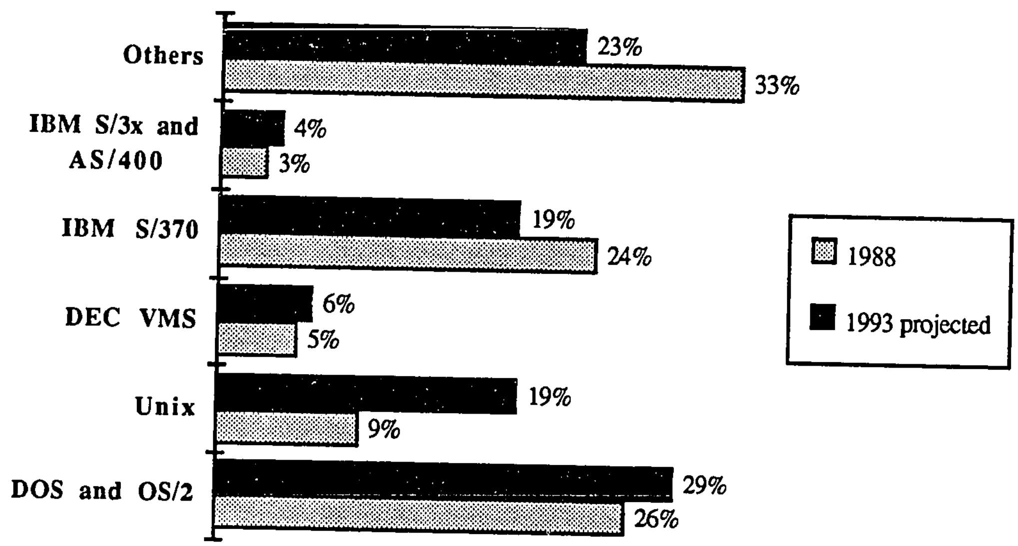
[1]Originally, national software would be protected if it were functionally equivalent, and was later changed to national similar.

Developing operating systems jointly with microcomputer projects is no longer required by SEI. According to SEI, Brazil has achieved a sufficient technological capability in software development. A more important reason for the decision is that the international market is now based on standard operating systems, and there is no justification for making Brazilian firms develop their own operating systems. SEI now prefers to leave the choice to the firms whether to develop operating systems or license foreign technology. Those firms that do develop operating systems, however, can count on protection. The decision by SEI reflects its conclusion that it was not worthwhile to develop all segments of the software industry because much of the technology is based on widely accepted standards available in international markets, and that for Brazilian firms the time and money saved by not developing operating systems will allow them to develop niche markets, like utilities, application and support software (Luca, 1988).

The treatment of operating systems was hotly debated in Brazil. Compucenter, Microsoft's distributor in Brazil, argues that to not standardize what the rest of the world has already standardized is absurd (see Figure 5.3). Many firms, along with the government, tended to support the need to license foreign programs[1], and users were very supportive of licensing foreign operating systems. Some large firms, like Itautec and Scopus, see the need for a national software industry and indigenous capability in software technology, but the high costs of developing operating systems with a policy that doesn't support these investments is quite a barrier. Scopus decided that rather than develop operating systems it will instead license Microsoft's OS/2 to operate its new machines based on Intel's 386 microprocessor, although it will continue evolving their operating system Sisne -- compatible with MS-DOS (INFO, 1988b). Sid Informática takes the position that it is not enough to invest 12% of their income in R&D to achieve competitiveness, it is also necessary to absorb technologies already in the international market, though through technological purchases, not commercial accords or joint ventures

[1]Microsoft proved that several firms had plagiarized their MS/DOS operating system software and planned to process these companies unless SEI licensed their software, recognizing it as proprietary and enabling royalty payments. Microsoft was able to prove this since they included camouflaged signatures of the developers within the software, apparently unknown to the Brazilian firms. In addition, Microsoft included useless code without any technical justification solely to catch illegal copies. Those Brazilian firms included Sid, Prológica, Microtec, Sisco, and the system house SSD (SSD licensed their operating system software to 15 other firms). The 'caught' firms then sent a letter to SEI urging the licensing of MS/DOS. Scopus, with their own operating system software Sisne, was the only locally developed software to pass Microsoft's technical audit (Chacel, 1986a). However, SEI felt that Sisne was not the functional equivalent of MS/DOS, paving the path for its legal entrance in the Brazilian market. With licensing from SEI Microsoft has the option to sell to OEM manufacturers, without licensing they could only sell to individual users.

(Luca, 1988). Figure 5.3 illustrates the present and future market strength of DOS and OS/2 operating systems. Note the projected future growth of Unix operating systems, which has the advantage of operating on all sizes of computers.



Source: Markoff, 1989.

Figure 5.3 Computer Operating Systems by Percentage Share of Total International Market.

Defending the need to require the development of operating systems in Brazil most forcefully was Cobra[1], Assespro[2] (an organization of national software producers -- Associação Brasileira das Empresas de Serviços de Informática), and SBC (an organization

[1]Cobra has invested heavily in the development of a Unix compatible software with hopes of gaining market acceptance and establishing it as the Brazilian standard.

[2]The president of Assespro argues that Brazil has a local capability to develop operating systems and was against the licensing of DOS. Brazil, he argues, should not open its rich market, already greater than 50,000 PCs, for foreign operating systems like DOS and OS/2. He feels the locally developed Sisne is a viable national standard, and there are no profit remissions abroad. Another reason is strategic in that basic software made in Brazil assurers independence in the fundamental software sector. Furthermore, hardware will have to follow all the details of IBM PCs, inhibiting the innovation of new products, increasing dependence on component imports, and limiting firms to only adapt such products to local conditions. (Mahlmeister, 1987b).

of the informatics academic community -- Sociedade Brasileira de Computação). According to Daniel Menascé, president of SBC:

> If we do not have the capacity to develop operating system standards more sophisticated in the country, we will arrive on day where we no longer dominate the technology to implant in our machines. And there we will encounter a closed door to our development (Luca, 1988: 25)

Cobra argues as well that local development of operating systems are fundamental for Brazil's technological capability in informatics, and to not give the country the chance to develop and produce them will leave the national industry the simple task of assembly. If licensing is the desired route, then, Cobra suggests, at least transfer source codes to let Brazil have real access to modern technologies. Digirede takes the position that Brazil should develop operating systems in areas that are not dominated by TNCs. In fact, they have developed a system to be licensed to TNCs called Transax (Luca, 1988).

Aside from the arguments on operating system software, many are incensed over the fact that even general software programs, when imported, are not taxed. Without tariffs, the only mechanism to protect national software is when a similar national software is protected. One single software program may be imported without any restriction on similarity (Pereira, 1989). The free import of a single copy, however, may facilitate the proliferation of firms specializing in pirating this software (Menascé, 1988). If a national software is considered 'similar', the foreign software is prohibited. If the national software is not considered similar, the foreign software is imported without any tax, which is unheard of in Brazil (Parra, 1988; Pereira, 1989). The association of software producers, Assespro[1], plans to raise the taxation issue once again to Congress (Pereira, 1989).

The situation is further complicated because of unclear guidelines for similarity. Officially, SEI plans to examine, on a case by case basis, each foreign software with a national similar, through an analysis based on the technical documentation, listening to the arguments of the involved parties, applying tests etc. Yet the pressure on SEI will be enormous because many Brazilian firms in other sectors use software that is likely to be prohibited with a strict application of the law. More significant, however, is the reaction stimulated from prohibition of any American software by U.S. software firms[2] and the

[1] A similar association for hardware manufacturers is called ABICOMP. Founded in 1979, the association defends national technology and a national industry.

[2] According to Kenneth Wasch (1988), director of the Software Publishers Association (uniting firms such as IBM, Microsoft, Lotus, Ashton Tate, and 331 other firms), the Brazilian software law has satisfied American firms and that commercial tensions between the US and Brazil have been reduced. He

U.S. Department of Commerce (Parra, 1988). With the existence of imported foreign software programs there is a fear that national firms will be inhibited to produce generic, basic support and application software. The market for national firms may be limited to applications that depend on the specific characteristics of the market (legislation, customs, inflation etc.), exactly the type of programs that do not permit economies of scale, large markets, and large profits (Parra, 1988).

Conclusion

Commendable as the policy objectives might be, there are arguments that Brazil is acting irrationally in its effort to create an indigenous industry: 1) Brazil does not have the required human resources for advanced technological development; 2) Brazil does not have the necessary financial resources to build a competitive indigenous computer industry; 3) Brazil's closed market runs the risk of technological retardation (Machado, 1985). Since the reserva prohibits the importation of state-of-the-art micro- and mini-computers from transnational corporations, industrial and business productivity might lag behind competitors with access to the most recent equipment.

Katz (1988) found that the net effect of the early phase of the reserva was the temporary slowing of the country's rate of computerization due to high final prices of informatics equipment. It is the final user of informatics, as Benakouche (1985) reminds us, that pays for the technological development in Brazil. Others argue that the policy is terrible for manufacturing computers (joint ventures would be better) but good for protecting the technology industry and promoting R&D in the country and the advancement of the industry of technological services (Machado, 1985).

Conflicts with the U.S. have always threatened Brazilian information policies. The threat of trade retaliation or import restrictions have serious implications for informatics policy specifically and the economy overall. For example, since 1985, the U.S. enacted an Export Administration Act that controls the commercialization of products that incorporate 'strategic' technologies. The aim of the act is to restrict the transfer of these products to hostile countries. For the transfer of these technologies, countries could sign side-letters to establish a type of commitment between the partners to avoid these restrictions. However,

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adds that, along with Japan, Germany and the Scandinavian countries, Brazilian software producers have the potential to compete with American firms. Brazil, in his view, is more developed than England in software production.

Brazilian law prohibits the transfer of technology with export restrictions. And the increase of U.S. protectionism has led to side-letters not being accepted. Brazilian firms, requiring access to foreign technology, have petitioned to the government to allow technological imports with restrictions that the transferrers face (INFO, 1989f).

In the political arena more voices are defending liberalization of the informatics law, in particular by allowing more access to foreign technology and greater involvement of foreign firms through joint ventures. Their position is highly criticized by defenders of the market reserve policy. They argue that such liberalization would seriously weaken Brazil's drive for technological autonomy.

Guinle, (1988), president of Elebra, views the gradual evolution of joint ventures at the end of the reserva. Staub (1988), president of Gradiente, argues that joint ventures should be allowed as a way to buy more technology. Saur (1989), argues that 'classical' joint ventures inhibit local technological development, but a viable alternative for the computer sector are 'joint projects' where two firms share the risks and successes of joint project development.

Brazilian 'information' policies, based on the principal of reserving the market for nationally capitalized firms, represents a significant change in attitude among Brazilian policy makers toward technological development. The aim of Brazilian policy is to create a new national high-technology sector, emphasizing the indigenous acquisition of technological know-how. The policy reflects the Brazilian view that information technology is one of the key components of international competitiveness, that indigenous capacity of the new technologies is vital to future technological autonomy and to ensure national security and sovereignty. While this policy is unquestionably a form of economic nationalism, it is important to point out that in practice the industry is highly internationalistic (Evans, 1985). For instance, national firms license foreign technology when needed and import microprocessors, and multinationals, with 100% foreign-owned subsidiaries, dominate the larger-sized computer market.

Brazilian policy offers fertile ground for examining the possibility of developing high-technology capability. Facing seemingly overwhelming barriers, Brazilian policy makers have remained faithful in their support to develop national capacity. The following chapter sheds light on the successes and limitations of the industry.

CHAPTER 6

THE GROWTH OF THE BRAZILIAN INFORMATICS INDUSTRY

This chapter presents an empirical analysis of the Brazilian informatics industry. The objective is to analyze to what extent Brazil has acquired a high-technology capability, using two general criteria. The first criteria is the nature and growth of industry. Of particular importance is the generation of new firms with technological competence and economic stability, the ability of local firms to develop products, follow international technological trends, develop successive generations of products, and create industrial linkages. A second criteria is the technological infrastructure, in particular the development of quality human resources, R&D linkages between universities, institutes and firms, capital availability, and access to foreign technology or knowledge. Together, these two criteria are important indicators of high-technology capability.

Analysis of the Brazilian industry begins with a general overview of the informatics market and manufacturers. The major multinational and national firms are identified, as are their specific markets and products. The development of local and international linkages are then examined, including backward supplier linkages and forward industrial market and export linkages. This is followed by an examination of prices, contraband imports, and industry productivity. The increasingly important software industry, with virtual 'free trade' competition in Brazil, concludes the analysis of industrial development. Next, the national industry is evaluated in terms of the the development of human resources, a research capability, linkages between universities and firms, agglomeration of high technology centers, linkages with foreign suppliers of technology, and the availability of capital.

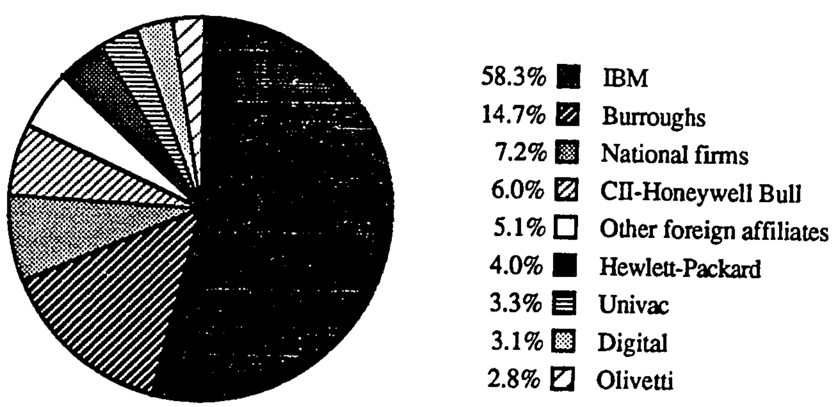
Data are drawn from a variety of sources to shed light on these many different aspects of high-technology capability. Contrasts between the national and multinational segments of the industry are made throughout to illustrate in a general way the differences between import substitution based on foreign and national firms. Case studies aim to portray 'sticky' concepts such as linkages between universities and firms. The breadth of the analysis allows us to examine much, but permits only more general conclusions.

General Overview of Computers and Manufacturers in Brazil

Computers were introduced into developing countries in the 1960s. These computers were large mainframes manufactured abroad by a few American and European-based companies. In Brazil, the main user was the state and subsidiaries of transnational corporations (Johnston and Sasson, 1986).

Before 1977, all computers were either imported to Brazil or supplied by small assembly plants of IBM or Burroughs. Import controls on computer products were implemented in 1976, and national firms soon developed plans for the local production of computers. Brazilian computers[1] first entered the market in 1978, with a market share of about 2% of the value of all computers sold that year. IBM's locally manufactured computers alone held 22% of the market (by value). The remaining three fourths of the market was satisfied by imports (Piragibe, 1985). When SEI was created in 1979, there were 37 national informatics firms and 2 MNCs located in the country. Of these firms, national firms accounted for 23%, and the two MNCs 77% of the market (O Globo, 1989c).

1980



Source: SEI, 1983

Figure 6.1 Share of Individual Corporations in the Brazilian Computer Market, 1980 (percentage of total value).

The market share of computer products manufactured by firms located in Brazil reached 31% by 1980; Brazilian computer manufacturers claimed 7% of the total market in

[1]Cobra and Sisco were the first national firms to introduce products.

terms of value and locally produced computers from foreign affiliates slightly rose to 24% (SEI, 1983). See Figure 6.1 for a more detailed breakdown of the market shares for the Brazilian market for the year 1980.

As desired by policymakers, the rate of computer imports declined and local production of computers, either national or foreign, rose, as a percentage of market value. By 1982, imported computers as a percent of the total Brazilian market had dropped to 46%. Brazilian national firms, on the other hand, were making rapid market advances, and by 1982 met 67% of the local demand for microcomputers and 91% for minicomputers (Piragibe, 1985). The modest beginnings of the industry, as a result of the national computer policy designed in the 1970s had, by the early 1980s, sprouted a rapid growth industry.

Table 6.1 illustrates the demand for the different classes of computers in Brazil during this early period. The data should not be misinterpreted; value figures for the equipment would show the overwhelming importance of the larger-sized segment of the industry. Average annual growth rates[1] for the data available indicate that the minicomputer segment -- class 2 -- grew the fastest (79% per year), closely followed by large computers -- class 5 -- (60%), microcomputers -- class 1 -- (46%), very large computers -- class 6 -- (37%), small computers -- class 3 -- (15%), and medium computers -- class 4 -- (10%).

Market shares for mainframes, classes 3 through 6, in 1982, remained largely in the hands of three firms with production facilities in Brazil, accounting for 83% of this market: IBM (61.8%), Burroughs (14.3%), and CII-Honeywell Bull (6.9%). Classes 1 and 2, had previously been dominated by Burroughs and Olivetti with imported products and accounting for 80% of this market in 1976 (Piragibe, 1985). It was in this sector of the computer market that Brazilian firms began to make their presence in the domestic market.

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[1]A medium or average annual growth rate refers to the geometric mean/average rather than the arithmetic mean; computed as the anti-logarithm of the arithmetic mean of the logarithms. Such computation records actual and uniform average rates of increase from the beginning year to the end year. Annual growth rates or rates of increase, based on the arithmetic calculation: - (Last year - first year)/first year/number of years - are often used but give results slightly exaggerated.

Table 6.1 Number of Installed Computers in Brazil, 1970-82, by Size.

Class	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Micro	a	a	a	586	1514	2143	3131	3846	4290	4791	4722	8756	17702
(%)	a	a	a	38%	54%	56%	60%	64%	62%	60%	53%	61%	73%
Mini	a	a	a	19	81	173	265	356	656	1015	1675	2719	3571
(%)				1%	3%	4%	5%	6%	10%	13%	19%	19%	14%
Small	378	403	454	639	775	1057	1309	1296	1378	1494	1688	1858	1950
(%)	75%	70%	68%	40%	27%	27%	25%	21%	20%	18%	19%	13%	8%
Medium	122	163	184	250	288	327	338	353	370	377	388	408	400
(%)	24%	28%	28%	16%	11%	9%	7%	6%	5%	5%	5%	3%	2%
Large	2	2	10	45	72	82	99	122	166	226	248	374	544
(%)	0%	0%	1%	3%	3%	2%	2%	2%	2%	3%	3%	3%	2%
X-Large	4	10	19	33	42	61	72	87	93	97	123	134	172
(%)	1%	2%	3%	2%	2%	2%	1%	1%	1%	1%	1%	1%	1%

Source: SEI, cited from Adler, 1986: 679.

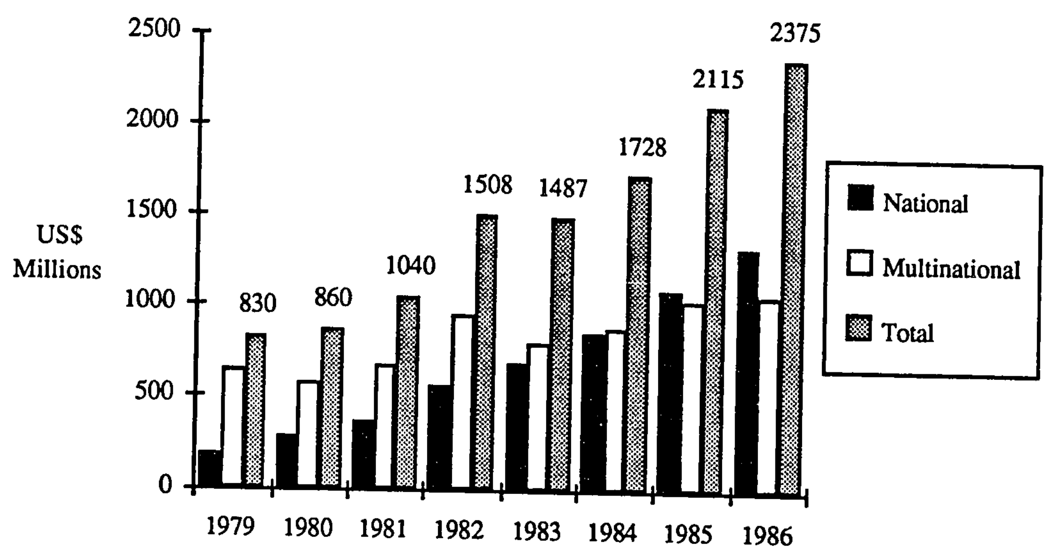
In 1984, when the informatics law was approved, there were already 203 national firms and 27 MNCs located in Brazil. Revenue for these firms was divided almost equally, national firms with 49% and MNCs with 51%.of the market (O Globo, 1989c). The quick proliferation of firms suggests that not only was a sufficient base of technical and entrepreneurial talent tapped to exploit market openings, but also that several supplier firms were stimulated into activity.

Table 6.2 Distribution of the Brazilian Computer and Peripherals Market by Economic Sector.*

Sector	1980	1981	1982	1983	1984	1985
Government	17.7	15.9	11.9	9.0	13.1	12.5
Commerce	34.5**	37.9**	19.6	16.8	19.4	18.3
Industry	26.2	25.6	29.1	28.2	27.7	32.5
Financial/Public					11.7	11.4
Financial/Private	20.7***	19.4***	29.6**	30.4***	17.8	16.6
Service			9.8	15.6	10.3	8.7

Source: SEI, 1987
*Data from national firms only.
**Includes Service Sector
***Includes Public Financial Sector

According to data from national firms, the market for computers in Brazil in 1985 was led by the industrial sector (32.5%), followed by the financial sector -- including private and public entities (28%), the commercial sector (18.3%), the government -- including administrative organs and state enterprises (12.5%), and services (8.7%) (see Table 6.2). Although the structure of demand has not changed significantly since 1980, the participation of the industrial sector has increased slightly at the expense of the commercial and service sectors, and the governmental sector, which is hobbled by deficits. The financial sector, during 1983 and 1984, led as the major market as a result of several banks automating their operations. As the data are based on sales from national firms only, total consumption of computers, including mainframes, would likely raise the participation of the government (Tigre, 1987).



Sources: SEI, 1987; SEI, 1986; Barbosa, 1985.
* 1986 data is preliminary.

Figure 6.2 Evolution of the Brazilian Computer Market - National and Multinational Firm Revenue.

Since the first Brazilian commercial computer entered the market in 1978, the Brazilian mini- and micro-computer industry has grown quickly. The demand for computers in Brazil can be documented by the increasing revenues of national and multinational companies, which almost tripled between 1979 and 1986. National firms between 1979 and 1986 experienced a average annual growth rate of about 32% (see Figure 6.2). The exception is 1983, a year of recession in Brazil. In 1987, the Brazilian computer sector generated over US$ 3.5 billion worth of revenues including both foreign and national computer firms (Arnt, 1989).

More recent data reveal slower growth rates; 9% in 1987, and 15% in 1988, with the national firm revenue reaching US$ 3.3 billion in 1989; remarkably, these growth rates occurred despite severe economic problems (INFO, 1989c; Mesquita, 1989). According to Arthur Pereira Nunes, director of Abicomp, the economic importance of the informatics industry, by 1989, almost reached that of the domestic automotive industry (Herédia, 1989). The multinational sector, with revenues in 1985 of US$ 1.1 billion, is dominated by IBM, which alone accounts for about 70% of the mainframe market (Chacel, 1986b; Tigre, 1987). Gross revenues for national firms increased by almost 7 times from 1979 to 1986, while multinational revenues, starting at a much higher base, grew at medium annual rate of 7%, and increased by almost 1.7 times.

Table 6.3 The Brazilian Information Industry[1].

Item	1980	1983	1986
Number of companies	29	80	310
Proportion of total (%)	75	80	90
Sales (millions of dollars)	280	687	1,520
Proportion of total (%)	32	46	51
Amount of equipment installed	1,588	7,684	800,000
Proportion of total (%)	17	91	98
Employment (direct)	7,264	15,734	40,316
Proportion of total (%)	40	60	89
R&D outlays (millions of dollars)	30	67	154
Ratio of sales (%)	8.7	9.8	10.1
R&D outlays/employee (dollars/employee)	4,130	4,260	3,850
R&D personnel	1,200	2,045	4,900
Proportion of total employment (%)	16.5	13	12.2

Source: Piragibe, cited from InterAmerican Development Bank, 1988

[1]These data are published by Abicomp. Data published by SEI (1987) are based on information from 60 firms. As a result, data from SEI do not always coincide with data from other sources.

In 1985, the market share of national firms[1], led by the rapid sales of microcomputers, surpassed that of multinational firms; only the U.S. and Japan can boast such market share statistics. By 1986, the number of Brazilian informatics-related firms increased to 310. The development and rapid rise of national firms has led in turn to the establishment of an important group of supplier companies. The infant industry has provided many new employment opportunities and created a large demand for skilled and highly educated researchers, managers, and technicians, and has resulted in increasing expenditures in R&D (see Table 6.3). These themes will be treated in more detail in sections that follow.

Table 6.4 Growth of the Principal Markets for Microcomputers.

1987 Rank	Country	(US $ Millions) 1984/1987	(%) Medium annual growth
1	U.S.	13,124-19,953	15%
2	Japan	1,618-2,920	22%
3	West Germany	730-1,774	34%
4	UK	544-1,319	34%
5	France	510-1,206	33%
6	**Brazil**	**189-992**	**74%**
7	Italy	334-680	27%
8	China	112-662	81%
9	Sweden	157-468	44%
10	Finland	133-334	36%
11	India	61-300	70%
12	Canada	208-274	10%
14	Holland	121-248	27%
15	Australia	144-210	12%
16	Mexico	74-179	34%
18	Korea	54-108	26%
20	Singapore	49-103	28%
24	Taiwan	29-70	34%
27	Hong Kong	20-44	30%
30	Argentina	13-17	9%

Source: Originally from U.S. Department of Commerce; cited from Rocha, 1987.

With the sudden worldwide popularity of microcomputers in 1980, local production of microcomputers became the most rapidly growing segment of the Brazilian computer market. By 1982, more than 15,000 units had been installed, with over two-thirds coming from four national companies: Cobra, Prológica, Edisa, and Dismac (Nochteff, 1985;

[1]National firms in 1985 paid income taxes to the Brazilian government equalling US $380 million (Fleury, 1988).

Piragibe, 1985). The demand for, and local production of microcomputers was strengthened in the mid and late 1980s, with several new firms entering products on the market. The value of the Brazilian microcomputer market rivals those of Europe, and surpasses them in terms of growth rates (see Table 6.4).

According to Flávio Sehn (1987), president of firm Edisa, the large number of Brazilian informatics producers for the reserved segments of the market has meant a high degree of internal competition. For example, by 1986, over 30 firms were producing microcomputers. Other sectors left open to MNCs, like the automotive industry, the chemical industry, or the pharmaceutical industry, according to Sehn, tend to be characterized by oligopolistic competition and its inherent negative externalities.

Even in market segments open to foreign firms, the number of foreign participants has increased. In 1986 there were approximately 30 foreign firms developing product lines that were outside the limits of the market reserve, or capability of national firms (Abicomp, 1986/7; Arnt, 1989). Attracted by the growing market and no longer fearing, or boycotting, the market reserve policies, several foreign firms have sought to expand their activities to Brazil.

Multinationals and Industry Development

The rapid computerization of Brazilian society has been a stimulant for the market for large computers as increasingly small computers are linked to mainframes for data networks. The sale of mainframe computers represented about 1.8 billion dollars of the Brazilian market in 1986, with an annual growth rate of about 20% per year (Monteiro, 1987a). In addition to the local manufacture and importation of mainframe computers, foreign firms are also developing local product lines outside the limits of the reserva and beyond Brazilian technological capabilities. MNC local projects involving state-of-the-art technologies, as opposed to simple or outdated technologies, are particularly encouraged by SEI. Furthermore, software for large computers is predominantly supplied by MNCs.

The major TNCs with operations in Brazil include several international market leaders (see Table 6.5): IBM, Unisys (formerly Burroughs), Digital Equipment Corporation (DEC), Control Data[1] (represented by Moddata), Fujitsu, Data General, ABC-Bull -- a joint venture of the group from Minas Gerais ABC (60%) and the French firm

[1]Control Data has also transferred technology to Elebra for the production of peripheral equipment, and to Villares for CAD/CAM solutions.

Honeywell Bull (40%), and Tesis (a union of Hewlett Packard and the Brazilian group Iochpe for the production of superminis, electronic calculators, CAD/CAM equipment, etc.). Several foreign software firms, as a result of the 1988 software law, are also setting up local offices in the states of São Paulo and Rio de Janeiro[1].

Table 6.5 The Top 15 International Mainframe Companies.

Rank	Company	1988 US$ Million	Market Share
1	IBM	12,138.8	40.1
2	Fujitsu	4,184.9	13.8
3	NEC	4,033.1	13.3
4	Hitachi	2,507.3	8.3
5	Amdahl	1,225.2	4.0
6	Unisys	1,175.0	3.9
7	Groupe Bull	901.0	3.0
8	Siemens	683.4	2.3
9	STC	658.4	2.2
10	Cray Research	632.9	2.1
11	Control Data	465.0	1.5
12	Nihon Unisys	384.8	1.3
13	National Semiconductor	372.0	1.2
14	Comparex	239.7	0.8
15	NCR	218.3	0.7

Source: Milunovich, 1989.

Mainframe computers are manufactured locally by MNCs and imported. MNCs manufacturing mainframes include IBM and Unisys (together accounting for about 75% of the mainframes manufactured in Brazil), ABC-Bull (which sold 36 million dollars worth of equipment in 1987), and Unisys. Firms importing mainframes include the local firm Moddata (with technology transferred form Control Data's Cyber), DEC (with the series 85XX, 8700, 8800 and 897X computers used for industrial automation), the state firm Cobra (which resales the CPU MV 20000 for Data General -- peripherals are produced locally), and Fujitsu (with the M3XX and M7XX families) (Monteiro, 1987a).

Of the foreign companies, IBM dominates with about 800 users and about 27%, in 1986, of the total Brazilian market by value (Dados e Idéias, 1987). The IBM plant in Sumaré, São Paulo, in 1987, was producing about 200 computers per year (Monteiro,

[1]For more detail on software and foreign firms see a latter section in this chapter entitled "The Software Sector."

1987a). In 1988 IBM do Brasil invested US$ 10 million to begin production of their most powerful and modern computer - the ES/3090 (UFRJ, 1989b). These computers are produced for local and export markets. Furthermore, IBM offices in Rio de Janeiro coordinate South American operations for the firm. IBM, in 1985, employed 5,000 people, the largest informatics firm in Brazil (Tigre, 1987). The market preference and growth of Brazilian IBM PC compatible computers has in turn increased the demand for IBM mainframes[1].

Unisys do Brasil, with revenues in 1987 of over 200 million dollars, manufactures a relatively recent mainframe, the A-15 (Eicher, 1988). The A-15, introduced in the U.S. market in 1986, began production in Brazil in 1988. The relatively quick introduction of the Brazilian model is suggestive of the different approach MNCs now have towards Brazil. It is also a testament of Brazil's informatics capability, which can absorb recent and sophisticated technologies, and supply many of the components locally.

SEI, perhaps as a reward to Unisys for bringing their state-of-the-art technology to Brazil, also authorized Unisys to produce 30 units per year of the systems A-1, A-4, and A-6 (class 2 type computers protected by the market reserve policy) exclusively for the export market. Unisys, which plans to sell about twenty A-15 computers per year, is located in Veleiros, São Paulo with 1,300 employees, all Brazilian (Monteiro, 1987a; Eicher, 1988). The importance of Unisys' plant in Veleiros is further illustrated in that, with Unisys' plant in Mission Viejo, California, it shares production of the A-5 and A-10 computers for worldwide distribution (Monteiro, 1987a).

The local manufacture of the A-15 provides a good example of what MNCs must do to produce in Brazil. A series of production phases, intended to gradually nationalize the production process, as required of foreign manufacturers, are submitted to SEI for approval. In the case of the A-15, the first phase, lasting about four months, was comprised of mounting and testing CPUs brought from the U.S.; this phase is to familiarize Brazilian technicians with the computer's architecture. The second phase, of six months, includes the testing of subassembly parts such as cables, interconnecting panels, control cards, etc. The third and fourth phases mark the process of nationalizing computer production, which, by the end of the second year, will reach the point where only 15% of the metal materials are imported. Unisys plans to locally source capacitors, resistors, connectors, terminals, printed circuit boards, cables, some discreet semiconductors, and

[1]IBM do Brasil, unable to sell PCs in Brazil, has purchased local IBM compatible computers for its offices and plants (O Globo, 1987c).

the cabinet; and local laboratories will test and analyse chemicals and the numerous components to meet international quality standards (Monteiro, 1987a).

While some essential components will continue to be imported, the high degree of nationalization and participation of local inputs indicate that Brazil has gone beyond mere assembly of computers based on cheap labor advantages. Although R&D for these computers is performed outside Brazil, local technological capability is aided by adapting and assimilating the technology and production process to the local environment and infrastructure. These 'benefits' are a result of the size of the market, which increases the government's bargaining position vis-à-vis foreign capital, and the market reserve policies that stimulated technological capabilities to a degree sufficient for providing the necessary infrastructure for the manufacture of computers.

DEC set up an office in Brazil in 1974. By 1987, Brazil received the fourth largest DEC investment outside the U.S. (Japan, Canada, and Australia are the first three) (Visser, 1987). According to Visser (1987), president of DEC do Brasil, the firm intends to continue manufacturing products and components, and to develop software. In 1985, DEC transferred technology to Elebra to manufacture and distribute the supermini VAX 750, which Elebra renamed the MX-850 (Jornal do Brasil, 1987d). DEC gains not only royalty payments but also a market for direct sales of its software (Tigre, 1986).

The Hewlett-Packard Company (active in Brazil since 1967) is expanding operations in Brazil under a new strategic partnership with Companhia Iochpe of Brazil and their informatics company Edisa Informatica, forming a new company Tesis, located in São Paulo. Brazilian nationals will be shareholders of the new company, and Iochpe will be the controlling shareholder, while Hewlett-Packard will provide technology and support (New York Times, 1989).

As the Tesis example illustrates, foreign firms are increasingly entering the Brazilian market in the form of joint ventures. Such partnerships with international market leaders were unheard of only ten years ago; Brazilian law limits foreign investment to 30%, and this participation is limited to risk capital while control remains with Brazilian firms. Even so, several foreign firms, including IBM, have been courting Brazilian firms to form joint ventures in the area of electronic data processing services and software development. For example, IBM and Gerdau formed a new company GSI, representing a significant shift in its Brazilian strategy.

Other unions include the European firm Ferranti and the group Mayrink Veiga; Control Data and the Brazilian firm Moddata; AT&T and Sid; Intel and Elebra

Microeletrônica; Compart of Rio de Janeiro and IBM; and two Brazilian companies, Engepel and Sicom, that have formed ventures with the Argentine firms Datash and Sistemas Logical. These new joint ventures have varying responsibilities, such as sales and marketing, joint production, and other services. Furthermore, these joint ventures have status as national firms, creating access to governmental and other reserved markets (Furiati, 1986).

The market reserve policy, while restricting MNC participation from lower end market segments, has not weakened the participation of foreign firms in the more sophisticated segment of the computer sector; indeed, the policy, and the strength of the market, arguably have strengthened foreign investment in manufacturing facilities in Brazil. MNCs in Brazil are being pressed to change their past lack of concern with the advancement of technological capacity in Brazil. After the informatics policy, some foreign computer firms began to increase R&D activities in Brazil and technology centers began to appear, although some question the authentic effort of this foreign R&D (Machado, 1985).

Foreign firms are also increasingly licensing current (rather than more outdated) technologies to Brazilian firms. Economic realities, in particular balance of payment difficulties, have forced the government to set quotas on mainframe imports. However, mainframes manufactured in Brazil have supplied local demands.

The Indigenous Development of Firms, Products, and Linkages

The market reserve policy is a first in Brazilian history; a segment of private industry has never before been closed to foreign participation (Schwartzman, 1988). The industry's response has been dramatic, as attested to by the large number of new informatics firms (350 in 1989) (Mesquita, 1989), employment growth, expanding revenues, product diversification, and by the diminishing technological gap between Brazilian firms and international leaders.

The national industry is characterized by firms with varied sizes, some producing for specialized niche markets while others offer a full range of products in the protected sector. Although the industry was initially dominated by Cobra, the trend has been against the emergence of a clear industry leader, and the entrance of new firms has meant more local competition (see Table 6.6). The structure of the national industry is perhaps best described as a handful of relatively large and established firms with diversified product lines, and several smaller firms and new entrants producing a limited or specialized product line for niche markets.

Many of the larger firms have diversified to other electronic sectors. For example, Sid, the largest firm in terms of revenue, Elebra, Itautec, and ABC are some of the firms that now have more diversified activities, such as consumer electronics, telecommunications, peripherals, and microelectronics. Product diversification is largely a result of technological competence and stable investment resources.

Organizational Structures and Economic Concentration

The dominance of the largest firms, facing competition from one another as well as new entrants, has weakened slightly over the years. The ten largest computer and peripheral firms, by revenue and employment, may be observed in Tables 6.6 and 6.7. The percent of total revenue of the top ten national firms fell between 1981 and 1985 from 67.3% to 64.8%; for the top five firms, their percent of total revenue fell from 50.5% to 45.9%. In 1985, the top ten national firms held 53% of total national employment, an indication that smaller firms are important factor in the industries total employment. Note the predominance of these firms located in São Paulo, and to a lesser extent Rio de Janeiro.

Table 6.6 Ten Largest Firms by % Revenue of Total Market.

	Firm	1981	1985
1	Sid (SP)	6.3%	13.6%
2	Cobra (RJ)	27.7%	13.0%
3	Itautec (SP)	1.2%	9.5%
4	Elebra Inf. (SP)	5.8%	5.0%
5	Prológica (SP)	1.9%	4.8%
6	Scopus (SP)	5.4%	4.7%
7	Labo (SP)	4.9%	4.2%
8	Sisco (SP)	4.9%	3.5%
9	Edisa (RS)	5.3%	3.4%
10	Polymax (RS)	3.9%	3.1%

Source: SEI, 1987.
Location by State:
SP = São Paulo, RJ = Rio de Janeiro, RS = Rio Grande do Sul

Table 6.7 Ten Largest Firms by Employment, 1985.

	Firm	Percent Employment of Sector
1	Cobra (RJ)	10.0%
2	Itautec (SP)	8.4%
3	Prológica (SP)	7.0%
4	Sid (SP)	5.8%
5	Digirede (SP)	4.6%
6	Elebra Inf. (SP)	4.4%
7	Scopus (SP)	4.3%
8	Racimec (RJ)	3.2%
9	Sisco (SP)	2.8%
10	Microlab (RJ)	2.7%

Source: SEI, 1987.
Location by State:
SP = São Paulo, RJ = Rio de Janeiro, RS = Rio Grande do Sul

Many of the largest firms have banks or large industrial groups as principal stockholders, including Sid, Itautec, Elebra, Edisa, Sisco, Labo, Sisco, and Scopus[1]. These financially secure firms benefit from stability and capital availability to increasingly diversify product lines. Elebra has obtained its dominance through the peripheral sector, manufacturing products such as printers and disk drives.

As the Brazilian industry matures alliances have arisen between firms of large Brazilian economic groups with capital and informatics firms with technological competence. The competitive advantages of these larger firms and their associations with large industrial or banking groups are numerous: privileged access to specific markets and better access to financial resources; superior technical capacity; and product diversification and integration with other types of electronics firms. All of which permit greater economies of scale and scope of activities, and greater leverage with foreign firms for access to technologies (Tigre, 1986).

While large firms have several advantages, this is not to deny the dynamism and potential of smaller firms that produce for niche markets and offer support services. Some of these firms have made great technological strides. However, considering the precarious state of the Brazilian economy and the difficulty, in general, firms face in attracting risk capital for new projects, small firms without financial backing are less secure in the current environment of economic uncertainty. With the current high cost of capital in Brazil, small, medium, and even large informatics firms are interested in alliances with large financial or

[1]The history of Scopus is very similar to Apple's, it was created 13 years ago by four recently graduated engineers and now has over 1,500 employees.

powerful industrial economic groups, as well as other informatics firms. Firm consolidation appears inevitable for the industry in the 1990s to meet the challenge of competition from foreign firms.

Table 6.8 Major Brazilian Economic Groups and Informatics Firms.

Economic Group	Firm(s)	Principal Products	Revenue in 1988
Group Itaú	Itautec (SP)	Microcomputers and Banking Automation (Itautec Informática); Microelectronics (Itaucom, Itaucam, and Adiboard)	US$ 205 million
Group Bradesco	Digilab Stock Participation Scopus (70%) (SP) Elebra Comp (30%) (RJ) Sid Informática (11.5%) (SP) Cobra (1.4%) (RJ)	Printers (Digilab); Banking Automation (Digilab)	US$ 60 million (Digilab only)
Group Docas de Santos	Elebra	Superminicomputers (Elebra Computers -RJ); Peripherals (Elebra Informática -SP); Modems (Elebra Comunicação de Dados -SP); Integrated circuits (Elebra Microeletrônica)	US$ 297 million
Group Machline	Sid (SP)	Micro and supermicrocomputers (Sid Informática); Microelectronics (Sid Microeletrônica and VSI Vêrtice Sistemas Integrados); Telecommunications	US$ 150 million
Group Iochpe	Edisa (RS) Stock Participation Tesis Informática	Supermicros, Superminis, Calculators, Measurement Instruments	US$ 71 million

Source: Fioravanti, 1989.
SP = São Paulo, RJ = Rio de Janeiro, RS = Rio Grande do Sul

Already the number of economic groups and informatics firms is significant (see Table 6.8), and includes: the group Mathias Machline and Sid; the group Docas de Santos and Elebra; the bank Itaú and Itautec; the bank Bradesco and Digilab and Scopus; and the group ABC and ABC Informática; the group Iochpe and Edisa; the group Brasilpar and Labo; the Argentine group Bunge y Born and Proceda (Proceda recently purchased Monydata); and the group Macksoud and Sisco. Other firms, like Microtec, EBC, Microdigital and Digirede, are potential candidates to be absorbed by large conglomerates

(Paula, 1988b). Unions among informatics firms are also increasing; for example, Villares Automação e Informática is the result of a recent -- 1988 -- fusion of three firms: Sistemas e Serviços de Informática, Eletrônica Digital, and Eletrocontroles.

The government clearly supports mergers and has actively encouraged joint research projects in an attempt to consolidate scarce investment and research resources. Associations among informatics firms to exchange software programs, and joint R&D activities are increasing as firms attempt to increase economies of scale and reduce R&D costs. In the past, each firm had its R&D department oriented towards internal products. This pattern is giving way to long-run joint R&D projects, similar to the international pattern of more joint R&D.

One example of a joint R&D project, in the area of software development, is between Scopus and Cobra. Each firm exchanged their internally developed operating system software programs for further joint development and marketing (Cobra with SOX and Scopus with Sisne) (Informática Hoje, 1987a). Although this strategy is actively promoted by government officials, joint R&D projects are relatively new and have not occurred to the same degree as in firms located in the industrialized countries.

There is some controversy over the number of large banks directing high-technology firms. For example, although Bradesco's recent purchase of Scopus will help facilitate the bank's own needs for banking automation and the financial security of Scopus, there is some worry that banks are unable to acquire the necessary administrative competence to accompany international technological trends. The merger trend is likely to continue regardless of these fears as the capital dependent high-technology firms search for financial security, and for significant in-house markets for their equipment.

Spatial Concentration and the Location of Informatics Firms and Markets

Joint research projects would seem to be assisted by the geographic propinquity of the firms. Most firms are located in the south central region of the country. Firms located São Paulo and Rio de Janeiro alone commanded 88% of the industry in 1986, although firms in other regions are slowly increasing their participation in the market. The state of São Paulo now has 166 informatics firms representing 66% of the total number of informatics firms in Brazil (Fleury, 1988). The following table and figure indicate the location concentration by state of informatics firms.

Table 6.9 National Computer and Peripheral Firm Location by State and Percentage of Market.

State	1980	1981	1982	1983	1984	1985	1986
São Paulo	39.8	43.1	50.7	61.3	65.8	62.6	66.1
Rio de Janeiro	52.2	42.5	36.8	28.2	24.9	25.1	22.1
Rio Grande do Sul	5.4	10.9	8.1	6.6	6.3	7.1	6.9
Others	2.6	3.5	4.4	3.9	3.0	4.9	4.9

Source: SEI, 1987.
* 1986 data is preliminary.

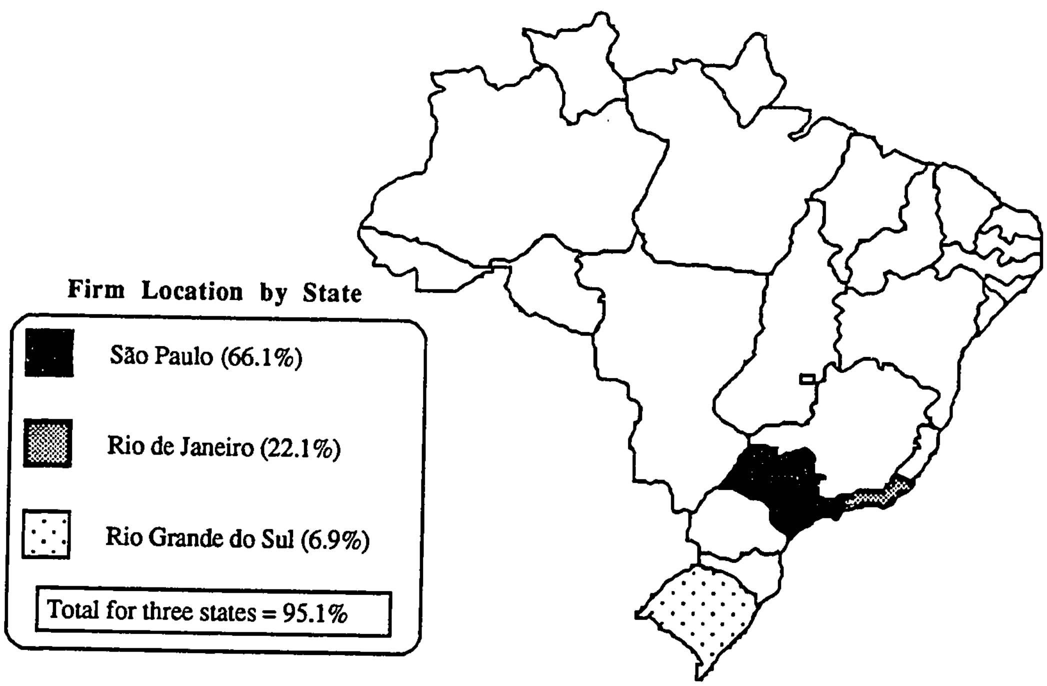


Figure 6.3 Firm Location by State.

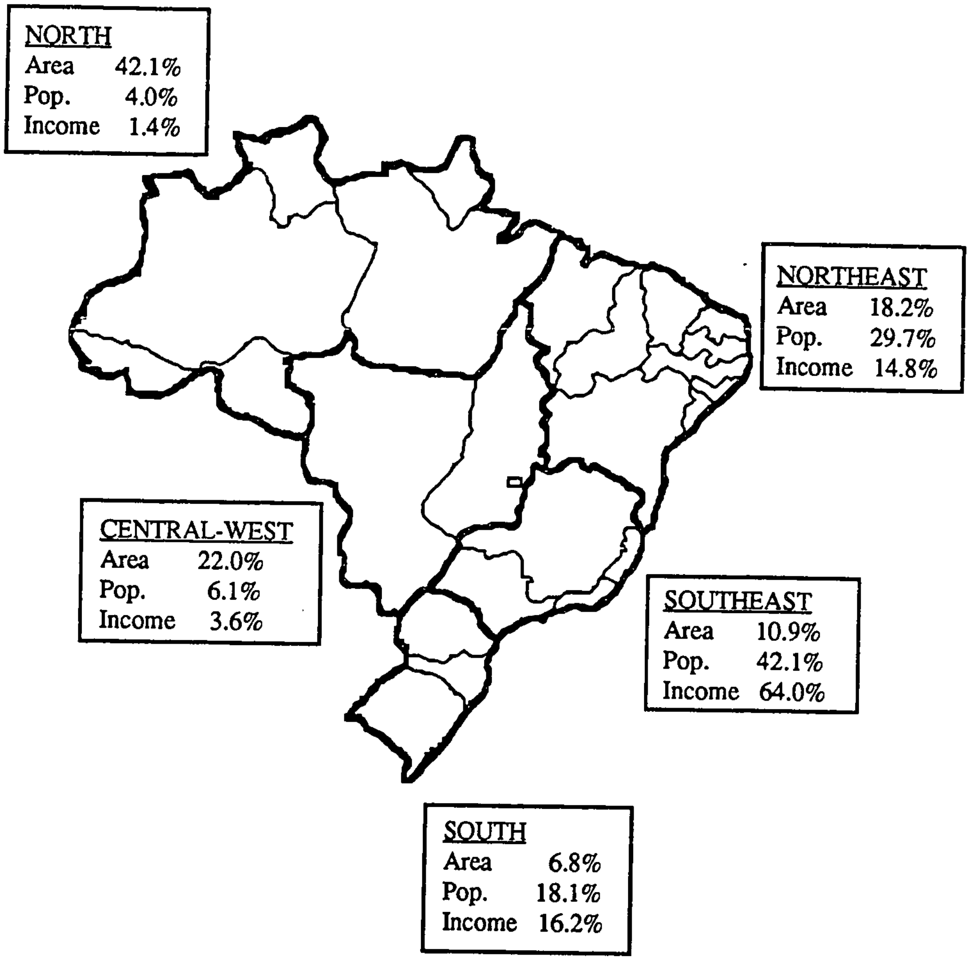
The extreme concentration of firms located in São Paulo and Rio de Janeiro is not surprising considering the significant level of industrialization and associated well-developed technological infrastructures in these two states. São Paulo and Rio de Janeiro are rich in research institutes and universities, skilled labor supplies, access to transportation systems, proximity to markets, and a variety of supplier firms. Other regions in Brazil are actively pursuing informatics policies to encourage better linkages between their universities and industries, as described later in this chapter. As in the U.S., state and local policymakers in Brazil view high-technology firms and centers as an answer to regional economic stagnation. Industries locating in these regions, however, will find themselves distanced from the market (see Table 6.10). One interesting anomaly is Gradiente, whose headquarters are located in São Paulo and manufacturing facilities are located in Manaus. Possible administrative problems resulting from the significant distance between plant and headquarters are remedied by data communication via satellite (O Globo, 1989d). By locating production in Manaus, Gradiente benefits from governmental incentives and fewer import restrictions.

Table 6.10 Distribution of the Brazilian Computer and Peripherals Market by State.*

State	1979	1980	1981	1982	1983	1984	1985
São Paulo/Capital	39.4	42.7	41.6	33.6	31.3	37.1	42.7
Rio de Janeiro	29.1	33.2	29.6	24.5	26.1	20.3	17.7
São Paulo/Interior				6.5	15.1	11.0	10.4
Federal District	8.8	5.4	7.4	10.8	5.2	6.5	6.3
Paraná		4.2	5.1	4.0	4.3	5.8	5.7
Rio Grande do Sul	4.8	7.1	8.2	9.0	5.3	5.2	4.7
Minas Gerais		2.7	2.7	3.9	4.7	4.3	3.9
Other States	17.9	4.7	5.4	2.3	1.9	3.6	2.8
Bahia				1.5	1.6	2.1	1.6
Ceará				1.0	0.9	1.2	1.6
Pernambuco				1.6	1.7	1.4	1.5
Santa Catarina				1.0	0.8	1.5	1.1

Source: SEI, 1987
*Data from national firms only.

The demand for computer-related equipment reveals a strong regional concentration. The states of São Paulo and Rio de Janiero alone account for 70 percent of the Brazilian market (see Figure 6.3). The geographic concentration of firms and markets reflects the general industrial concentration of the Brazilian economy. Figure 6.4 reveals the concentration of income relative to population in the southeast geoeconomic region of Brazil.



Source: Anuario Estatistico do Brasil.

Figure 6.4 Brazil's Geoeconomic Regions.

Brazil's regional industrial concentration may be explained by raw material export policies of the colonial and early independence periods, and new strategies of the post World War II. The colonial legacy led to coastal areas with rich hinterlands developing into primate regions, as was the case first with Rio de Janeiro and later with São Paulo. Industrialization strategies of this century, exemplified by import substitution policies, magnified the economic and political advantages of these centralized regions. As the industrial process proceeded, so did the clustered locational pattern. Industrial policies have reinforced the concentration of the industrial structure in the São Paulo - Rio de Janeiro area, the core region of Brazil (Edwards, 1983; Haddad, 1981; Stöhr and Taylor, 1981; Hewlett, 1982; Suarez-Villa, 1983). A number of indirect effects from ISI have contributed to industrial concentration. For example, associated with ISI are high tariffs on industrial products (relative to raw materials and foodstuffs) that shift the internal terms of trade in favor of the primate urban-industrial sector. Highly protected industrialization combined with significant governmental incentives have also encouraged multinationals to locate within national boundaries. Multinationals have often located their activities in core cities for their cosmopolitan environment, modern living conditions, accessibility, community attitude, and the prestige effect of the location (Gwynne, 1982).

As the most accessible location in Brazil, the Rio-São Paulo axis (around which the nation's transport system revolves) offers the most advantageous location for several different industries. The region contains a large reserve of relatively skilled labor, an economic infrastructure and capacity for innovative change, and cultural and social variables conducive to entrepreneurship. Additionally, the region possesses a wide variety of goods and services that are absent in peripheral regions (especially higher order goods and services such as financial institutions, wholesale activities, professional services and governmental offices), and a greater number of lower order goods and services (including retailing, entertainment activities and personal services). These factors play an important role in attracting industry to the region.

Not surprisingly, market distribution, although more diversified than firm location, parallels industrial concentrations and regions of population (see Figure 6.5). The Southeast and South geoeconomic regions, with 60.2% of Brazil's population and 80.2% of the country's income, account for 86% of the computer market. While the diffusion and use of informatics technologies are occurring at a quick pace within industrialized regions, diffusion to other less industrialized regions appears to be emerging at a very slow rate. The result of increasing productivity of firms that have adapted informatics technologies in core regions is likely to further intensify industrial concentrations.

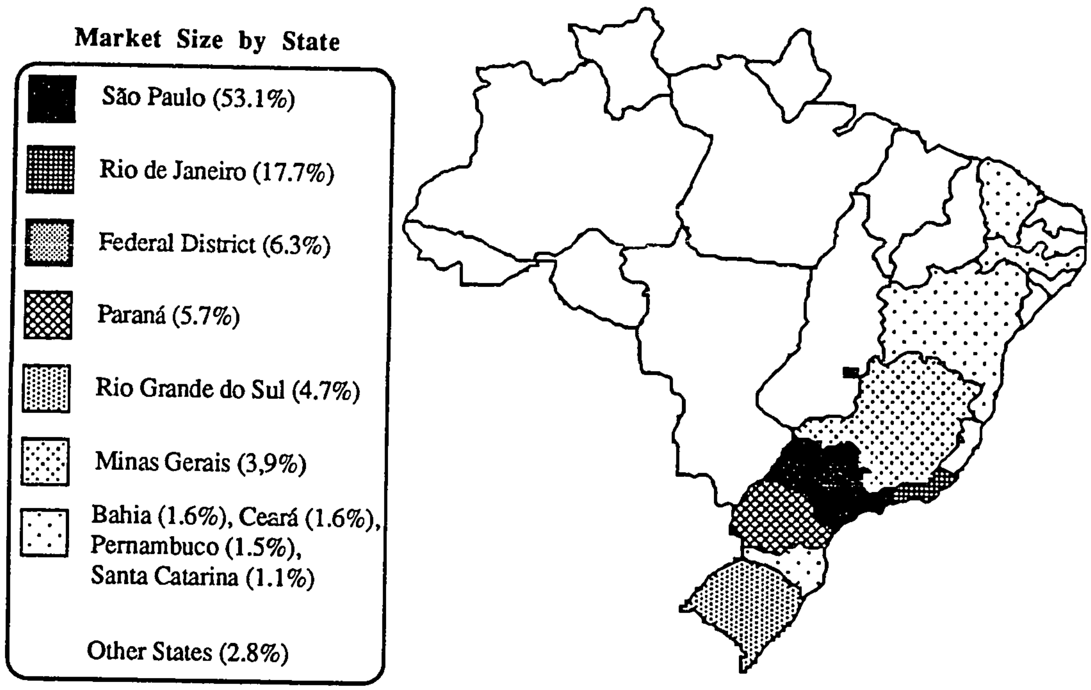


Figure 6.5 Computer and Peripheral Market by State (1986).

Overview of Products and Technological Development

This section will survey Brazilian-made computer products. After a brief overview of the sector, computer systems and peripherals will be explored at more depth. Note that the products manufactured by national firms are those that enjoy protection from foreign competitors[1]. Of particular interest is the degree of local competitiveness and the ability of local manufacturers to follow international technological trends.

[1]SEI regulates activities in the fields of real-time control systems, microelectronics, electronic instrumentation, software and services, computer systems and peripheral equipment, banking and other terminals, data communications products (modems, teleprinters, facsimile), CAD-CAM equipment and software, advanced terminals, and numerical control equipment (including robotics).

Table 6.11 Information Technology Equipment Sold in 1986 and 1987 (data from 77 Firms).

Product	1986	1987*
Superminis	86	91
Minis	1,370	621
Supermicros	1,240	1,273
Personal Micros	32,814	28,995
Professional micros-8 bits	49,261	6,762
Professional micros-16 bits	56,636	58,139
Serial printers	60,857	88,242
Line printers	1,890	1,499
Communication terminals	32,940	27,913
Financial terminals	18,134	8,932
Point of sale terminals	1,223	2,519
Videotext terminals	3,621	4,875
Telex terminals	n.a.	2,261
Video monitors	7,886	18,439
Process control equipment	332	351
Magnetic tape unit (reel)	1,110	941
Magnetic tape unit (cartridge)	7,360	5,804
Winchester disk unit	26,374	44,370
Floppy disk unit 5 1/4	118,902	76,355
Multiplexers	816	570
Modems	33,840	37,615
Local networks	n.a.	1,190

* The data for 1987 includes figures of sales actually made for the first semester of the year and estimates for the second.
n.a.: Not applicable.
Source: ABICOMP, cited from Gomes, 1987; Inter-American Development Bank, 1988.

Table 6.11[1] shows sales data from 77 firms according to specific product lines. The data illustrate strong sales numbers for supermicros and 16-bit microcomputers, which represents, according to the Inter-American Development Bank (1988), a maturation of both the Brazilian computer industry and market. In other words, national firms were capable of following international market trends and technological developments. National firms assimilated new international shifts in technology for microprocessors and quickly manufactured computers using these more sophisticated components. For microcomputers, the time gap between international releases and subsequent Brazilian

[1]These numbers slightly differ from other data sources. For example, small computers for home use represent one the the fastest growing segments of the market; apparently these product were not covered in the below survey. Personal computers in the home represent about 20% of the computers sold by national firms (Paula, 1988a). Data found in SEI (1987) estimate the market for small computers for home use at 226,466 units in the year 1986, and even SEI's data are incomplete as a major manufacturer (Sharp with over 60,000 micros installed) was not included in their survey. Another discrepancy: SEI data for video terminals estimate sales of 35,661 units in 1986.

releases of compatible equipment has been, in some cases, less than a year. According to a study of the industry by Abicomp, Brazilian micros, that only a few years ago appeared on the market with a time lag of three years after their introduction internationally, now lag only one year or less (Mesquita, 1989). This indicates that Brazilian firms have increased their technological capacity to more closely follow international technological changes.

By 1986, some 800,000 computers were in use in Brazil, 98% being from national manufacturers, although by value this represents 51% of the total computer market, reflecting the higher value of multinational-built mainframes. In 1987, over 700,000 microcomputers had been installed in the Brazilian market. The following table shows national production by value of equipment. Sales figures illustrate the importance of microcomputers and the initial entrance of superminis, which, since 1986, have increased their market share. Superminis and micros, similar to the international market, are increasingly replacing minicomputers.

Table 6.12 National Output by Product Type (as percentage of total sales).

Type	Percent of total sales	
	1985	1986*
Microcomputers	35.4	42.8
Minicomputers	39.7	33.2
Peripherals	18.6	16.6
Other	5.8	5.9
Superminis	0.5	1.5
Total	100	100

Source: SEI, 1987
* 1986 data is preliminary.

Note that these data represent only the computer industry. The total Brazilian electronics market is much larger; in 1985, it was estimated the electronics sector reached US$ 8 billion; including computer and peripheral equipment, industrial automation and instrumentation equipment, telecommunications equipment, components and parts, and consumer electronic goods (Miranda, 1987).

Microcomputers: The market segment with the highest growth rate, since its Brazilian introduction, is the microcomputer. Several firms compete in this market with many different products and price ranges. SEI provides data for 1985 on the micro industry based on 8 and 16 bit machines. Data shown in Table 6.13 reflect the variety of products, i.e., some firms have large numbers of units sold but at less value. Growth rates from the previous year, 1984, for 8 bit machines was 76%, and for 16 bit machines 454%; a signal that the industry, especially for 16 bit machines, was just initiating production. For comparison, internationally, microcomputer sales, in 1988, grew by 26% over the previous year (Kelly, 1989).

Table 6.13 Ten Largest Microcomputer Manufacturers by Value of Equipment Sold in 1985.

8 Bits			16 Bits		
Firm	Quantity	Value*	Firm	Quantity	Value*
Cobra (RJ)	2469	147,800	Cobra (RJ)	531	148,200
Prolόgica (SP)	40999	129,867	Microtec (SP)	2727	81,400
Itautec (SP)	5273	125,957	Scopus (SP)	2165	73,138
Microdigital (SP)	50947	88,836	Itautec (SP)	1350	55,553
CCE (AM)	16200	77,550	Prolόgica (SP)	1729	53,309
Sid (SP)	1040	61,933	Polymax (RS)	444	17,200
Dismac (SP)	3270	44,900	Softec (SP)	544	15,383
Polymax (RS)	1526	40,500	Medidata (RJ)	206	14,000
Gradiente (SP)	9116	33,600	Monydata (SP)	36	1,500
Epcom	7980	26,742	Novadata (FD)	3	280

Compiled from data in SEI, 1987.
* Millions of Cruzeiros.
AM = Amazonia, FD = Federal District, SP = São Paulo, RJ = Rio de Janeiro, RS = Rio Grande do Sul.

The Brazilian personal micro market segment is based on computers compatible with IBM, MSX[1], and Apple standards. Internationally, IBM PCs alone, in 1988, accounted for 25.5% of the worldwide market share for microcomputers; equipment compatible with IBM's standard would significantly raise this figure, suggesting the international dominance of the IBM standard (Ewell, 1989). 'Compatible' equipment can be produced since microcomputers use non-proprietary chips, such as Intel's 80386 or Motorola's 68030 microprocessor.

Within the Brazilian microcomputer market, the IBM PC compatible segment has the highest degree of competition with numerous firms manufacturing equipment[2]. The

[1]MSX, or Microsoft Super Extended, is a new standard for personal computers based on the microprocessor Z-80. Its development began in 1984 by Microsoft in conjunction with Japanese electronic giants. The MSX standard is popular in Japan, Taiwan, Hong Kong, South Korea, and Europe (Paula, 1988a).

[2]By 1987 there were over 150 PC compatible models on the Brazilian market, however, only 55 were approved by SEI, including firms offering one model- Basic, Cobra, Compuleader, CRT, Dynacon, EBC, Elόgica, Hengesystems, Houston, JNS, Labo, Microcraft, Monydata, Proceda, Quartzil, Sid, Sid da

first IBM PC compatible computers appeared on the market[1] between 1983 and 1984 with Scopus and Microtec dominating the market with high quality machines. In 1985, Itautec joined the market. Other large firms offering IBM PC XT compatible machines include Monydata, Microtec, Prológica, and Scopus.

IBM PC AT compatible machines first appeared in the market in 1986, and are produced principally by Microtec, Scopus, Itautec, Monydata, Dynacom, Quantum, Sid, Novadata, and Softec (the first producer of PCs in Brazil) (Paula, 1988c). IBM compatible ATs occupied, as of 1988, about 60% of the micro market (Paula, 1988c).

By 1988, the first PS/2 model 30 compatible computer entered the market by Itautec Informática. The computer uses an Intel 8086 processor, with all messages in Portuguese, and is intended for professionals, and small to medium sized firms (INFO, 1989a). The computer also uses a chip set, GAC/30, developed by Itaucom, that substitutes for about 40 imported components (INFO, 1988m).

By 1989, several firms were manufacturing computers using the Intel 80386 chip: Quantum, Monydata, Microtec, Microlab, Itautec, Sid, and Medidata (INFO, 1989g; Dados e Idéias, 1988e; Lucena, 1987). These computers, using DOS or Unix operating systems, are used for CAD, desktop-publishing, and as workstations. Brazilian compatible computers, as illustrated by the Itautec example, entered the market relatively quickly after their appearance in the international market.

Apple compatible machines have been quite popular due to their lower final price, however, the failure of Unitron's 'Macintosh' clone to be licensed by SEI[2] in 1988 has inhibited some manufacturers from continuing manufacturing Apple compatible equipment. Only three firms remain as manufacturers of Apple compatible equipment: Unitron, Microdigital (SP) and CCE (AM) (Nepomuceno, 1989). Unitron, for example, produces a national equivalent to the Apple II and II-E (Paula, 1988a).

Amazônia, Techlog, Teslist, and Troppus; firms with two models - ATS, CCE, CP, Distronic, Edisa, Itautec, Medidata, Novadata, Polymax, Sector, Sisco and Sysdata; firms with three models - Softec; and with five models - Microtec (O Globo, 1987a)

[1]IBM's original shipments of the XT began in March 1983, and the AT in August 1984 (Moad, 1989).

[2]Pressure from the US government stopped Unitron from selling the first Macintosh clone in Brazil. Unitron's Mac 512 was not licensed by SEI on the grounds that it was an illegal copy, but Unitron felt it was caught in a political game and was sacrificed to temper the Reagan administration's threats of sanctions because of Brazil's computer barriers. SEI's action was surprising as Unitron received government R&D funding, but the decision was largely the result of President Sarney's action to temper the tension between the two countries (Veja, 2/24/88).

Table 6.14 Brazilian 8 Bit Microcomputers.

Standard	Model	Manufacturer	Number Installed	Price CPU Only	Price CPU, Monitor, Drive
MSX	Expert	Gradiente	100,000	43 OTNs	155 OTNs
MSX	Hot Bit	Sharp	61,500	38 OTNs	150 OTNs
Apple	TK 3000	Microdigital	25,000	63 OTNs	110 OTNs
Apple	AP-II	Unitron	18,000	50 OTNs	98 OTNs

Source: Paula, 1988a

MSX microcomputers entered the Brazilian market in 1984. Two computers, the 'Expert' computer by the firm Gradiente and 'Hotbit' computer by the firm Sharp, were introduced and quickly became the fastest growing segment of the sector (see Table 6.14). Initially entering the market for video games, it was rapidly adopted as an inexpensive computer by professionals (Gallo, 1988). For example, Sharp's Hotbit micro is increasingly being used to automate small offices (Staub, 1988). Between 1983 and 1987, 15% of all computers sold in Brazil were MSXs. Gradiente had two-thirds of the MSX market, representing 10% of the total number of computers sold in Brazil. MSX computers are less expensive than PCs and have proved extremely adaptable for Brazilian users.

Within the microcomputer segment of the market, however, are several small, backyard type firms that mount pirated or contraband equipment for sale at low prices, but without registry by SEI (INFO, 1988e). In addition to saving overhead costs on R&D, these 'manufacturers' are able to produce at lower costs due to circumventing SEI's requirement for nationalization indexes and by utilizing imported components and peripherals at cheaper black market rates (imported components are heavily taxed through official routes). The purchaser of low cost equipment runs the risk of questionable quality and lack of support services that 'established' firms offer.

In addition, complete foreign microcomputers are illegally imported and sold on the black market. Foreign computers may be found in the want-ads of most major newspapers. The number of these 'illegal' microcomputers represents, according to one estimate, 55,000 computers or 22% of the total market of 250,000 professional micros installed in Brazil; the preferred products being from Apple (40%), IBM (40%), and IBM compatibles (20%) (Ordoñez, 1988). The reason for the high contraband figures is generally based on the perceived quality of original products from IBM or Apple (Ordoñez, 1988).

Users of microcomputers continually voiced two complaints: the quality of local equipment and high prices. Cheaper local computers from backyard manufacturers have questionable quality, but high quality computers from reputable manufacturers come with high price tags. Data for the year 1989, however, indicate that prices for computer products have fallen to the point of competing with contraband products[1], resulting in more sales for national products and a drop in sales for contraband (Dias and Arruda, 1989). This is evidence that if reputable manufacturers can reduce final prices of their products, market response will be favorable.

Supermicros: Supermicros were first commercialized by Brazilian firms in 1984, and have since begun to invade markets traditionally occupied by mini computers, local networks, and in some cases superminis. From 1984 to 1987, the annual market growth for minicomputers was 15%, with a total of 3900 computers sold. During the same three year period sales of supermicros grew about 60% per year with 1600 units sold (Moura, 1988).

A supermicro is a 16/32-bit machine that imitates the basic architecture of a mainframe. A supermicro is differentiated from a mini and supermini-computer by the fact that only one microprocessor (fabricated by firms like Motorola, National, Zilog, or Intel) is required for general use. The central processing unit, therefore, costs less than that used by the mini and supermini-computers, making their prices more attractive. Supermicros are versatile machines that use software allowing for multitasking and multiuser environments. Brazilian supermicros use one of the numerous Unix-like operating systems available locally. Edisa, Digirede, Medidata, Prológica, and Villares Informática were the pioneers in the supermicro market, but the success of the computer has led other principal computer manufacturers to enter the market, like Cobra, Sid, Scopus, and Itautec (see Table 6.15).

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[1]Computer prices have fallen relative to foreign computers due to increased productivity by national firms and exchange rate fluctuations that make the dollar price of foreign computers more expensive.

Table 6.15 Brazilian Supermicros (1987).

Firm	Date Introduced	Comments
Cobra (RJ)	1984	Developed own Unix operating system (SOX).
Digirede (SP)	1986	Estimated sells by 1987 - 470 units.
EBC (RJ)	1986	Interested in the industrial automation and process control market, Developed software with NCE and Coppe.
Edisa (RS)	1984	Sales in 1986 - 586 units. Market leader in 1988.
Elebra (SP)	1988	Technology acquired from abroad.
Holon (SP)	1986	
Itautec (SP)	1988	Technology acquired from abroad.
Labo (SP)	1988	Technology from Nixdorf.
Logus (SP)	1987	
Medidata (RJ)	1984	Sales in 1986 - 225 units.
Microtec (SP)	1988	
Proceda/Monydata (SP)	1988	
Prológica (SP)	1986	Licensed Unix-like software developed at USP; Sales in 1986 - 50 units.
Scopus (SP)	1988	
Sid (SP)	1987	Technology from Convergente.
Villares (SP)	1986	Technology from Hitachi, Intended market: industrial automation and process control.

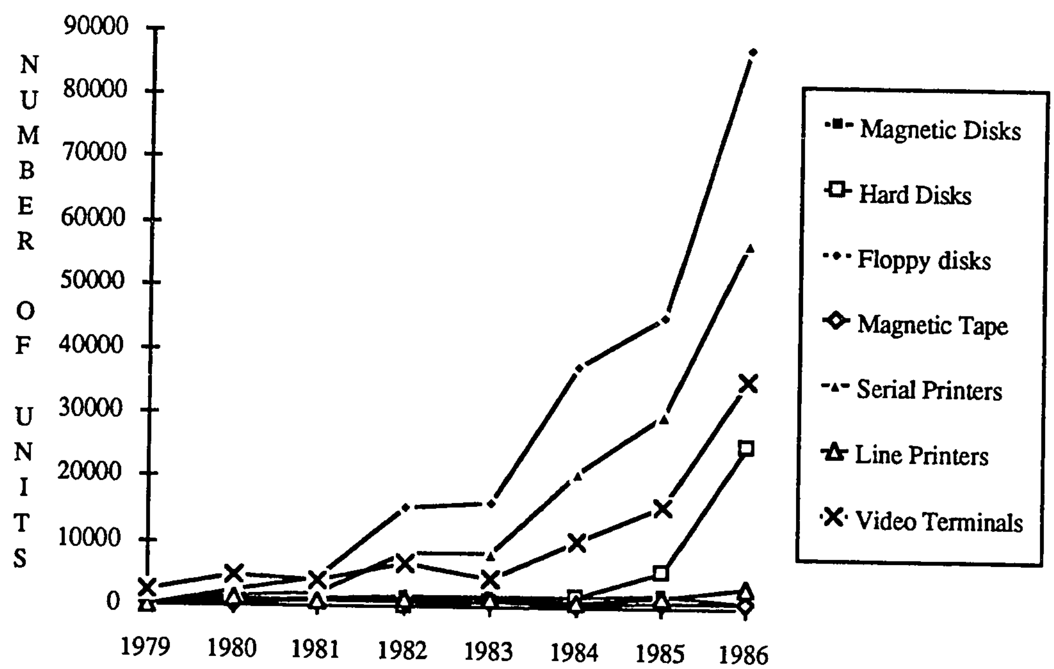
RJ = Rio de Janeiro; SP = São Paulo; RS = Rio Grande do Sul
Source: Constructed from information in Paula and Beck, 1987b; Luca, 1988b; Moura, 1988; SEI, 1987.

Minicomputers and Superminis: Minicomputers initiated the Brazilian computer industry after the market reserve policy was introduced in 1978. During the early 1980s the mini market developed quickly, primarily due to the automation of the banking sector and large purchases by state firms. By 1983, however, microcomputers encroached on mini markets. Micros, while less powerful were much lower priced. The trend parallels sales on the international market. Worldwide, minicomputer sales registered a growth rate in 1988 of only 8% (Kelly, 1989). Manufacturers of minicomputers in 1985 include Edisa, Cobra, Medidata, Sisco, and Sid. Several of these mini producers subsequently began to manufacture more powerful superminis[1] (Tigre, 1987).

The superminis were produced with technology initially acquired from foreign sources. According to Saur (1988), Edisa, Labo and Sid have acquired the internal capacity to dominate the necessary process and manufacturing technology for this equipment. In other words they have absorbed the technology originally imported. Cobra, Itautec, Elebra Computadores, Tesis, and ABC Computadores also manufacture superminis. The potential of this market, however, remains uncertain.

[1]Superminis are computers that range from US$ 500,000 and US$ 800,000 in Brazil (Cline, 1987).

Peripherals: The growth of peripheral equipment produced and sold by national firms has paralleled the growth of computer sales. Figure 6.7 represents the quantity of equipment sold. These sales figures predominantly represent equipment sold via Original Equipment Manufacturer (OEM) and to a lesser extent direct sales. In terms of value, serial printers and floppy disk drives contribute the largest share, accounting for 29.7% and 44.8%, respectively, of the total value of the peripheral market. With the exception of magnetic disks and magnetic tapes, all segments have grown, in terms of constant values, over 90% between 1985 and 1986 (SEI, 1987). A brief synopsis of the modem and disk drive sectors follows.



Source: SEI, 1987
* 1986 data is preliminary

Figure 6.7 Peripheral Equipment Sold by National Firms by Quantity.

By 1986, there were 17 firms exclusively producing modems, dividing the annual market of about 30 million dollars. In 1986, 80% of the market was in the hands of two firms: Moddata (Rio de Janeiro) and Elebra Telecon (São Paulo). Other firms like Parks and Digitel - both in Rio Grande do Sul, Tropical in Minas Gerais, and Rhede from Brasilia have strong market penetration regionally.

Brazilian modems are of good quality and with internationally competitive prices. As such, national firms are looking to foreign markets in Latin America, Asia, Africa, and even the U.S.. Embratel, a governmental communications agency, is a significant market and in 1985 purchased over 10,000 modems from national firms, including ABC Dados, Moddata, Digitel, Elebra, Parks, and Rhede. Supplementing the governmental market is the banking sector, where automation has led to an increased demand for modems. International technological developments have been closely followed; three firms, Moddata, Elebra, and Rhede, by 1986, were producing high velocity modems (9,600 band), the latter with its own technology (Paula, 1986a).

The firm Digitel provides an interesting 'technological strategy' example of a very successful firm, with growth rates between 1987 and 1988 of 80%, and from 1988 to 1989 of 50% (O Globo, 1989a). Digitel is a university spin-off, founded by three university professors (INFO, 1989c). It specializes in the production of data communications equipment, with much of its technology indigenous. The firm has invested heavily in R&D (15% of gross revenue), production automation equipment, and the computerization of the firm (O Globo, 1989a). Digitel imports some state-of-the-art technology and production equipment, but bases its success on acquiring indigenous technological capability. The 'success' case of Digitel illustrates for industrial development, a firm should have linkages to its technological environment and to foreign technology and knowledge, in addition to a strong local research capability.

Brazilian manufacture of disk drives began in 1980. Before this date the Brazilian market for disk drives was supplied principally by IBM do Brasil and Burroughs do Brasil. These foreign firms manufactured only rigid drives of 8 and 14 inches for use in their medium and mainframe computers, although some products were used for the infant Brazilian minicomputer firms -- microcomputer production only began in the 1980s. Since 1980, five firms have come to dispute the market for disks for the mini- and microcomputer market in Brazil (Elebra Informática S/A, Flexidisk Tecnologia Eletrônica S/A are the firms that offer the most diverse product line) (Perine, 1985). In 1985, the value of hard and floppy disks sales totaled Cr$ 80 billion and Cr$ 112 billion respectively (SEI, 1987). The leading manufacturers, according to data from SEI, are shown in Table 6.16.

Table 6.16 Manufacturers and Percentage of Market for Disk Drives.

Manufacturer	1983	1984	1985	1986*
Hard Disks				
Flexidisk (SP)	13.0	20.8	37.5	34.4
Multidigit (RS)	75.0	76.2	26.6	21.4
Percomp		3.0	23.3	21.8
Elebra Inf. (SP)			2.6	6.9
Microlab (RJ)			1.1	7.6
Prológica (SP)	12.0		8.9	7.9
Floppy Disk Drives				
Elebra Inf. (SP)	14.2	43.9	64.1	60.3
Flexidisk (SP)	78.0	47.9	30.4	8.4
Prológica (SP)	7.8	5.9	4.2	23.3
Multidigit (RS)			1.3	8.0
Periféricos		2.3		

Source: SEI, 1987.
* 1986 data is preliminary.

SP = São Paulo, RJ = Rio de Janeiro, RS = Rio Grande do Sul

Elebra, the largest manufacturer of disk drives, sells a major part of its output as OEM and its principal clients are Itautec (floppy), Sid, Medidata and Edisa (Winchester). Flexidisk's principal OEM clients are Itaú (Winchester), Digirede, Sid, Unitron, CCE and Polymax. Microlab's principal clients are Edisa, Sisco, Cobra, Labo, Sid, Novadata. Multidigit sells to Edisa, Polymax, Prológica and Brascom. Prológica produces drives principally for their own microcomputers (Perine, 1985).

Perine's study of prices showed that the national products were, in 1984, between 1.98 to 3.52 times more expensive than similar American models although prices were falling. Manufacturers highlighted three reasons for the costliness: high tariffs on component imports (averaging 40%), the high cost of capital, and the small scale of production. The production of disk drives still depended on the importation of heads, step motors and electronic components. Manufacturers claim that tariff reductions could lower final prices up to 50%. On the other hand, high tariffs stimulate firms to indigenize technological solutions and to incorporate components made in Brazil. The time gap between products released in the U.S. and in Brazil was also diminishing, to as little as 8 months (Perine, 1985; Paula, 1986c).

Table 6.17 Disk Drive Manufacturers for Microcomputers in Brazil.

Manufacturer	Date Launched	Diameter (in inches)	Type	Capacity (by megabyte)	Technology
Elebra	80	14	Rigid	32, 64, 96	Control Data
	81	8	Floppy	1.6	Control Data
	82	5 1/4	Floppy	.25, .5, 1.0, .218	Control Data
	82	5 1/4	Rigid/Winchester	40, 60, 80	Calcomp
	82	9	Rigid/Winchester	340, 515	Control Data
Flexidisk	82	5 1/4	Rigid/Winchester	5, 10	Seagate
	82	5 1/4	Rigid/Winchester	30, 50	Vertex
	84	5 1/4	Rigid/Winchester	70	Vertex
	80	8	Floppy	.8, 1.6	Shugart
	82	5 1/4	Floppy	.125	Shugart
	80	5 1/4	Floppy	.125, .25	Shugart
Microlab	80	14	Rigid	12, 82, 320	Ampex
	80	14	Rigid	12.5+12.5	Own
Multidigit	82	5	Rigid/Winchester	5	Own
	83	5	Rigid/Winchester	10, 80	Own
	84	5	Rigid/Winchester	15	Own
	83	5	Floppy	.5, .7, 1.0	Own
Prológica	82	5 1/4	Rigid/Winchester	5, 10	Own
	84	5 1/4	Rigid/Winchester	15	Own
	82	5 1/4	Floppy	.175, .35, .7	Own

Source: (Perine, 1985)

For peripherals there is a tendency to verticalization of production and a reduction of third party purchases. This is a reaction to high costs of third party purchases, and guarantees the quality of peripheral equipment for computer systems manufacturers. Hence, there will be more competition between drive producers and system manufacturers (Perine, 1985). It remains to be seen, however, if system manufacturers will be more adept at indigenously producing disk drives, or if they too will be handicapped by high prices of imported components.

The industry for larger hard disk drives, 2.5 to 5 gigabytes, relied on technological transfers. For example, Sid signed a contract with Fujitsu, Microlab signed with Ampex, Elebra and Itautec both signed with Hitachi, and Cobra with Century Data. As Table 6.19 indicates, only Multidigit and Prológica relied on technology developed locally.

The example of the disk drive industry illustrates a market segment in which it is much more difficult to achieve technological capability. The technological complexity of the product, and especially of certain components, dictates a greater reliance on foreign sourcing of inputs and technology. Governmental attempts to create supplier firms has meant that users (system manufacturers and final users) face much higher costs. Overall, the examples of the modem and disk drive sectors represent a contrast between abilities to balance local and foreign technology. Foreign technological inputs supplement the modem industry but dominate the disk drive industry. As a result the modem industry has shown greater technological capability. The 'dilemma' of developing local backward linkages as opposed to cheaper foreign imports will be examined in the following section.

The Development of Industry Linkages -- Backward Effects

Since the beginning of the market reserve policy and the subsequent import substitution of computer related equipment, the importation of key components and computers has continued to supplement national production of computers. Imports of final products have became much less important and are only permitted in special situations. Imports of components began to face stricter restrictions in 1982, which has led to a debate, as this section will show, as to the costs and benefits of developing strong local backward linkages.

The local production of components are stimulated by policies that encourage computer manufacturers to buy locally, or more precisely, policies that require local computer manufacturers to meet national indexes for their products (i.e., the use of locally produced components must reach, on average, 85% of the final product) (INFO, 1988h). Additionally, severe balance of payments problems have forced the government to limit imports, primarily by reducing government-determined allocations for imports. These policies have increased the nationalization of equipment manufactured in Brazil and have promoted the development of local parts and component manufacturers (Tigre, 1987).

Government policies and economic realities, then, have ensured strong multiplier effects through the creation of a locally supplied component sector and links between contractors and subcontractors. Furthermore, the high domestic content of final products ensures the development of indigenous manufacturing processes rather than simple assembly operations.

These import restrictions, although promoting higher amounts of local inputs for Brazilian products, have meant that local manufacturers must use local components that are more expensive than components available internationally. Local component manufacturers have small scales of production. The result: high final prices for Brazilian computers.

According to Saur (1988), if the free importation[1] of components were allowed, final prices of Brazilian computers would drop by at least 30%.

Computer manufacturers are interested in purchasing low cost but high quality components, which means they prefer the international market. Being forced to purchase inputs locally has led to many complaints. Computer manufacturers have cited the lack of reliability of national component suppliers in terms of insufficient supply, time delays, price, and quality, and the difficulty of acquiring imported components as major problems for the Brazilian computer industry (SEI, 1987). Industry pressures for free importation of components, however, have remained in conflict with government policies.

One positive side effect of the high cost of components has been the drive by computer manufacturers to increase production efficiency as a means to lower final prices of their equipment (Monteiro, 1987b). A negative side effect is that computer firms are not able to compete in export markets, limiting scale economies and thus a potential avenue to lower final prices.

Technologically, SEI policies that limit imports of components have been criticized by firms requiring state-of-the-art components for local product development. Producing computer systems requires the ability to import certain essential components, allowing firms to gain the know-how that enables them to advance technologically. SEI import policies, however, do not distinguish between firms that are simply consumers of imports producing copied products, and R&D oriented firms that are investing in advancement. Firms argue that the lack of access to the best and cheapest components worldwide severely limit their ability to export computers. SEI has recently considered adjusting domestic content requirements and removing certain key components from market reserve protection (Moad, 1989). The new Collor government will no doubt move in this direction.

The following figures present data on computer firm imports. The 1986 figures are lower for national firms due, in part, to some firms being reclassified as tele-informatics firms. Imports are generally limited to integrated circuits and advanced components (Inter-American Development Bank, 1988).

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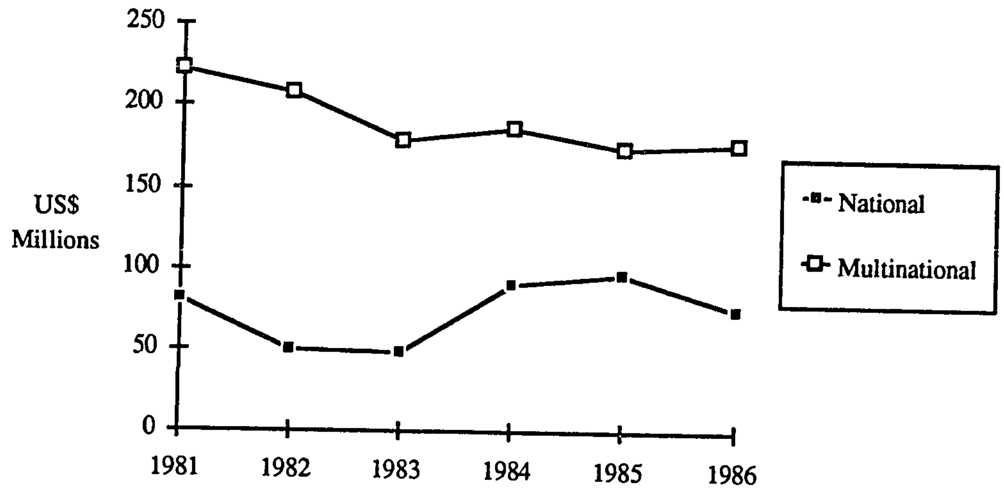
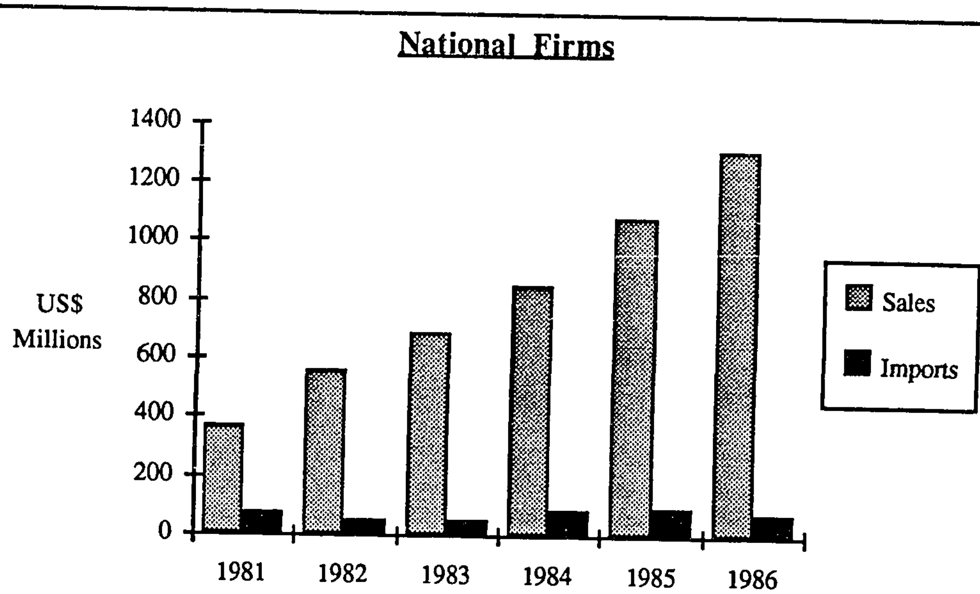
[1]Imports of components and chips face import taxes that average between 55% and 85% (Monteiro, 1987b).

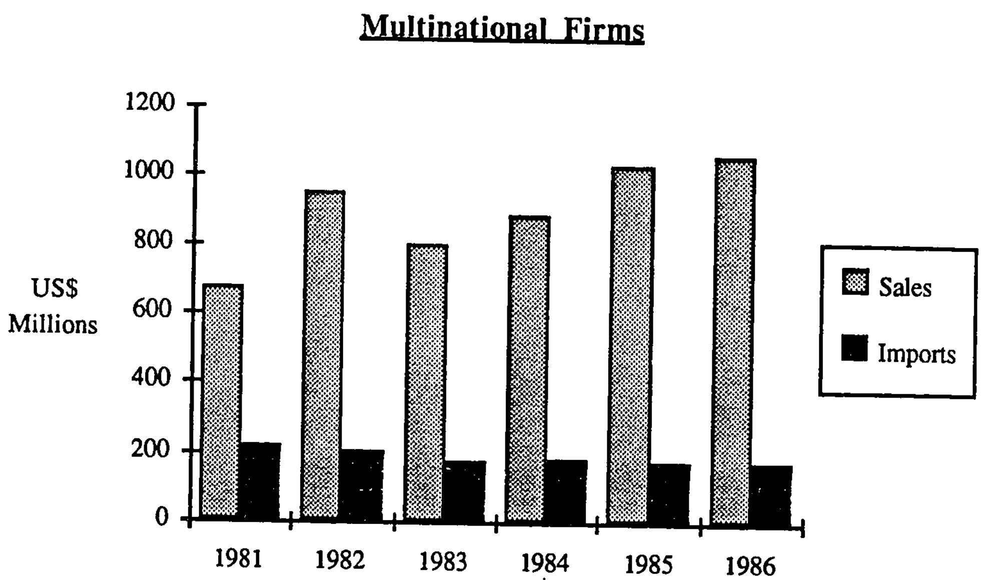


Source: SEI, 1987.
* 1986 data is preliminary. Eight national firms and one multinational firm have been reclassified to tele-informatics and are not included here.

Figure 6.8 Imports by National and Multinational Informatics Companies in Brazil.

In 1985 and 1986, SEI allotted import quotas of US$ 280 million and US$ 260 million, respectively. For MNCs, imports represented about 17% of revenues during 1985 and 1986; for national firms corresponding figures were 9% and 6%, respectively (see Figure 6.9). Unofficially, imports for national firms are probably much higher due to the use of imported contraband components and to the practice of labelling slightly modified imported components as national. Requests for imports are much higher than actual imports. SEI, for example, received import requests of US$ 1 billion in 1988 and US$ 750 million in 1987 (Dados e Idéias, 1988d).





Source: SEI, 1987.
* 1986 data is preliminary. Eight national firms and one multinational firm have been reclassified to tele-informatics and are not included here.

Figure 6.9 Imports and Sales by National and Multinational Firms in Brazil.

Computer firms point out that quotas and the limited dollars available (officially) to import components (as a result of the debt crisis) can only be circumvented by importing components illegally. According to one estimate, the illegal entrance of electronic components and contraband computers is about $300 million per year. Some firms are accused of using dollars acquired on the black market (more expensive than dollars acquired at official rates) to purchase contraband components, even realizing savings over purchasing the components locally. Planes allegedly bring in illegal components, principally chips, from the U.S. and Japan daily (Santos, 1988). There are three explanations for the high contraband figures: (1) the excessive bureaucracy that firms face when importing a specific component and a preference of foreign components; (2) the unavailability of some products in the local market; and (3) the quality of imported products, like original equipment from IBM or Apple (Ordoñez, 1988).

On the positive side, data suggest that the infant local component sector has increased its participation for both national and MNC computer producers and that backward industrial linkages have increased. For example, Monydata and CCE are large national firms supplying components: 60% of Monydata's production is concentrated in OEM transactions with Cobra, EBC, Proceda and Edisa (INFO, 1988l). Overall, the component suppliers for informatics are composed of about 300 firms. The sector has managed to export some components (e.g., fiber optics, connectors, condensers) (Fonseca, 1987).

While foreign firms clearly are more dependent on imports, they are also required to export. Between 1979 and 1982, exports from MNCs increased by 200% (Piragibe, 1985). According the the Inter-American Development Bank (1988) further nationalization requirements for TNCs would probably result in higher costs and limit export potential.

According to the president of Sid, imported components represent about 10% of the total cost of materials used by the informatics industry, roughly in accordance with official government statistics (Jornal do Brasil, 1987b). The Brazilian informatics industry has a high degree of local inputs (backward linkages) for its products: 95% of the central unit is Brazilian - the keyboard and the monitor in micro-computers, or in the case of the Cobra 500 mini-computers, 97% is Brazilian (Garza, 1985). While true for some firms and products, these figures are likely to be much lower if one considers illegal or 'hidden' component imports. Brazil remains dependent on the importation of vital components for its informatics industry, and since it exports little, the sector has a trade deficit. As Tigre (1987) notes, however, the higher levels of local inputs have the strategic advantage of promoting national capacity of key component technologies, although the small local market is insufficient to justify local production of more complex components such as magnetic disk heads or memory chips.

Imported integrated circuits represent the single most important factor in terms of the final price of computer equipment in Brazil (Fonseca, 1987). Brazil is attempting to reduce its dependence on integrated circuits through heavy government financing for firms producing integrated circuits and the efforts of universities and research institutions. This government funding has been criticized by some. According to Staub (1988), president of Gradiente, Brazil should be more concerned about the general use of informatics products by other sectors than with learning how to produce chips, which might be wasted money.

In the area of microelectronics, or chip technology, two universities in particular have attained significant technological capability. The University of São Paulo and Unicamp already possess, in laboratories, the necessary capacity to project, fabricate masks, execute physical-chemical processes, process silicon, control, test and encapsulate the chips (Bensimon, 1988). The CTI research institute in the early 80s acquired a semiconductor installation from Burroughs and shortly had the capacity to encapsulate, mount, and test integrated circuits (Piragibe, 1985a). Other universities investing in integrated circuit research include the federal universities of Rio Grande do Sul, Rio de Janeiro, Minas Gerais and Santa Catarina, and the Aeronautics Technological Institute (ITA).

The local production of digital integrated circuits was initiated in 1982 when two firms submitted production proposals to SEI: Docas de Santos and Itaú (Piragibe, 1985a). Currently, there are three firms working on microelectronics in Brazil with the goal of introducing Brazilian chips by 1990: Itaucom, Sid Microeletrônica, and Elebra Microeletrônica. These three firms have had their chip projects approved by the government and have received a series of financial incentives and by 1990 should have the capability to develop and produce general use chips, and the more sophisticated custom and semicustom chips. The government considers the domination of this technology essential for technological autonomy (Bensimon, 1988). Elebra, one of the firms, is located in Campinas. Its emphasis, as of the start of 1988, is in the production of components of the type VLSI, based on technology transferred from Intel. The other two companies working on integrated circuits are 'Itaucom' and 'Sid'. In 1986 Sid Microeletronica produced 18 million circuits and Itaucom 10 million. Elebra is in third place (Lachtermacher, 1987).

Even with these firm efforts, approximately 75% of the integrated circuits used in Brazil are imported. Of these imported circuits, only the resin used for encapsulation is fabricated in Brazil (Lachtermacher, 1987). Sid is the only firm in Latin America to master the whole process of circuit production from start to finish. Sid achieved this capability through R&D investments and by transferring state-of-the-art technology from Philips of Holland in 1988 to produce bipolar integrated circuits (O Globo, 1988b). The technological transfer is an attribute to Sid's technological capability and bargaining power.

For an international comparison, Tigre (1987a) notes that a major difference between production of computers in Korea and Brazil is that the later incorporates a greater percentage of its parts and components locally because the reserve permits a more vertically integrated production, although at higher costs. Another difference is that Korean computer producers also produce consumer electronics. In Brazil consumer electronics producers, as of televisions, are foreign firms principally located in the Manaus Free Trade Zone, limiting opportunities for technological transfers and economies of scale and lower prices. Furthermore, the Manaus Free Trade Zone, in reality, acts as a pole for TNCs to import consumer electronics into the Brazilian market and not as a generator of exports:

> Pressed by technological competition and the imperatives of the market, most [Brazilian] enterprises have finished up as mixed enterprises and, more frequently still, have fallen into foreign hands. Between 1965 and 1975, the share of Brazilian national enterprises in the domestic electrical appliance market fell from 70% to 20%. During these ten years, over 20 nationally owned enterprises passed into foreign control or closed down. In 1975, seven of the eleven firms controlling the color television market belonged to transnational firms. Two of these, Philco and Philips, represented 45% of the market. 80% of the electronic components used in this industry were imported (Mattelart and Schmucler, 1985: 17).

The Free Trade Zone[1] in Manaus has hurt Brazilian technological capabilities. The opening of the zone led to the eradication of Brazil's television firms, and now only foreign brands are consumed (Barbosa, 1988). The industrial structure in Manaus has very little to do with the economy of the region (Mattelart and Schmucler, 1985). Manaus lacks the necessary human resources to support technological development in the region and to operate a sophisticated industry (Tigre, 1987a). And as Tigre (1988) concludes:

> The contrasting strategies pursued by computer and consumer electronics firms clearly show that when the free flow of technology is permitted, either by direct foreign

[1]Free trade zones generally offer firms the following advantages: free importation of raw materials and semifinished products; export without restriction; exemption from corporate income taxes, import duties, import quotas, property taxes, and excise taxes (Mattelart and Schmucler, 1985).

investment or by passive reliance on continuous licensing, the local capability to create know-how may not develop at all (p. 13).

The example of Manaus illustrates that an open technological strategy severely limits technological development. Equally important is that Manaus has a limited technological environment, insufficient for advanced industrial development.

By comparison, a free market approach in the computer sector would likely limit the development of local backward linkages, but allow final prices of Brazilian computers to be much lower, and more competitive in international markets. The current policy stimulates backward linkages, yet local computer users pay higher prices for final products and local manufacturers encounter problems when purchasing local components of quality, delays, etc. Recent policy statements from SEI indicate a possible movement to compromise between these two extremes. Mature computer firms, located as they are in advanced technological environments, given more freedom on input sourcing, would have better opportunities to carefully search for the best technological solutions.

The Development of Industry Linkages -- Forward Effects

The development of forward industrial linkages has been driven by firms desiring to automate production and services. The financial automation market has been the most important, and prospects for the industrial sector have been increasing. Needless to say, the high inflation and interest rates that currently plague Brazil have dampered firm investment in automation. Regardless, manufacturers of automation equipment have prospered and, more importantly, much of the equipment is of local design; this is due to the higher tendency for custom-made equipment to fit the specialized demand of each client (Tigre, 1988).

One main growth market for the computer industry has been banking automation. In 1988 alone, the automated banking market was over $53 million dollars nationally. Growth rates in 1987 averaged between 30% and 35%, and in 1988 between 25% to 30% per year (Sproesser, 1989). The emphasis placed on banking automation is not surprising as several of the largest informatics firms have banks as their major stockholder.

Interesting and unique Brazilian solutions in terms of software and hardware for the banking sector have been driven by a combination of high inflation rates, rapidly changing economic indicators, and short-term government economic policies to combat inflation, bank's attempts to live with high numbers of short-term transactions[1], and the fact that banks operate on a nationwide basis with branches dispersed over large areas. Domestically produced software runs all aspects of banking from financing, investments, savings, deposits, all of which must have rates adjusted to inflation on a daily basis. Large banks use their own technicians for software development, while smaller banks purchase programs from software houses.

In addition to firms that sell computers and peripherals to banks, several have obtained recognition for pioneering banking automation equipment. The software house Cetil leads the market in banking automation software. They have developed software for all the principal banking functions to run on equipment ranging in size from micros to mainframes (Sproesser, 1989). Sid has about 35% of its business in automating banks, including the Bank of Brazil, Caixa Econômica Federal, and Bradesco. For Edisa, banking automation represents about 25 to 30 percent of their revenue. Procomp, from São Paulo, is a new and rapidly growing firm that was formed in 1985 by three engineers from Sid. Visualizing a small niche market, they aimed at automating small agencies located in the interior of the country. Digirede has developed banking automation for small, medium and large bank branches. It has also developed a 24 hour cash machine. Itautec produces a full range of products for automation that are fully interconnected.

The bank Bradesco is one of the largest users of computers in Latin America. In 1989 alone, Bradesco announced it would invest about US$ 150 million for the automation of its branches (Bianchi, 1989). In order to link geographically dispersed branches, Bradesco plans to transmit via satellite. Itaú also plans to use the Brazilian satellite -- Brasilsat for data transmission (Dados e Idéias, 1988c).

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[1]The bank Bradesco estimates that it handles 6 million checking transactions per day (Moad, 1988). Inflation for 1987 was 365%, for 1988 it increased to 934%,and in 1989 inflation reached 1,765% (Kamm, 1990).

Table 6.18 Banking Automation in Brazil (the Eight Largest Banks by Volume of Deposits).

Bank	Number of Agencies	Agencies Automated	Supplier of Equipment
Banco do Brasil	4665	290	Itautec (the group Itaú) Sid (the group Sharp) Procomp
Bradesco	1721	1539	Digilab (the group Bradesco) Sid (the group Sharp)
Itaú	1680	920	Itautec (the group Itaú)
Banespa	591	350	Sid (the group Sharp) Digirede Procomp
Citibank	20	20	Sid (the group Sharp) Itautec (the group Itaú)
Unibanco	606	270	Digirede
Real	545	35	Procomp Sid (the group Sharp)
Bamerindus	863	580	Digirede Procomp

Source: Veja, 1989a.

In general, banks are automating offices, computerizing administrative units, interconnecting agencies dispersed throughout the country (some by satellite), decentralizing data processing centers (based on mainframes)[1], and installing automatic 24 hour banking machines. Firms that in the past have developed equipment for banking automation have since entered industrial automation markets.

Industrial automation is a relatively recent phenomenon. The market for industrial automation grew from $125 million in 1984, to about $253 million in 1986, for an average annual growth rate of 42% (SEI, 1987; Beck, 1987a). The growth rate for the sector from 1986 to 1987 was 31%, with specific segments like robots reaching 117%, and programmable logic controllers 48.7% (Beck, 1987a). From 1987 to 1988 the industrial automation sector grew 51% (Grego, 1989). These high growth rates are likely to continue for some time as the market is still in the beginning stages. Most firms are only now investigating automation possibilities. The growth of this market segment reflects well on the capability of firms to use informatics technologies for industrial automation equipment.

[1]Mainframes are widely used in banks as central or regional data processing center, for example the bank of Brazil has 17 mainframes, and Banespa has 15 mainframes.

Market for Industrial Automation by State

State	Percent of Total	
São Paulo (Capital)	1984	1985
São Paulo (Interior)	48.3	32.6
Minas Gerais	24.4	21.3
Rio de Janeiro	3.2	13.1
Rio Grande do Sul	6.8	10.4
Paraná	5.6	7.4
Pernanbuco	2.1	3.7
Bahia	3.0	3.7
Santa Catarina	3.5	2.5
Federal District	0.9	0.8
Pará	0.4	0.4
Ceará	0.1	0.3
Other States	0.4	*
* Value less than 0.1%	1.3	3.8

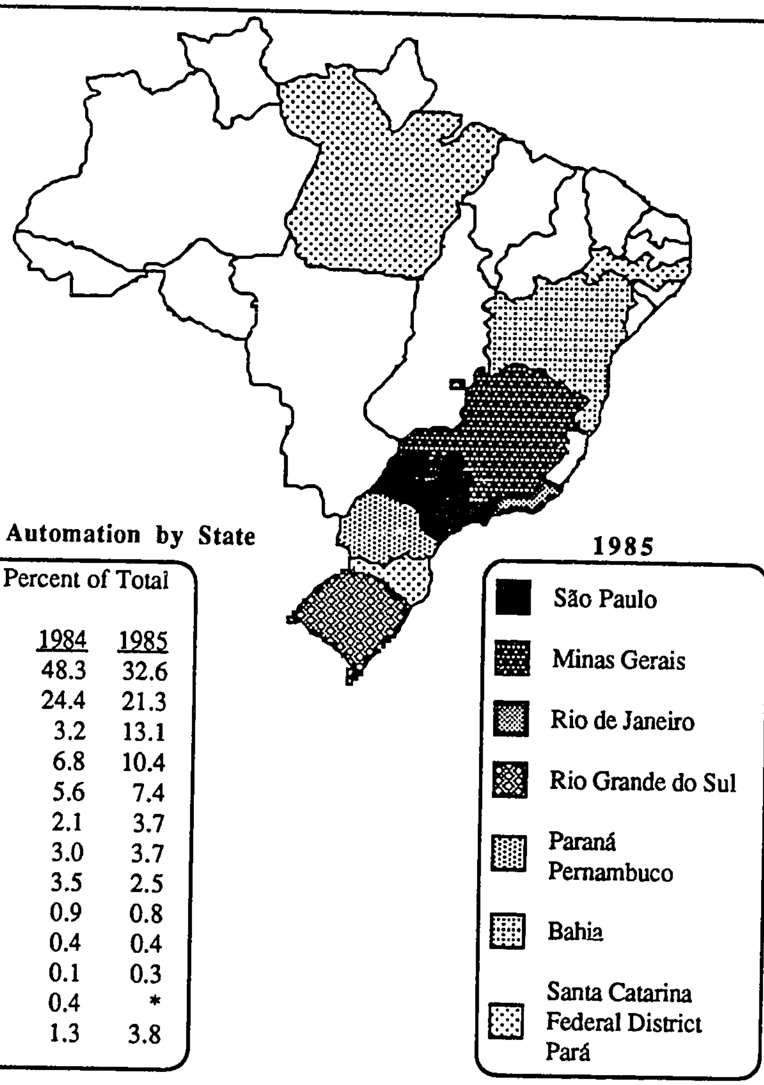

Figure 6.10 Industrial Automation Market by State.

Expectedly, São Paulo leads the market for industrial automation. In 1984, the state of São Paulo alone accounted for about 73% of the market, however; by the next year other states, in particular Minas Gerais and Rio de Janeiro, increased their market shares as São Paulo's fell to 53.9%. The 'apparent' anomaly of Pará is in part explained due to the free economic zone located along the Amazon river. A feature of industrial automation is the diffusion of new production processes over the space economy, an indication that important forward linkages are taking place.

Industrial firms are increasingly relying on automation systems such as CAD (Computer Assisted Design) and CIM (Computer Integrated Manufacturing) to ensure quality control and efficiency. The market growth of CAD systems is significant. These systems are primarily based on microcomputers (84% of total), due to lower equipment costs for users, although sales of systems based on larger computers have also increased rapidly. The market for CAD systems based on micros was 250 units sold in 1986, 350[1] in 1987, and in 1988, a total of 780 units worth $29.5 million. By 1989, the market was estimated to reach US$ 44.5 million (Grego, 1989). It should be emphasized that as recently as 1984, Kaplinsky (1984) wrote that developing countries had only a very limited capability to produce CAD-system software, noting that there was only one example of a CAD-system produced by a developing country.

The market potential, however, has only begun to be tapped. Industrial firms participating in international markets tend to invest more in automation, although not so much for reducing labor inputs as for increasing productivity, quality control, and greater flexibility of and control over the production process (Tauile, 1988). Some TNCs, deciding that computer policies will not change, have started to invest in industrial automation. For example, General Motors do Brasil is developing a new car manufactured with a computer designed by Edisa (O Globo, 1987b).

Firms producing complete CAD workstations include Itautec, Comicro, Sysgraph, Villares, Scopus and Numericon. Villares is a major force in the industrial automation with CAD/CAM systems, process control, programmable controllers and robotics. Sysgraph and Villares offer systems for larger computers, and due to market forces, are offering micro solutions. Firms producing peripherals include, for plotters: Digicon, Smar, and Logical, and for digitized tables: Digicon and Digigraf. Digitized tables produced in Brazil have high prices, but technology at international levels. Imported software runs most of these systems (e.g. Autocad), however Cadtec from Itautec is the most successful national program (Luca, 1988c). Universities with strong research programs in CAD/CAM include the Federal University of Santa Catarina, PUC/RJ, University of São Paulo, and Unicamp (Lucena, 1988).

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[1]The Brazilian Society for Numerical Control supply data indicating 540 systems were sold in 1987 (Tauile, 1988).

Commercial automation is the most recent growth market, the impetus coming from large commercial chains with a need to automate and link several branches. In 1987, major chain stores such as Mesbla, Lojas Americanas, C&A, Sears, the Portuguese firm Hipermercado Continente, and Unipark, signed large contracts with informatics firms.

Digirede, initially active only in banking automation, diversified in 1985 to the commercial market (as well as to the production of superminis, supermicros and disks). In 1987, Digirede signed large contracts with C&A (for a value of US$ 6.5 million) to automate 45 stores, and with Sears (for a value of US$ 1.5 million) for 12 stores. Sid has about 10% of its revenue from the commercial sector. Sid signed contracts with Mesbla (for a value of US$ 4 million) to automate a total of 46 stores and Unipark, a parking lot chain to interconnect 143 lots (for a value of US$ 1.1 million), and with Lojas Americanas to automate one store, with the possibility of more in the future. Labo and Itautec also signed contracts, with Itautec being the first firm to export in the area of commercial automation. They signed a contract with Hipermercado Continente for a value of US$ 300,000, with a strong possibility of future contracts (Arreaes, 1987). Itautec introduced a scanner for supermarkets that reads bar code labels on products.

The automation of Brazilian firms, although in its infant stage, is an indication that indigenous computer technologies have begun to diffuse to other industrial sectors. The ability of computer firms to spread their know-how and products to other economic sectors is essential for national productivity and economic growth. And the spread of knowledge about new products and new methods of production ensure the diffusion of technological capability. This has been especially important for the banking sector where local firms have used their technological knowledge to design products specifically for Brazilian banking needs.

Defense Markets: Considering the Navy's role in the initial development of the informatics industry one would expect the military to comprise a significant market for informatics firms. The Brazilian arms industry, the world's fifth largest exporter, however, only uses about three to five percent of its hardware from national sources; more important for the military is national software which supplies about 20% of the military's needs (Beck and Lapa, 1987). There are some examples of the use of local suppliers, in 1989, the Navy received a computerized 'combat operations center' system for its frigates from the Brazilian firm SFB Informática S.A. with technology licensed from the English firm Ferranti (O Globo, 1989b).

Military officials argue that the technological know-how for their 'products' is Brazilian and that the potential for Brazilian computer firms to increase their participation in the military market over the next ten years is likely to be about 50%. Even so, in 1986, the Brazilian military imported over 14 million dollars worth of information equipment and components, an increase of 50% since 1985 when about 10 million dollars worth of equipment was imported (Beck and Lapa, 1987).

Firms that do have military projects approved by SEI include: ABC Teleinformática - flight simulators, Datanav Engenharia - instrument panels and radar, Ensec Engenharia - installation of security systems, Prólogo - cryptographs, electronic approximation detonators, and EMBRAER - aircraft (Beck and Lapa, 1987).

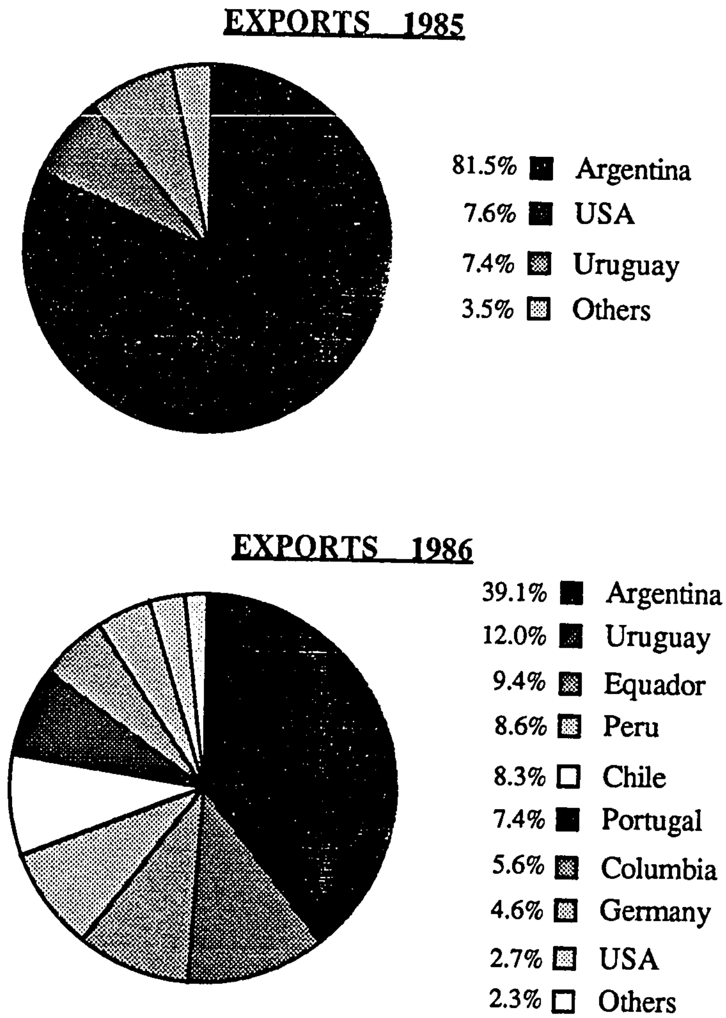
The insignificance of the military in Brazil is contrasted with that of the U.S., where military procurement was an important factor in the development of high technologies, and defense R&D accounts for a major share of government funding of industrial research.

Export Markets: Many firms realize that they will eventually need to export to survive. To export most firms need a greater ability to import components and significant increases in production efficiency (Magalhães and Lucena, 1987). While export earnings in general are relatively small, there are some important exceptions.

From 1980 to 1984 Brazil cut its balance of payment deficit in informatics equipment by 50%. Over 30% of its data processing related equipment exports go to other Latin American countries (Domínguez, 1989). Informatics exports are dominated by MNCs based in Brazil, accounting for 93% of all informatics exports.

> Computer and related exports have been growing rapidly in recent years - 100 percent in 1985 - but they are still far below exports by foreign companies operating in Brazil. In 1985, while foreign firms exported equipment valued at $193 million (mainly mainframes, parts, and peripherals) from Brazil, national firms exported just $11 million worth. IBM accounted for 80 percent of total computer exports. That company's recent selection of Brazil as the site for an international procurement office should increase its exports sharply, as an increasing number of parts and components for IBM equipment world-wide will be bought in Brazil.
>
> Brazilian-controlled firms export primarily to Latin America. Three Brazilian firms have entered the Argentine market for banking automation after winning contracts in competition with major international companies. Digirede established a joint venture with an Argentine firm, while Sid and Itautec are selling their technology. Racimec has also signed contracts totaling $20 million to export unique lottery-processing technology to several countries (Botelho, 1987: 42).

Although exports are growing, data from SEI indicate they only amounted to US$ 5.4 million in 1986.



Source: SEI, 1987.
* 1986 data is preliminary.

Figure 6.11 Exports by Brazilian Informatics Companies.

Microcomputers accounted for 75.3% of total exports by national firms, with printers and video terminals represented 8.6% and 7.7%, respectively. In 1985, Argentina was the dominant market, but subsequent Argentinean import restrictions on computer products led to a drop to 39.1% in 1986. However, other markets in Latin America, and Portugal and Germany began to import products made in Brazil. The Latin American and African market are two regions where Brazilian firms compete more competitively (Machado, 1985).

There are several promising recent examples of Brazilian firms exporting computer equipment. Itautec is implanting commercial automation system in Portugal. Itautec competed against large firms such as IBM, MCR, Nixdorf, and Sweda to automate the largest 'hipermarcado' from Portugal (Jornal do Brasil, 1987c). Elebra, focussing in the peripheral segment of the industry, also has competitive products internationally. For example, Elebra's printer 'Diana' was commercialized in Argentina in 1987 (Rímoli, 1987a).

Sid plans to enter the Soviet market through the exportation of banking automation products after signing a contract with a conglomerate of Soviet banks. Equipment will begin to be exported during the first half of 1990 to banks located in Moscow (UFRJ, 1989c). The Soviet Union has shown interest in purchasing Brazilian PCs (INFO, 1987f). Unfortunately for Brazil, many informatics products incorporate chips imported from the U.S., and current U.S. policy prohibits the exportation of products that incorporate these chips to Soviet bloc countries. These restrictions have added fire to Brazil's drive to dominate custom and semicustom chip production (Bensimon, 1988).

Unitron, the firm that cloned the Macintosh[1] but was unable to license their project in Brazil due to U.S. pressure now has 30 foreign firms interested in licensing their technology (INFO, 1988i).

Chinese officials have made several visits to Brazil to evaluate the reserva and made initial contacts for technology and equipment with Elebra, ABE, Sharp and Gradiente (INFO, 1987g.).

The growing number of recent examples of exports suggest that as the computer industry matures, and some firms acquire the technological capability to develop unique solutions particular to the Brazilian market, international markets have become more approachable. The experience of the aeronautics industry has relevance for the informatics sector. The airplane manufacturer Embraer, according to Gomes (1985) is argued to be

[1]Unitron's Macintosh was the first Mac clone in the world. Unitron's Mac project, according to the firm, was based on reverse engineering. Apple, however, alleged that the operating system recorded in the computers ROM (Read Only Memory) was an exact copy. SEI, initially supporting the project, decided not to license the Brazilian Mac after threats of trade retaliation by the US against Brazilian exports.

successful, especially on the international market, because: 1) much of the firm's technology is developed internally; 2) the internal market was of sufficient size to eventually permit exports; 3) the firm produced products required by Brazil; 4) product differentiation led to the firm entering unique products on the international market.

The failure to vigorously enter international markets limits production scales to the national level, a market that is rapidly growing but alone not sufficient to allow producers to significantly reduce prices of final products and enjoy higher profits to be reinvested for product development.

Prices, Contraband, and Industry Productivity

One of the main complaints of Brazilian users, and of scholars analyzing the 'success' of the computer industry, is the high final price of Brazilian equipment relative to prices for similar equipment in the U.S.. Direct comparison with prices in the U.S. is somewhat unfair as most other industrialized countries, including Japan, cannot equal final prices of U.S. equipment. Others note that multinationals operating in Brazil also charge high prices, suggesting that even without the market reserve policies Brazilian users would pay high prices. José Ricardo Tauile (1988) explains that numerically controlled machine tools are not covered by import substitution and are produced in Brazil by foreign oligopolies. The products are not developed in Brazil and are sold at three times international prices by local subsidiaries which operate with cheap labor.

As the industry is still in its infant stage, higher prices are to be expected. The fact that users must absorb the higher costs for computerization, threatening or slowing the growth of forward linkages, remains problematic. The primary reasons for high final prices are the relatively small scales of production and higher costs for components.

Cline's (1987) analysis revealed that prices of Brazilian computers and peripherals range from one to three times more expensive than in the U.S., depending on the sophistication of the product. An evaluation by INFO (1988e) indicates that hard disks, or winchesters, and IBM PC ATs, are expensive but of good quality (see Table 6.19). Modems made in Brazil are of good quality with reasonable prices. Printers are expensive and the technology is not well developed. Scanners for PCs, laser printers[1], and 3.5 disk drives should be on the market by 1989, suggesting that peripherals have a much longer technological time gap than computers.

[1]The first Brazilian laser printer will be introduced by Elebra.

Table 6.19 Quality and Price of Brazilian Personal Computers and Peripherals.

Product	Level of Technology			Price		
	Good	Medium	Poor	High	Medium	Low
Apple		xxxxx			xxxxx	
PC	xxxxx				xxxxx	
Disks	xxxxx			xxxxx		
Tapes		xxxxx		xxxxx	xxxxx	
Modems	xxxxx				xxxxx	
Printers			xxxxx	xxxxx		

Source: INFO, 1988e.

According to Sehn (1987), high prices are due to costs and not to firms enriching themselves. Mammana (1988), president of Abicomp, agrees that the reason for high final prices of Brazilian equipment is the cost of electronic supplies, which account for about two-thirds of the final price. Many of the electronic suppliers are multinational firms that, he alleges, charge prices higher than international levels. The network of Brazilian component suppliers, he adds, is still in the development stage.

Guinle, (1988), president of Elebra, finds high prices due to the lack of scale economies, high import tax on imported components (double the FOB price), the fact that the industry is still in the learning stage, and the high cost of capital equipment. What are the ramifications of high prices?

The user pays the price for Brazilian informatics development. Carlos Ingouville, director of a consulting firm for informatics systems -- Arthur Andersen -- argues that the elevated costs of national equipment inhibit a broader use of computers in other industries. He contends that Brazilian firms invest less in computerization than American firms and as a direct result of the elevated costs of equipment, hence, Brazilian firms acquire less equipment than they really need. He offers the example that while banks in the U.S. reinvest 8% or their receipts in informatics, that figure in Brazil is 5%. Furthermore, U.S. industries in general reinvest 2% of revenue in informatics, while Brazilian firms rarely reach 1% of revenue, and this 1% does not buy the same quantity of equipment as in the U.S. (Frucht, 1987). Other economic sectors, like textiles, have been threatened by threats from the U.S. to restrict the markets for traditional Brazilian exports because of conflicts over the informatics policy. Moreover, textile firms, especially small and medium sized firms, complain that they do not have access to technology in light of the high prices of computer equipment.

In the long-run, however, prices are coming down, even to the point of competing with contraband products (Dias and Arruda, 1989). For example, several national firms selling IBM compatible computers and peripheral equipment such as printers and disk drives have been able to reduce production costs during the last three years to match the reduction of costs in the U.S. and in addition to the elevated cost of the dollar on the Brazilian black market, final prices have become more attractive than similar contraband products. Tigre (1986) found that the price of the Brazilian compatible Apple II, between 1982 and 1984, fell 250% and in 1984 was only 8% more expensive than in the U.S.. A study by Abicomp revealed that since prices fell by 50% from 1983 to 1988 (Mesquita, 1989).

The government has tried to be responsive to complaints by manufacturers. In 1987, the government decided to allow firms to import components using dollars purchased on the black market, permitting firms greater access to necessary components (Jornal do Brasil, 1987a).

Firms have also responded to user complaints of high prices and increased competitiveness. With the initial phase of the reserva, that being the implantation of the industry, complete, a more competitive phase is now underway and firms are responding by improving production processes and increasing quality control.

Firms are investing in new production processes to reduce costs, improve product quality control, reduce the production time, and increase the ability to modify products. For example, Digilab, following a 'total quality' concept, increased productivity by a factor of two and one half; Cobra is now fabricating its PCs utilizing the 'just-in-time' concept and has significantly reduced production costs; Sid has adopted an automated production layout modelled after firms located in Silicon Valley; Conpart recently invested and radically transformed its production process for fabrication and quality control. In addition, many ideas have been borrowed from the Japanese, such as giving workers more responsibility to use machines to test the quality of their work (Magalhães and Lucena, 1987; INFO, 1989c).

High prices have been justifiably identified as a serious negative outcome of Brazilian informatics policy. Small scales of production, high cost of components, and the infant stage of the industry have been identified as contributing factors for high final prices of Brazilian equipment. Evidence suggest, however, that as the industry evolves prices have declined appreciably for the low end of the market segment. Factors contributing to price reductions include firm experience and improved manufacturing techniques, a competitive environment, and greater access to imported components.

The Software Sector

The international importance of software vis à vis hardware has led to an enormous demand for highly skilled programmers and software engineers, creating a shortage of skilled labor worldwide. Internationally, while the demand for software is increasing at an annual rate of 12%, the number of software professionals is growing at only 4%, creating a shortage of software developers (Schware, 1987). The single most important factor in the design, application, and marketing of software products is people, and the training and experience they represent. Software development is a highly labor-intensive process and for this very reason may find competitive advantages in developing countries, especially considering that annual salaries for software specialists in Latin America range from $18,000 to $25,000 against $60,000 to $140,000 in the U.S. (Hurtado, 1987; Junne, 1987; Schware, 1987).

Several developing countries are interested in developing a software industry, with hopes of applying abundant human resources to this high growth industry. Other advantages for software development in the developing countries is that locally made programs are less expensive, save foreign exchange, and may work better than imported ones because local programmers are in closer contact with the environment in which they will be used (Hurtado, 1987).

The existence of a large and sophisticated domestic software market is very important for building an indigenous software industry. High marketing costs combined with little marketing experience will make it difficult for most developing countries to enter software development, especially for export software. The lack of capital will likely be a problem, as well as the required flexibility to maneuver and compete in an industry characterized by rapid technological change, short product cycles, and dramatic market shifts (Schware, 1987).

In Brazil, there are basically three types of software and service firms: state-owned firms that primarily support the government; foreign affiliates; and private firms. Many large industrial and state firms have internal software groups servicing their own data-processing departments (SEI, 1983). Of the 12,000 software programs registered by SEI, 60% are foreign and 40% are national. Of the foreign registered software programs, 50% are programs registered by firms located in Brazil like Digital, IBM, and Unisys and 10%

are foreign programs distributed through a national firm (Datanews, 1989). These large MNCs are also dominant in the international market for software (see Table 6.20). The software market for mainframes is dominated by IBM with about 70% of that market, the remainder of the market divided by other MNCs in Brazil and local distributors of foreign software (Jornal do Brasil, 1986a). There are approximately 40 national distributors of software from foreign sources and over 500 national software firms (Frucht and Sproesser, 1988).

Table 6.20 The Top 15 International Software Companies and Global Sales.

Rank	Company	1988 US$ Million	Market Share
1	IBM	7,927.0	38.5
2	NEC	890.0	4.3
3	Unisys	875.0	4.2
4	Digital	691.1	3.9
5	Computer Associates	497.6	3.4
6	Fujitsu	515.9	3.3
7	Siemens	550.8	3.0
8	Microsoft	397.3	3.0
9	Hitachi	448.8	2.9
10	Groupe Bull	546.1	2.8
11	Hewlett-Packard	415.0	2.4
12	Lotus	380.6	2.1
13	Oracle	198.0	2.1
14	Nixdorf	405.8	2.0
15	Olivetti	347.9	2.0

Source: Braude, 1989.

Data on the Brazilian software industry are scarce. Assespro (Associação Nacional das Empresas de Serviços de Informática) recently polled its members and came up with these data: in 1987 domestic software firms generated about 400 million dollars worth of income and, even with pirating and contraband of software, the total Brazilian software market was estimated in 1987 to be worth at least $1.5 billion (INFO, 1987c). Real growth in the total software market was 50% in 1987 (Brazil Export, 1988).

Table 6.21 Registered Software in Brazil by Origin.

	1983		1984		1985		1986	
(A) Nationally developed	441	(9.9%)	1,627	(19.0%)	2,171	(21.6%)	2,926	(24.9%)
(B) Developed abroad, commercialized by Brazilian firms	56	(1.4%)	60	(.08%)	60	(.05%)	63	(.05%)
(C) Developed abroad, commercialized by branch or subsidiary	3,949	(88.8%)	6,874	(80.2%)	7,791	(77.7%)	8,740	(74.5%)

Source: SEI, Adapted from Correa, 1989.

According to SEI, software registered and developed by national firms increased more than thirty per cent annually between 1984 and 1986 (see Table 6.21). National software firms have entered several niche markets in specific areas that are not solved by imported programs.

Brazilian software exists for all computer sizes, from micros to mainframes, with diverse applications, from spread sheets to communication software to desktop publishing software, etc.. According to Lucena (1988), local software houses have the skill to develop and market generic applications, and especially business applications; however, programs requiring more sophisticated technology and large investments (like CASE[1] or artificial intelligence) remain a grey area. Even so, there are fifteen universities and research institutes, a handful of software houses (including Biosapiens and Tecsis), and one large informatics firm (Sid) researching artificial intelligence (Jornal do Brasil, 1986c; Lucena, 1988). In general, markets that require programs to cater to the Brazilian specific environment will be much more accessible to domestic producers.

With the growing market for supermicros and superminis, Brazilian firms attempted to license Unix from AT&T as the operating system for these machines in the early 80s, without success. Cobra has accumulated a significant amount of know-how in developing software operating systems, including: SOM and SOD -- both proprietary and exclusive operating systems of Cobra, MUMPS, SPM, and SBC. Its most important accomplishment to date is the Unix compatible SOX, which resolves the problem of many different operating systems used by Cobra machines. By 1988, Cobra had invested 20 million dollars over the previous four years to develop SOX, with a team of 80 professionals from Cobra and help from research institutes (Marques, 1988). For example, the CTI joined forces with Cobra to develop SOX for non-Cobra machines. The

[1]Computer-assisted software engineering (CASE), is used to increase productivity and convenience, and is designed as an infrastructure for program creation.

release of SOX is comparable to the launching, in 1981, of the 500 line of computers that were completely developed and fabricated locally based on experience accumulated by the G-10 project.

The SOX operating system (complying with international standards - Posix, X-Open) comes with boards to make it compatible with other computers in the Brazilian market, including the PCs of its own and other firms like Itautec, Scopus, Microtec, Labo, Monydata, and Basic. Cobra expects to license SOX to other firms; those already licensing the technology are Labo, Monydata, and Itautec -- both computer firms, EBC, ESCA and TASK, which are specialized systems suppliers, and INPE (National Institute for Aerospace Research (Marques, 1988; INFO, 1989e).

Table 6.22 Unix-like Systems in Brazil, 1986.

System	Supplier	Machine	Technology
EDIX	EDISA	ED-680/690	SYSTEM III
ULTRIX	ELEBRA	MX-850	DIGITAL
DIGIX	DIGIREDE	8000	SYSTEM III
SODIX/SOX	COBRA	C-500, LINE-X	COBRA
DG-UX	COBRA	1200/1400	DATA GENERAL
MV/US	COBRA	1200/1400	DATA GENERAL (SOBAOS/VS)
UNIX	SID	3B15	AT&T
ANALIX	SOFTEC	EGO	SYSTEM III

Source: Taurion, 1986.

Brazilian users of supermicros and minicomputers have required a Unix-like system because of its multiprocessing capability. Many producers of supermicros have also been investing in their own projects, and as in the U.S. there is no one national standard (see Table 6.22). Cobra aims to become the national Unix-like standard; to guarantee the licensing SOX to all interested national firms, and even to market the software to industrialized and socialist countries[1]. AT&T, the owner of Unix, did not license Unix to Brazilian firms until 1988, first to Sid in the form of single copy (Luca, 1988a; 1988b). Four domestic firms have been attempting to license Unix from AT&T: Sid, Sisco, Medidata, and Edisa. Sid must pay at least $77,000 dollars to license the software,

[1]As of 1988, interested countries included USSR, Cuba, India, US, Canada, Japan, Korea, and Portugal. On the international market, SOX will cost 30% less than UNIX from AT&T, due to the difference in the cost of labor (six times less than in the US) (O Globo, 1988a). Furthermore, royalties are not charged.

furthermore, if approved by SEI, royalties must be paid on future subsequent sales. According to Cobra, with 13,800 computer systems that will use Unix systems in Brazil by 1990, royalties could reach $10 million dollars by 1990 (Luca, 1988b). To commercialize AT&T's Unix would require enrollment by SEI, however, SEI decided to veto enrollment in 1989 (INFO, 1989d).

Operating systems for PCs, as mentioned in the section on the software law, have encountered political conflicts as to the whether the market should be limited to Brazilian designs. The advantages of a national standard operating system is that there are not remissions abroad and it assures technological independence in this fundamental sector (Mahlmeister, 1987a). Sisne is the dominant Brazilian developed operating system for microcomputers, compatible with Microsoft's MS-DOS, although the latter permits the use of windows and powerful graphics. Developed by Scopus, it offers an advantage to new users in that all messages and some commands are in Portuguese (INFO, 1989b). With the enrollment of MS-DOS by SEI, however, future market penetration of Sisne is limited.

The market for basic and generic software, such as word processors, data bases, and spreadsheets, is dominated by imported software with only about 10% of Brazilian software firms involved. The major reason for low number of firms in basic and generic software is insufficient capital for firms to engage in costly R&D. Important exceptions exist.

In 1987, there are about 25 strong Brazilian software firms, including some exporters (Frucht and Sproesser, 1988). Examples of high quality and widely used software programs, include the communication software 'Z' by Humana Informática; 'Carta Certa' and 'PANGLOSS,' word processing programs, by Convergente and Don Quisoft respectively; 'Dialog,' a data base program by the firm Soft.

Several software programs are now exported, including: 'Global', by Villares Automação e Informática, which is exported to Canada, U.S., Japan, and Latin countries (Paula, 1988d); 'X2' (data compactor) by Pars, which is exported to Italy, Portugal, Spain, and France; 'Pater' (artificial intelligence) by Tecsis, which is exported to Portugal; Samba and 'ABC Plus' by PC Software, exported to Portugal; 'Autoprogram' by Amerinvest Informática, which is exported to Portugal, Spain, and Argentina (INFO, 1988g).

With the approval of the 1988 software law, however, foreign firms are looking at the Brazilian market more seriously. Most major American software firms already have local distributors, like Compucenter (the largest distributor of imported software in Brazil). And most large international software firms have found, or are in the process of finding commercial partners in Brazil. Those with branches in Brazil already include Lotus, Microsoft[1], Ashton-Tate, Oracle Corporation, and Apple. As a first priority, Lotus, and most other foreign software firms now located in Brazil, intend to take Brazilian firms selling cloned software to court. Lotus contends that well over half of their software program 1-2-3 in Brazil is pirated (Mattos, 1989).

Lotus do Brasil, set up in 1989, plans to provide support for training centers, consulting services, and the retailing of their software. In the area of development, Lotus plans to find local partners that complement their software with ADD-INs. The local partners will receive technological support only; Lotus does not plan to directly invest in local development. In addition, Lotus is planning to commercialize their other software programs, including: Symphony, Agenda, and Freelance (Mattos, 1989).

How do local software firms compete with firms like Lotus and Microsoft? What follows is a brief panorama of the spreadsheet and word processing markets.

According to direct sales data supplied by distributors, Lotus 1-2-3 spreadsheet software dominates in Brazil with 62% of the market, followed by a locally registered software program (with 17% of the market): called Samba -- from PC Software (Frucht, 1989). With the increased market pressure due to the opening of the market to foreign suppliers, one would expect Samba sales to be on the decline, but during the last six months of 1988, sales actually increased by a dramatic 500%. Supercalc sales only represent one year in the market. Quattro and MS Excel were only recently introduced in the market which accounts for their low sales (Frucht, 1989).

Table 6.23 Direct Sales and Prices of Spreadsheet Software in Brazil.

Firm	Software	Sales (% of market)	Price (OTNs)	Year Introduced
Lotus	1-2-3	18000 (62%)	152	1985
PC Software	Samba	5000 (17%)	85	1984
Computer Associates	Supercalc	3500 (12%)	109	1987/8
Microsoft	Multiplan	1500 (5%)	38	1983
Microsoft	Excel	500 (2%)	145	1988/9
Borland	Quattro	500 (2%)	72	1988/9

Source: Compiled from data in Frucht, 1989.

[1]For Microsoft, Brazil represents 75% of their sales in South America (interview with Mauro Moratomote - Microsoft)

The competitive advantages of Samba, compatible with Lotus 1-2-3, are that all of its commands are in Portuguese, it has natural accentuation (acentuação natural) from the keyboard, it has three dimensional graphics, and it has a low price (Frucht, 1989).

There are at least 14 domestic and imported word processor software packages available. The imported (American) word processors find their markets largely in the transnationals, who try to adopt the same line of software as headquarters to maintain compatibility. In addition to transnational firms, the main users of imported word processing software are state firms, financial conglomerates, commercial and industrial firms whose size ranges from medium to large, and firms that specialize in research and statistics (Paula, 1988d). Brazilian word processing software is acquiring increasingly larger markets in national firms and in state firms. By 1988 the top three best sellers are Microsoft Word (American), ABC from PC Software (Brazilian), and Carta Certa from Convergente (Brazilian). Brazilian software is argued to be better adapted to the Portuguese language and less expensive. Note that the 1988 software law does not tax imported software making for more direct price competition (Paula, 1988d).

Table 6.24 Word Processing Software Sold in Brazil.

Software	Price (OTN)
Foreign	
WordStar 2000 Personal Edition 3.0	145
Microsoft Word 4.0	126
WordPerfect 4.2	100
National	
Carta Certa 3	90
Carta Certa Júnior	50
Bestword	52
Fácil (DSW)	48
ABC Plus	80

Data Source: Paula, 1988d.

Both foreign and national text editors face the problem of being heavily pirated. Pirated in this sense can refer to 'corporate robbery' where large firms purchase two copies and distribute dozens among their workers. Other forms of pirating includes software producers that make illegal copies for resale in the Brazilian market, and the individual copier that plagues software producers in every country. One estimate puts the number of text editors used in Brazil at 70,000 copies (30% of the 16 bit machines in use), and of this 50,000 copies are pirated (80%). The same estimate puts the pirate rate in the U.S. at 25% of the one million copies sold per year in the U.S. (Paula, 1988d). The regulation of the 1988 software law should decrease, but not stop, the amount of pirated software.

Brazil, as a result of its market reserve policy, has the human resources and technical foundations to build a competitive software industry. With little government support several firms have successfully competed with foreign software. The examples of spreadsheets and word processors illustrate that Brazilian software is price competitive and better adapted to the Portuguese language. In terms of specific applications for niche markets, such as financial automation and other industrial applications, local development of software has ample potential. Somewhat perplexing is the government's refusal to impose a small tax on imported software for the purpose of generating investment for university research and human resource development. Brazil might be missing a golden opportunity to solidify their local software sector that has the potential to penetrate the high growth international market.

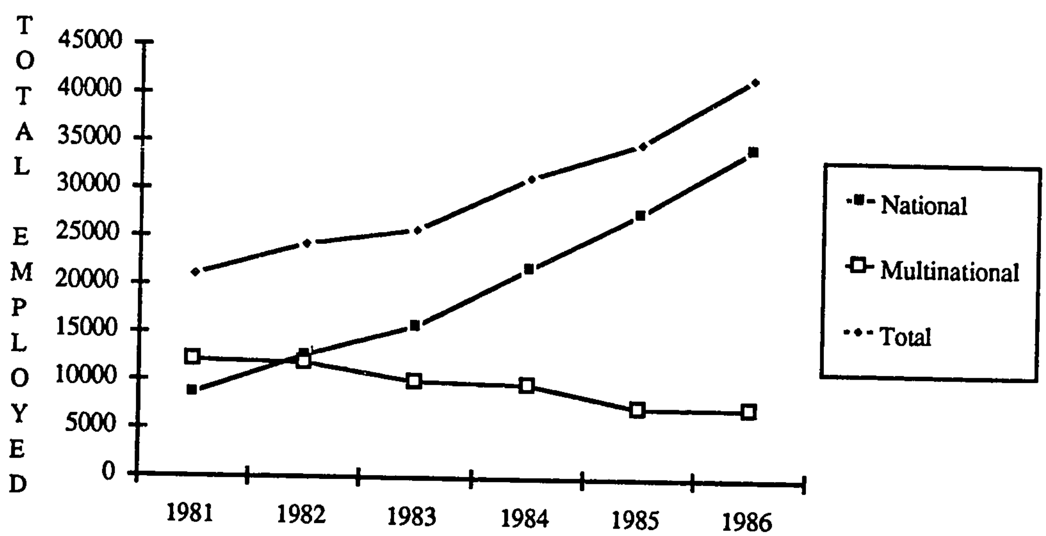
The Development of a High-Technology Infrastructure

This section analyses firm technological capability by examining the high-technology infrastructure. Of importance is the development of a local research capability, linkages between research centers and the industry, the use of foreign technology and knowledge and the availability of capital.

A Human Infrastructure

As stated in chapter 2, the most important component for technological activity and change is the availability of a quality human resource base. Indigenous technological capability is acquired mainly through human capital formation, which involves formal education, on-the-job training, experience, and concerted efforts to learn from the assimilation, adoption, improvement, and creation of technology. This ability relies critically on a pool of skilled workers capable of engaging in either formal or informal R&D activities. In order to create a knowledge base, universities and research institutes are fundamental. To improve on this knowledge base, and provide important learning-by-doing experience, industry must demand and effectively utilize this resource base.

The computer industry is a knowledge-intensive industry that relies on people, and the creation of an indigenous computer industry is likely to stimulate the development of a highly skilled human resource base. An important question is to what extent the Brazilian computer industry has utilized and contributed to the formation of a highly skilled labor force. Measurement or comparison over time should reveal a marked growth in industry employment of quality human capital, especially those engaged in R&D activities. Since a major argument for the industrial development of some market niches in the informatics industry rests on the fact that multinational corporations fail to bring R&D centers to locations in developing countries, one would expect local firms to employ relatively more R&D personnel than the multinational segment of the industry. This has been the case in Brazil.



Source: SEI, 1987.
* 1986 data is preliminary.

Figure 6.12 Total Employment by National and Multinational Companies in Brazil.

There has been a high demand for and utilization of labor by the national segment of the industry. Total employment growth, including national and multinational firms, has increased at an average annual rate of 15% per year since 1981 and by 1988 boasted over 42,000 employees, with national firms alone accounting for 37,300 employees (Mesquita, 1989).

As can be seen in Figure 6.12, employment growth is derived principally from national firm demand. Employment in just the national firms, which in 1986 was about 35,000, grew at an average annual rate of 31% during 1981 to 1986.

These figures represent only the number of jobs generated directly by Brazilian firms; indirect employment must not be overlooked when considering the full impact of the Brazilian computer industry. High-technology firms, according to Hall, Breheny, McQuaid and Hart, (1987), tend to have strong multiplier effects due to the fact that many of the workers are in managerial, professional and technical occupations with higher than average salaries and greater spending power. The implication being that these workers are consuming goods and services from other sectors According to estimates from the IBGE, the national informatics industry in 1986 generated, indirectly, a total employment of about 150,000 (Chacel, 1986b).

The Development of Qualified Human Resources: In Brazil, employment training in the area of informatics is rapidly increasing; workshops abound for corporations and individuals, and several universities now offer informatics-related departments in computer science and electrical engineering. Before the development of the local industry, most universities offered degrees in 'data processing' rather than 'computer science,' a left over from when the country prepared individuals to run computers imported from abroad rather than to develop technology. Currently, several universities offer graduate level programs in computer science and informatics. While the bulk of these universities are situated in the Southeast region, federal universities in states of the South and Northeast regions have also developed strong departments, in particular Rio Grande do Sul, Santa Catarina, Pernambuco, and Paraíba. Graduates from these universities now find abundant employment opportunities, primarily with national firms.

The following table illustrates educational level for different employment activities. University graduates comprise 24.8% of total workforce for national firms. This figure would be higher if there were a greater number of graduates; demand outstrips supply. As a consequence firms have hired and invested in training programs for presently available human resources. Of the 60 firms included in SEI's study, 43 invested in employee training programs. Several firms have established in-house training centers, and those without send employees to specialized institutions (SEI, 1987). The firms Itautec and Sid were the largest investors in worker training programs (SEI, 1987). In order to compete for university graduates, firms have developed residency programs or internships that are offered to engineering students in their final year, and, after graduation, they try to employ them on a permanent basis.

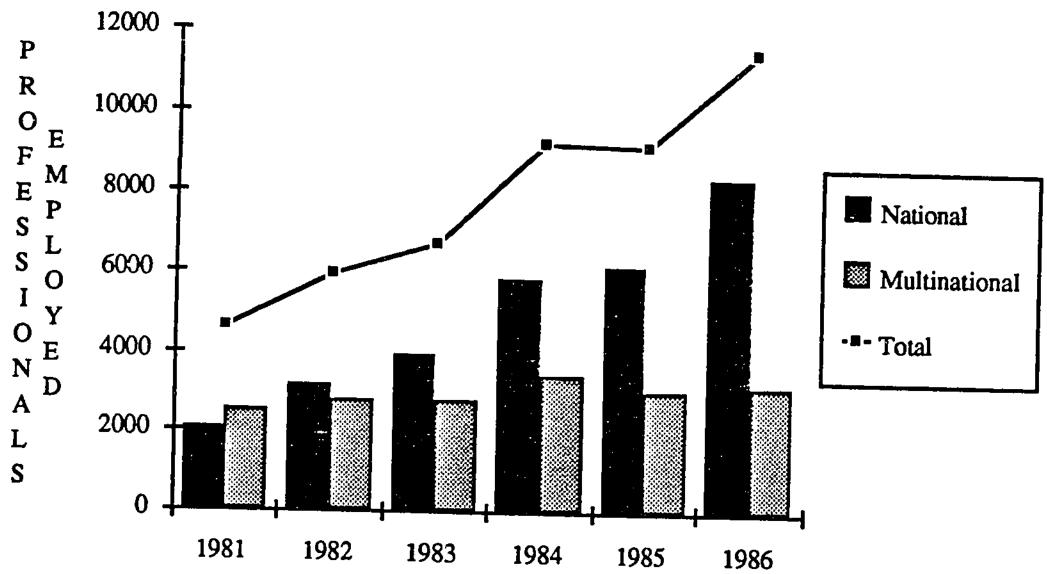
Table 6.25 Persons Employed in the Computer and Peripheral Segment by Type of Activity and Level of Education.

1986*				
% Persons Employed	Type of Activity	EDUCATION		
		Jr. High	High School	University
11.2	Sales/Marketing	5.1	47.0	47.9
15.7	Administration	15.4	56.9	27.7
44.3	Production	41.5	48.9	9.6
14.7	Technical Assistance	4.2	76.6	19.2
11.6	Product Development	4.4	33.4	62.2
2.5	Development of Human Resources	16.6	52.5	30.9
	TOTAL	22.9	52.3	24.8

Source: SEI, 1987.
*Data preliminary.

Computer and peripheral firms have the largest percentage of their workforce (44.3%) in production activities. Production workers, in terms of education levels, were led by high school graduates, closely followed people with a Jr.. high school education. Employees with a junior. high school level of education were expectedly most predominantly represented in production activities. Technical assistance employees, dominated by workers with high school educations, were significantly involved in firm training programs to improve their capabilities (SEI, 1987). The large representation of high school educated employees results from the limited supply, and thus high salaries, of qualified personnel.

When considering the employment of qualified professionals, defined as employees with university degrees, national firms are significantly more important as employers than MNCs. The average annual growth rate of university educated employees from 1981 to 1986 for national firms was 32% and for multinational firms 4% (see Figure 6.13). By 1986, national firms employed 8,308 professionals, and multinational firms 3,156. Considering firm revenue and the utilization of professionals, for each 100 million dollars of income generated in the Brazilian market, national firms employ 632 persons with a university degree, while multinational firms employ 298 (SEI, 1987). This reflects the differing manufacturing orientations of the firms: assembly oriented for the multinationals and the product development oriented for national firms. National firms, with higher technological requirements, have much higher demands for qualified professionals.



Source: SEI, 1987.
* 1986 data is preliminary.

Figure 6.13 Total Number of Professionals with University Degrees Employed by National and Multinational Companies in Brazil.

The rapid growth of employment of qualified professionals by national firms alone lends weight to the argument that contributions are being made to solidify Brazil's technological capability. Additionally, Marques (1987) argues that the rapid growth of professionals employed by Brazilian firms is amplifying the middle class and has the indirect effect of strengthening the Brazilian internal consumer market.

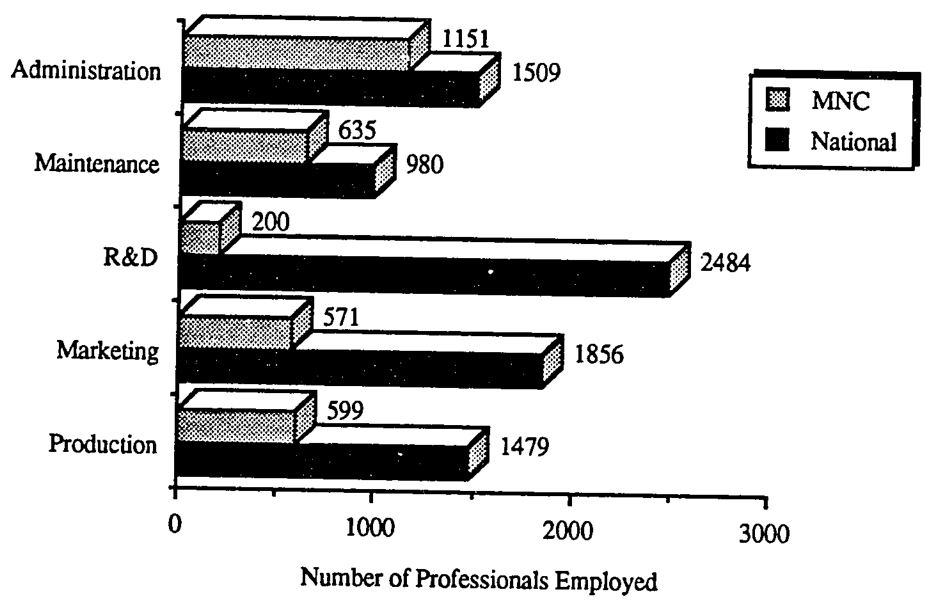
The activities of these professionals are distributed quite differently among the national firms and the multinational firms. Foreign firms concentrate their most highly qualified human resources in administration and marketing (54%), with little emphasis on R&D (6%). IBM, with over 4,000 employees in Brazil, has about 40% of its total workforce employed in marketing, maintenance, and technical assistance (INFO, 1988f). National firms devote the largest percentage of their qualified human resources to R&D

activities. The strong role of highly qualified workers, but particularly in R&D activities, is a consequence of industry's technological efforts and reflects the high demand for know-how fundamental in informatics production.

Table 6.26 Activities of Professionals Employed by National and Multinational Firms in 1986. (in order of importance)

National Firms (8,308)		Multinational Firms (3,151)	
R&D	30%	Administration	36%
Sales/Marketing	22%	Maintenance	20%
Administration	18%	Production	19%
Production	18%	Sales/Marketing	18%
Maintenance	12%	R&D	6%

Source: SEI, 1987.

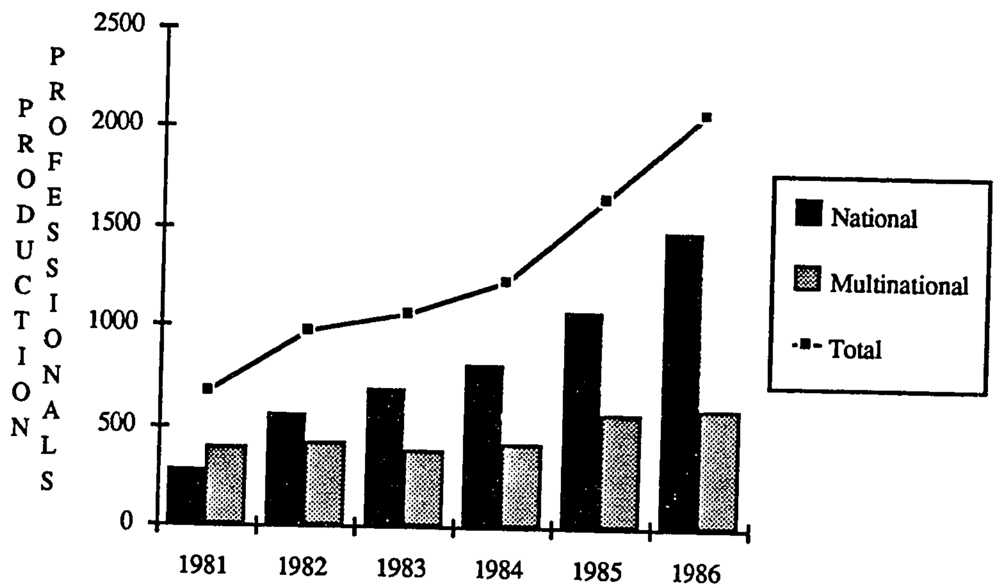


Source: SEI, 1987.

Figure 6.14 Number and Activity of Professionals Employed by National and Multinational Companies in 1986.

Absolute differences between national and multinational firms reveal the different emphasis placed on the number of professionals in marketing, production, and R&D activities (see Figure 6.14 and Table 6.26). Important is the creation of jobs for production and R&D professionals and their exposure to practical experience and learning on the job.

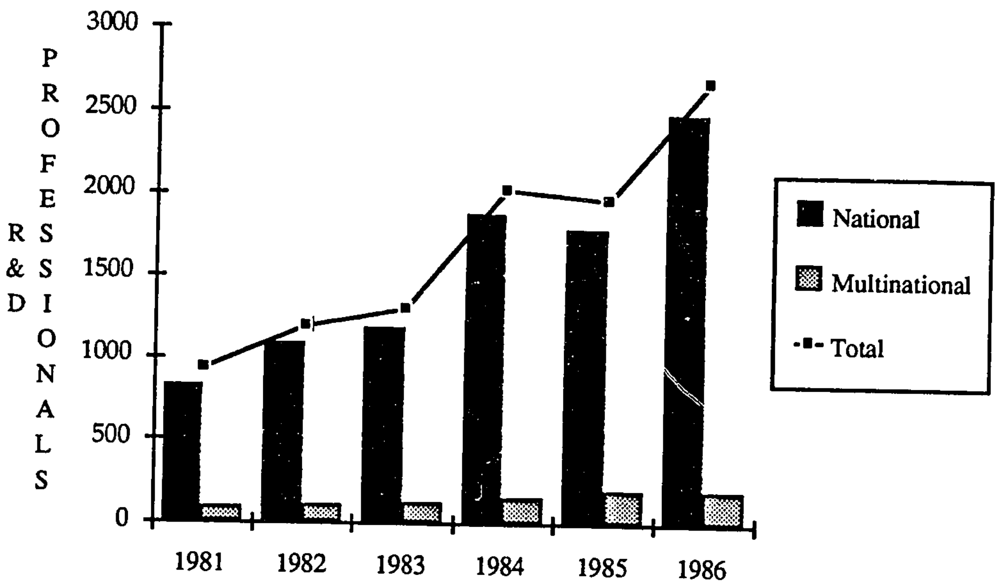
The high demand for scientists and engineers by national informatics firms prompts one to speculate where these workers would be without the development of a national industry. If there were no reserva many engineers would wind up either unemployed or underemployed as sales, marketing, or maintenance personnel. TNCs employ engineers as sales and maintenance personnel and are more concerned with using qualified employees to satisfy user-oriented demands rather than R&D. By contrast, national computer firms hire engineers for R&D and production activities. National informatics firms represent an industrial sector that is currently one of Brazil's major employers of university graduates, with a large majority being engineers (INFO, 1987e).



Source: SEI, 1987.
* 1986 data is preliminary.

Figure 6.15 Total Number of Production Professionals with University Degrees.

In 1986, 24% of the workforce employed by national firms held university degrees, of which 45% were directly employed in product development. Fifteen years ago, the number of Brazilian professionals qualified to work in a computer industry was limited, as there was low industry demand for such talents. Brazil now has a base of technicians and scientists in the informatics field, of which about 2,500 are responsible for R&D work in the computer industry, representing 7.5% of all employees from national firms in the computer industry. According to Fleury (1988), by general industrial standards in Brazil, this is a large number. Figures 6.15 and 6.16 represent the evolution and high growth rate for production and R&D professionals.



Source: SEI, 1987.
* 1986 data is preliminary.

Figure 6.16 Total Number of R&D Professionals with University Degrees Employed by National and Multinational Companies in Brazil.

Qualified production personnel in Brazilian computer firms increased approximately 530% from 1981 to 1986, or at an average annual growth rate of 40%. The multinational companies increased their use of qualified production personnel at a much slower pace, at an average annual rate of 9%. However, considering that total employment for multinationals declined over the years, the proportion of production personnel is significant and an indication that simple assembly has transformed to more sophisticated processes. One can safely deduce, however, that significant learning of production processes occurs within national firms.

Figure 6.16 illustrates the rapid growth of qualified R&D personnel in Brazilian computer firms that from 1981 to 1986[1] increased almost 300% or with the average annual growth rate was 24%. It also reveals, however, the striking disparity in R&D personnel between national and multinational firms. Brazilian firms, with slightly over half the market in terms of sales, devote more than 10 times the amount of qualified personnel resources to R&D efforts than the multinational firms. As late as 1976, Brazilian informatics engineers could only hope for employment as computer salespeople with MNCs.

This section reveals that there has been a rapid growth of qualified human resources, especially in areas fundamental for developing technological capability. While the growth of R&D employment does not necessarily indicate innovation, the accumulated technical knowledge acquired by an indigenous work force through formal or informal on-the-job learning by doing is an important indication of capability. Furthermore, comparisons between firm origin suggest that multinational firms operating in Brazil in general contribute to human resource development, although in terms of R&D, they are a limited source of technical training and learning for Brazilian personnel.

Accomplishments and Limitations of the Human Infrastructure: The national computer sector is now one of the country's major employers of university graduates. High industry demand for skilled labor has motivated students to enter departments specializing in computer science or informatics. And students are assured of a job once they graduate. Along with this rapid growth of skilled employees, however, is a continuing shortage of skilled labor in Brazil. Furthermore, the relatively small absolute number of qualified R&D personnel prompts speculation as to whether Brazil is in fact creating a sufficient critical mass of S&T personnel. The solutions appear to rest on the education infrastructure.

SEI, at an early stage, recognized the importance of education as a component of the computer policy. To that end it sought to improve and increase graduate and post-

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[1]Data from Abicomp indicate that, for 1986, the number of R&D personnel in Brazilian firms was 4,900 (IADB, 1988).

graduate curricula, create specialized didactic laboratories, install informatics equipment in universities, upgrade the teaching staff, and improve the diffusion of applied and experimental research throughout the country (SEI, 1983). Universities do have much to offer; the Brazilian higher education system is considered to be the best in Latin America (Cameron, 1989).

In the area of informatics, university development of human resources appears to be going in three directions. First, graduates specialized in hardware projects and production, with knowledge of digital electronics, computer projects, etc. A second direction is the development of professionals with the capacity to produce software for final users, operating systems, language compilers, and general applications. A third area is in complex applications for large and medium sized systems, involving data banks and the integration of computers etc. (Paula, 1987a). While these directions are important, academics and executives alike are criticizing the government for its weak investment in universities.

Most executives, like Sehn (1987), argue that the government needs to invest more in Brazilian universities to increase the number of qualified graduates to meet market demand. Technical schools and universities can not keep up with the industry's demand for qualified professionals, which SEI estimates will reach 600,000 by the year 1990 (Rivera, 1987). The University of São Paulo traditionally has an average of over 100 students attempting to enter its computer science department that only has space for 36 new students. Other universities with strong computer science departments experience the same high student demand (Paula, 1987a).

The area of computer sciences is one of 27 that receive support from CNPq, and it has not competed well for funding. As the following tables indicate, there is a limited capacity for the formation of new masters and doctorates in informatics due to the limited number of graduate-level scholarships. Education abroad has historically been a very important means of transferring technology and developing technological capability. Unfortunately, the results are not immediate and the process costly; the latter significantly affecting the number of Brazilian scholarships abroad. Tables 6.27 and 6.28 indicate the number of government financed scholarships for study abroad.

Table 6.27 Scholarships Abroad Financed by CNPq and Capes.

Year	Total (all areas)	Informatics (% of Total)
1981	1188	31 (2.6%)
1982	1308	41 (3.1%)
1983	1315	47 (3.6%)
1984	1264	43 (3.4%)
1985	1412	52 (3.7%)

Note: (Capes is an organ of the Minister of Education
Source: CNPq/MCT, cited from Paula, 1986b.

Table 6.28 National Scholarships Financed by CNPq and Capes.

	Undergraduate		Masters		Doctorate	
Year	Total	Informatics	Total	Informatics	Total	Informatics
1980	1079	27 (2.5%)	7190	149 (2.0%)	1093	42 (3.8%)
1981	1052	18 (1.7%)	7040	194 (2.7%)	1240	39 (3.1%)
1982	1274	27 (2.1%)	7377	182 (2.5%)	1350	41 (3.0%)
1983	1175	20 (1.7%)	7454	191 (2.6%)	1585	38 (2.4%)
1984	1321	31 (2.3%)	7938	191 (2.4%)	1848	40 (2.1%)
1985	1600	26 (1.6%)	8293	223 (2.7%)	2167	51 (2.4%)

Source: CNPq/MCT, cited from Paula, 1986b.

In 1985, there were only 480 Ph.D. and Masters level 'informatics' graduates, or 1.2% of the total number of graduate level degrees in Brazil. The number of university professors with Ph.D.s in informatics in 1985 was 156, an increase of 12 from the previous year. The number of graduate level students (Ph.D. and Masters) in Brazil in the area of informatics in 1984 was only 715 (82 - Ph.D. and 633 - Master), and in 1985 the number increased slightly to 786 (92 -Ph.D. and 694 - Master), an increase of only 10% (Paula, 1986b). By 1987, however, these figures were expected to significantly increase as the CNPq and Capes increased the number of scholarships abroad 40% from 1984. For 1988, the government planned to send a total of 3,400 masters and doctoral students abroad (Aquino, 1987). In order to combat the problem of lack of sufficient educators the government recently announced increased funding for scholarships for doctorates in informatics outside the country, from 50 to 600 (Dados e Idéias, 1988a). Within three years the government hopes to add 200 Ph.D. graduates in the area of informatics (Aquino, 1987).

Even with new doctorates and professors, the problem remains that university faculty are hard to keep. Salaries are established uniformly by categories, for example all assistant professors earn equal wages, no matter what they do or what they teach. Variation in salaries only occur, with very few exceptions, from the assistant position up to full professorship. As a result it has been easy for the computer industry to compete favorably for faculty (Machado, 1985). In an attempt to rectify this situation, the new president elect, Fernando Collor de Mello, has announced plans to increase funding for research and make salaries of scientists competitive with international levels (UFRJ, 1990).

Some of the resolutions of the 8th Congress of the Brazilian Computation Society held in 1988 are particularly salient in terms of education. Aside from noting the obvious, the need for more federal monies for informatics education, they recommend contracting foreign visiting professors to bring knowledge in areas where Brazil lacks, and setting up international research networks (SECOMU, 1988).

Finep has plans to help firms invest in the development of their human resources, Methods include helping firms send employees abroad for training, graduate work, or to enroll in special courses. The idea is to get specialized instruction or experience to meet the particular needs of the firm. The firm would continue paying the individual's salary, with the government providing a sort of scholarship (Guimarães, 1987).

In summation, without the market reserve policy, and with the same level of computerization, the country would have to import 47% more computer related equipment and not count the 40,000 jobs directly generated by national firms of which 13,000 have university diplomas (Frucht, 1987). Comparisons between the national and multinational sector emphasize the lower utilization of university educated personnel in all types of activities. The most revealing comparison illustrates how few human resources are devoted to product development by the MNCs while national firms have increased their employment of skilled personnel in R&D. In terms of human resource development, the Brazilian computer industry has significantly contributed to national technological capabilities in Brazil. A major bottleneck, however, is the limited capacity to significantly increase the number of qualified graduates and the limited government funding available for advanced students and future new professors.

A Research Infrastructure

Industrial R&D is a relatively recent phenomenon in Brazil. Industrial firms in Brazil installed R&D centers (if at all) years after the firm was founded, according to research carried out by Maximiano (1985). By contrast, Brazilian computer firms started with R&D departments.

Bothelho (1987) considers that Brazilian computer firms invest heavily in R&D, citing R&D investments of approximately US$ 69 million in 1982 and in 1985 US$ 130 million, or 11% of gross revenues. SEI (1987), which considered R&D as expenses applied to the development of new products and the improvement of existing products, found that computer and peripheral manufacturers spent about 9% of gross revenues on R&D in 1985. Abicomp put industry R&D investment at 10.1% for 1986, or US$ 154 million (InterAmerican Development Bank, 1988). As a percentage of revenue, Brazilian computer firms invest roughly the same in R&D as firms in the U.S., absolute values of R&D investment, however, are much smaller. According to Arnt (1989), national computer firms invested US$ 195 million in R&D in 1988, or about 8% of total firm revenue; ten years ago this represented the value of the entire market in Brazil. For comparison, in the U.S., R&D investments by the largest 100 informatics firms during 1988 averaged 9.9% of total revenue (Kelly, 1989).

From 1982 to 1988, R&D investments by informatics firms increased at an average rate of 20% per year. On average, R&D expenditures by informatics firms were 13 times larger than all the other sectors of the Brazilian economy, which invest on average 0.6% of revenues in R&D. This advance of R&D within the country is probably the most important precondition to achieving a successful locally-owned computer industry.

Brazilian informatics firms, in general, are oriented toward increasing profits, productivity and market expansion; it is the larger, more financially capable firms that have invested more heavily in R&D. In 1987, with hopes of increasing firm R&D investments, the government[1] amplified fiscal incentives to benefit firms with minimum R&D expenditures of 10% of revenues. While the role of development is largely in the hands of private firms[2], research investment is dominated by the government; according to one estimate about 80% of total research was sponsored by the government (Guimarães, 1987).

Firm strategies for technological development in the Brazilian computer industry include one or a combination of: 1) own development, 2) reverse engineering, 3) licensing (Tigre, 1987). Firm technological development strategy is based on various factors, including governmental policies, technical capacity, costs, market value, technological complexity of the product, the time required for the project, the availability of software, and the position of competitors (Tigre, 1986).

In general, larger Brazilian computer firms, which are backed by large and powerful economic groups, have greater ability to define and execute R&D policies internally. Local manufacturers that do not have as secure a financial backing are not able

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[1]R&D policies are proposed by Planin, SEI does not officially deliberate on R&D matters, nor does it directly finance R&D activities.

[2]Important exceptions are the research and development initiatives that occur within the realm of State-affiliated enterprises like SERPRO, EMBRATEL (the Brazilian Telecommunications Enterprise), and Cobra.

to invest as significantly in R&D. A number of smaller manufacturers have produced and marketed a considerable number of machines in response to growing demand in the PC segment, many of these firms resort to attempting to duplicate (copy) microcomputers from the U.S. and Japan (Machado, 1985).

The following table indicates the average R&D expenditures by market segment. More technologically sophisticated minicomputers have required larger R&D investments. The greater ease to reverse engineer minicomputers is shown by lower R&D expenditures. Peripherals, in general, have been more difficult for manufacturers to produce locally, and there has been a greater reliance on licensing foreign technology than internal R&D.

Table 6.29 R&D Expenditures by Sector Segment.

Segment	Average percent of revenue applied to R&D	
	1985	1986
Minicomputers	51.8	55.4
Microcomputers	36.0	24.9
Peripherals	8.8	14.7
Other	3.4	6.0
Total	100%	100%

Source: SEI, 1987

The strategy of 'own development' requires capital to invest in costly R&D, sufficient market size to pay off the high development costs, and skilled and experienced technical personnel to design new products. Firms choosing to develop their own products are those that have strong government backing for their efforts, such as the state firm Cobra and its development of the 500 line minicomputer and its more recent development of the SOX operating system. Other firms developing their own products are those that participate in niche markets, where specific activities require specific products. Such has been the case in the banking automation sector, where the Brazilian banking sector is operationally different than in the U.S..

In the case of Brazil, as Tigre (1987) notes, the risks of developing new products are great considering shortages of capital, the limited supply of highly qualified human resources, and the availability of commercially tested technologies through licensing. In those cases where 'own development' does occur, such as banking automation, export potential is much higher as products are not restricted by licensing agreements.

Reverse engineering is a common technological strategy in market sectors based on computers with open architecture, or, in general, products that are less technologically sophisticated. Reverse engineering is particularly prevalent for microcomputers where local manufacturers must achieve compatibility with international market standards (IBM or MSX), even though firms might have the capability to develop their own products (Tigre, 1987).

There are two different ways to clone computers, basically distinguished by how one treats ROM programs[1] within the computer. One method of cloning is to simply copy the programs in the original computer's ROM (read-only memory) and transfer the programs to the ROMs of their own computers. This is really not a clone but a direct copy and is illegal in the U.S. market. A second method is to duplicate the functionality of the ROM programs without exactly copying the programs. This is done by reverse engineering the features and functions of the software and designing a different group of ROM programs to do the same thing as the original. Duplicating functionality without directly copying constitutes a legitimate clone (Davis, 1988).

According to Machado (1985), much firm R&D has been restricted to reverse engineering and as a result there is more development than actual research, and more imitating than inventing. To make good clones, however, firms need to have some indigenous technological capacity. As economic historians have noted, Americans and Japanese in their past development extensively borrowed technology with little genuine inventive activity of their own. Their eventually improvement of skill levels led to more discriminating and selective borrowing patterns and helped diffuse and ultimately improve on these technologies (Ranis, 1984). Evidence today suggests that the primary means of international diffusion of innovations is not through technology agreements or intra-corporate channels, rather through imitations based on reverse engineering (Pavitt, 1988). Pavitt (1988) adds that it is the accumulation of technological skills for the production and local adaptation of international innovations and the existence of local firms capable of innovation and imitation that is vital for national technological accumulation.

According to Ivan Moura Campos (1987), president of the Foundation for Research Development at the Federal University of Minas Gerais, computer products in Brazil are limited to clones or copies of products already existing on the international market, especially IBM compatible computers. He argues that although it is necessary to know how to copy, what is lacking is the know-how to generate new projects, and that policy does not force national firms to generate new projects. However, there are several

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[1]ROM programs control the computer's operating system, and, in conjunction with the computer circuitry and disk operating system, are what makes one computer compatible with another. Copyright protection, in the US, includes ROM programs (Davis, 1988).

exceptions of Campos's view. For example, the Cobra 500 was completely produced and the hardware and software was entirely developed by local technicians and is recognized as a good system with 3,000 systems sold by 1987. Also developed was a project to automate the development of software called Mosaico[1] from Iesa Informática, to support CASE (computer aided software engineering) systems (INFO, 1987e) All the technology for banking automation was developed locally (Porto, 1986). Brazilian banking automation systems are superior than in Europe and comparable to systems found in the U.S., argues Antônio Filho, chief of Electrobrás .

A critical view of Brazilian computer policy posits that resource scarcity will prevent Brazil from investing in R&D at a level sufficient to maintain appropriate growth of the local industry; that 9% R&D investments may not be sufficient to respond to technological requirements in the long-run. A nationalistic view argues that Brazilian firms already invest about 9% of revenues in technology generation and that the alternative, traditional joint venture arrangements, produces no real technological knowledge and are not well suited for increasing R&D in a developing country. Before the market reserve policy, industrial research in informatics concentrated on user support and marketing studies; now with the reserva there is an increasing range of R&D.

A more accurate assessment combines these two extreme views. Certainly Brazilian firms suffer from a limited availability of capital for R&D activities, and as a result a limited number of technologies and market segments within the grasp of the industry. In technologies where Brazilian firms have invested heavily, however, they have acquired capabilities to either produce unique solutions or follow international technological trends. The accumulation of technological experience, moreover, has meant the increased ability to search and select for the most appropriate technology for the most favorable price, either internally or externally. The search process draws from publicly available scientific knowledge, or by monitoring and imitating activities of other firms, it involves the utilization of information that results from a firm's linkages with suppliers and customers, or it may involve the knowledge and capabilities internal to the firm. As the informatics industry evolves, and with the full backing of the government, firms are moving toward more R&D cooperation with universities and joint R&D project with local firms. Planin supports project cooperation in R&D activities, with universities and research institutes becoming more important in this process, a topic that will be more fully developed in a following section.

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[1]Mosaico was developed based on three academic theses from PUC-RJ and UFRJ, and ten engineers from Iesa.

University/Industry Linkages

While the reserva de mercado was necessary to initiate a Brazilian computer industry, future development depends on continually improving existing product lines and developing new products, a feat that will require continual upgrading of Brazil's technological capability. According to the Minister of Science and Technology, Luiz Henrique Silveira (1987), one of the main policy goals is to unite the four basic pillars: (1) universities as generators of science, (2) firms as generators of applications, (3) government as the instrument to coordinate and subsidize research, and (4) the user. Policy makers at all levels of government echo the above sentiments of the need to improve the linkages between firms, universities, the government and users in the area of informatics.

Most universities with strong departments in computer sciences or informatics have been targeted by administrators and local policymakers as potential technological poles for regional development. Due to an increasing awareness of the importance of university/industry linkages, these universities now enjoy varying types of arrangements to exploit university research for commercial purposes. According to Santos[1] (1984), there exist numerous cases of firms that have their origin in universities, particularly in areas of advanced technology, unfortunately statistics do not exist. Documentation of case studies may be found in trade journals and academic articles (INFO, various issues; Dados e Idéias, various issues; Rímoli, 1987b; Fleury, 1988; Dantas, 1988).

Traditionally, the Brazilian industrial sector and universities have had little interaction. The nature of industrialization has led to little firm interest or demand for the work carried out in universities. This results from two reasons: either the technology demanded by firms is stable and therefore widely available, or, on the other hand, the technology comes from foreign subsidiaries, developed in research centers abroad.

University/firm linkages in the computer sector have a quite different history. The first prototype computers developed in universities and the technology was later transferred to industry. Firm efforts to acquire their own technologies have greatly increased the demand for technical know-how in universities. The number of firms linked to universities has recently been increasing, as well as the number of researchers that have created spin-off firms. The most frequently cited example is the case of the firm Scopus.

Scopus was founded by three individuals with roots in university research institutes. At the time, in 1975, there was little opportunity for their engineering skills in

[1]Fregni (1985) and Fleury (1988) concur that there are a number of university spin-offs.

the industrial sector. Their job options were limited to sales positions for MNCs, or as 'systems engineers' for either IBM, Burroughs, or Siemens, which meant working with equipment produced and conceived abroad to find applications for users in the Brazilian market. They started Scopus to utilize their specialized skills in digital electronics. Scopus was originally conceived to offer technical and consulting services, and eventually work on projects with commercial potential. Initially, work mainly involved repairing electronic equipment, an area where most firms had little technical know-how. At the same time, however, wanting to use their creative skills, they began to develop a video terminal, and eventually manufactured it with the help of two or three employees. Although the market was small, enough terminals were sold to make a profit. One year later the reserve was implanted and demand for their video terminal jumped dramatically. Without much capital and weak marketing and industrial operations skills, Scopus originally relied on other firms to resell their products to Philips, Burroughs, Univac, Olivetti, and some national firms. Scopus' strength was in their technological know-how, and this knowledge led to increasing profits. The new income financed new projects, and experience strengthen their marketing skills. Scopus has now become a firm known for their indigenous development of finished products (without imitating), and using original process technologies to blend with the firm's characteristics, culture, and necessities (Fregni, 1985). Scopus today considers vital its close relationship with university research.

While several university/firm spin-offs exist, at the national level research examining university/industry linkages is practically nonexistent. One exception is Custódio *et al* (1985). Their research, based on a relatively small number of firms and universities, concluded that firms used universities primarily as a source of labor (e.g., especially technicians and to a lesser extent executives) and secondarily as a source for technology. This is similar to the relationship between universities and firms in the U.S.. In addition, Brazilian firms used university laboratories for their own experimental research, they tapped university experimental research, and worked with universities for software development. Most firms were aware of the benefits of university R&D, an intended to make more use of that research. While national firms used universities as a source of technology, interestingly, their research found that other national firms were a more significant source of technology. Again, this parallels technological strategies internationally.

Machado's (1985) research found that the informatics industry significantly depended on university research, and that universities are increasing collaborating with the informatics industry. These 'cooperative agreements' are often aimed at developing particular kinds of products or at helping each firm solve a specific research or development problem. Large and technologically advanced firms turn most frequently to universities for assistance and as a source of technology. Firms so classified include: Scopus, Prológica, Sid, Itautec, Elebra, Cobra SERPRO, EMBRATEL (manages long-distance telephone service - national and international), and TELEBRAS (government owned holding company controlling telephone systems). University/industry collaboration exists for virtually all segments of the protected market, including software, automation, and computers, and for segments of strategic importance like integrated circuits (Rímoli, 1987b). According to interviewed academics, however, these linkages are not as strong and well developed as in the U.S..

However, this new linkage between the universities and firms is a much more intensive, dynamic relationship than in Brazil's past, especially in the area of problem-solving. The emerging problem-solving relationship brings benefits to both parties. The firms gain products designed to suit their particular specifications. In addition, firms benefit by the opportunity to expose sophisticated users (university researchers) to their particular equipment-- a widely practiced marketing strategy used by foreign computer manufacturers to expand their market. Universities can engage in research and earn resources via royalties or through funding to set up new laboratory facilities for research and teaching. Projects that have been discarded by firms, perhaps for lack of resources or commercial potential, are increasingly being transferred to universities for possible joint development at a later date. Firm investment in university research and facilities has been important to equalize tightening research funding from governmental organizations such as CNPq, Capes, and Finep.

The universities located in the southeast and south of Brazil seem to be benefiting the most from the emerging relationship with industry (Machado, 1985). For example, in 1986, Sid signed several scientific cooperation contracts with the major research universities in informatics technology, including USP, PUC-RJ, UFRGS, the Institute of Technological Research (IPT) in São Paulo, Unicamp, UFSC, UFRJ, UFPe, INPE, and UFMG[1]. The contracts give Sid access to studies already in development at these research institutions. This knowledge could then be purchased by Sid for product development (Jornal do Brasil, 1986b). The project is called ESTRA, with Sid investing approximately

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[1]USP = University of São Paulo, PUC-RJ = Pontifical Catholic University of Rio de Janeiro, UFRGS = Federal University of Rio Grande do Sul, IPT = Institute of Technological Research in São Paulo, Unicamp = Campinas State University, UFSC = Federal University of Santa Catarina, UFRJ = Federal University of Rio de Janeiro, UFPe = Federal University of Pernambuco, INPE = National Institute for Aerospace Research, and UFMG = Federal University of Minas Gerais.

US$ 1 million per year. Several research results have already been commercialized and approximately two hundred academic articles have been published based on Sid sponsored research (Savadovsky, 1989).

Some firms, like Prológica, Scopus, and even IBM, provide hardware as a donation or at discounted prices. The 1986 Planin gave incentives for firms to use university R&D and to donate equipment to universities. In return, the university might help the firms solve a problem or develop a particular product - usually software - that the firm wanted to make available to customers. Universities researchers have also recently (1989) benefitted by being allowed to import any equipment for scientific means. The Ministry of Science and Technology expects that state research institutes[1] will import up to US$ 80 million annually, including equipment classified as 'reserved' and without paying import taxes.

IBM began in the 1980s to invest in Brazilian universities through cessions of equipment and licensing of software. By Brazilian law MNCs must devote a percentage of their income (2%-5%) to research. One of the ways to fulfill this requirement is to donate equipment and software to Brazilian research institutes.

IBM benefits from the positive image that is generated from its concern with the future of university research. Furthermore, new users are won by researchers using the machines in university laboratories. IBM has donated equipment to the Federal Universities of Paraíba, Bahia, Minas Gerais, Rio de Janeiro, Brasília, São Paulo, and to Unicamp, NCE of UFRJ, PUC of Rio de Janeiro and of Rio Grande do Sul, and the Military Institute on Engineering.

In order to preserve the universities' autonomy and to not become limited to the 'world of IBM,' the university contracts have the following stipulations: avoid the monopoly of one firm - especially if it is a foreign firm; assert university autonomy; protect

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[1]For an example of this type of transaction:

Sun has been selling systems in Brazil for about 1 year. We sell through a distributor named Scopus. Currently all systems are exported completely assembled. At this time, I know of no plans to license technology. I know of no investment in Brazil by Sun. Scopus is the only distributor authorized to sell Sun systems in Brazil. We know that the market for workstations in Brazil is huge. There are a number of obstacles to be overcome such as the high import duties (100%), closed market, and poor economic conditions. Also, the sales cycle is VERY long in Brazil (6-12 months) because of all the necessary approvals required from the government to purchase a computer system that is not manufactured in Brazil. Still, Brazil will become the largest of our distributors in South America. I think our distributor has been concentrating on placing Sun workstations in the universities. Sun recently sold approximately $3M of SparcStations and Servers to a university in Brazil. I don't remember the exact reason for this, but for some reason, it is easy for the university to get the financial backing for the purchase.

Gary W. Cook
Manager, Latin America
Sun Microsystems, Inc. (e-mail communication: March 2, 1990)

the interests of national informatics policy; release to the public the results of research realized from the equipment ceded; guarantee that the equipment will be used for educational purposes, research and extension; establish commitments from both parties that new projects will have agreements specified with results being public domain; guarantee that equipment comes from different companies; establish a minimum time for the agreement to be 4 years; guarantee that for the first year maintenance will be free, the second year at market prices; prohibit the use of the equipment for administrative used; define that the equipment of each university accommodates its necessities (Damasio, 1988).

A scientific and technical agreement recently signed between IBM and PUC-RJ was valued at US$ 15.5 million, the largest agreement between a MNC and an educational institution. PUC-RJ will receive the IBM computer 3090-180 with hundreds of peripherals, software, a scholarship fund valued at US$ 500,000, and 33 work stations based on the microcomputer PS/s and RT/PC (Informática Hoje, 1989). IBM benefits in that the company's image appears to be tied to the future of university research, not to mention winning over new users (Damasio, 1988).

Other MNCs have signed agreements with universities. Unisys and UFRJ signed an agreement valued at US$ 2.5 million for the supercomputer CONVEX C-220-128 with vector and parallel processing capacity. UFRJ now is the largest university center for computation (UFRJ, 1989a).

Informatics technologies represent one of the few examples in Brazil where universities and firms have engaged in a mutually supportive relationship. Firms, especially those developing indigenous technologies, have turned to universities for technical assistance, particularly in the area of problem solving. Research projects in universities and institutes that led to, or motivated commercial projects include a long list of firms such as: Cobra, Scopus, Embracomp, Digiponto, Parks, OZ Eletrônica, Elebra, Exata, Prológica, and Polymax, Sid, and Itautec. Universities for their part, have received much needed investment for research projects, funds for scholarships, and equipment at favorable rates.

Regional Informatics Centers

States have been taking an increasing role in attempting to stimulate the creation of new high-technology firms by integrating universities and research centers with industry. Eight state governments now have a Ministry of Science and Technology, including: São Paulo, Rio de Janiero, Santa Catarina, Minas Gerais, Rio Grande do Sul, Bahia, and Sergipe. Aside from creating new firms, the states hope that better integration diffuses information technologies to established industries to automate and improve industry processes (Beck, 1987b). A process that will increase productivity of older, less competitive firms.

Internationally, government policies been important in the development of high-technology industry, but influence on the location of these industries is more limited. Even so, many regions and states within the U.S. have begun to take a more active role in promoting high-technology development. Attempts to clone the Silicon Valley and Route 128 experiences are widespread. Developing a local high-technology industry through policy presupposes some basic requirements, which are not found in most regions. In addition, the industry's success depends on overcoming barriers such as: 1) access to information, 2) funding to invest in ideas and facilities, 3) educational levels, and 4) a sufficient financial capital market (Vaughan and Pollard, 1986). Malecki and Nijkamp (1988) have identified the following locational conditions for policies to be effective to develop local high-technology clusters or regions:

> (1) availability of research institutes acting as seedbeds for new activities;
> (2) availability of a high-skill labour force;
> (3) government support for R&D activities of starting firms;
> (4) availability of spatially discriminating venture capital;
> (5) availability of a stimulating and innovative entrepreneurial climate;
> (6) availability of inexpensive buildings for starting firms (p. 387).

Even if a region possesses the above conditions, actual policy design and implementation is not easy, and may be costly if inappropriate. Assuming that a region has the locational requirements, a regional development strategy for high technology, according to Miller and Côté (1987: 132-133), should have the following characteristics: a long planning horizon (ten to twenty years), creating favorable institutional conditions, activating regional linkages between start-ups and growing new firms, mature firms, financial institutions, universities, and research centers, assisting the emergence and growth of local high-technology firms, and developing a business climate hospitable to entrepreneurial initiatives in the high-technology area.

In Brazil, one of the more common means to accomplish technological diffusion of academic research to the productive sector is through 'technological poles.' Common to most of these technological poles is the location of small and medium sized firms around a university. Many professors and present and former students with scientific knowledge or good ideas have created new firms in the poles. According to Veja (1989), most of these firms are not producing state-of-the-art technology; their merit, however, is the production of equipment that had formerly depended on importation. Entrepreneurs that locate in poles have the advantage of access to many business type services, venture capital, and university research. Poles have been formed throughout the country, including the more industrialized states of Minas Gerais, São Paulo and Rio de Janeiro, but also in peripheral regions of the Northeast and South.

São Paulo: The state of São Paulo[1], and in particular Campinas, is a high-technology region that some call the Brazilian Silicon Valley. Officially there is a 'Pole' to unite firms and research centers in the region, called Companhia de Desenvolvimento do Pólo de Alta Tecnologia de Campinas (CIATEC). The São Paulo region encompasses several research institutions, and those specifically located in Campinas include: Campinas State University (Unicamp), Pontíficia Universidade Católica de Campinas (PUCCAMP), Center of Research and Development of Telebrás (CPqD), the CTI, Centro de Pesquisas da Companhia Paulista de Força e Luz (CPFL), and the Companhia de Desenvolvimento Tecnológico (CODETEC). Firms locating in this area receive fiscal incentives from the state, in addition to those granted by the Council for Informatics and Automation[2] (Conin). The Development Bank of the State of São Paulo (BADESP) finances firms that locate in the pole with favorable interest rates and payback periods (INFO, 1986a).

Rio de Janeiro: The state of Rio de Janeiro, and its industrial core, fluminense, is dominated by traditional industries. The state aims to revitalize its future through the development of high-technology industries, linking its numerous research centers with surrounding industries. Rio de Janeiro has several high-technology poles, with one for the informatics sector located in Jacarepaguá. The region has a rich informatics research infrastructure[3] including: the Pontíficia Universidade Católica do Rio de Janeiro (PUC), the Coordenação dos Programas de Pós Graduação em Engenharia (Coppe) da UFRJ[4], the Núcleo de Computação Eletrônica (Nce), and the Laboratório Nacional de Computação Cientifica (LNCC), the Centro Tecnológico do Exército (Cetex), and the Instituto Militar de Engenharia (IME).

Jacarepaguá is located on the southern outskirts of Rio de Janeiro. Officially labelled Riotec S/A, it pools 73 firms, and each firm can acquire up to 10% of the voting stock; public stock is limited to 49%. Firms have access to a CAD/CAM laboratory to assist project development, a computational center, university research laboratories, and

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[1] São Paulo has other technological poles that the state government is actively supporting (see Tofik et al, 1985).

[2] Conin controls SEI and develops the National Informatics Policy

[3] Overall, the region has eight research centers, seven universities with informatics-related technology departments, and three technical schools, and several informatics firms.

[4] A team of computer scientist, and 13 researchers at the Federal University of Rio de Janeiro (UFRJ) and COPPE have recently completed construction of Brazil's first supercomputer, the Multiplus. The project took two years to complete and US $1 million.

conference and training centers (Fluery, 1988). Electronic components may be tested by all firms at the laboratories of Cobra Computadores and Standard Elétrica SA (Sesa). Riotec functions as a firm and as such gains some tax benefits. Riotec purchases electronic components for its members, lowering costs by buying large quantities. In 1988, the first group of students trained at Riotec graduated (INFO, 1988a). Riotec has also arranged Japanese technological participation in some projects like robotics. Personnel exchanges have also been organized between Riotec and university laboratories in Japan (INFO, 1987b).

Rio Grande do Sul: The technological pole at UFRGS is the third largest in the country for informatics and and second for industrial automation. The institution draws in funding from the state and the local community (Oliveira, 1986). The university, with 60 professors, offers a Ph.D. program with 300 graduate level students. Research is concentrated on CAD, digital systems, VLSI, and software. Firms tied to the research carried out by the Computer Science Graduate School (Pós-Graduação en Ciência da Computação - PGCC) at the Federal University of Rio Grande do Sul (UFRGS) include firms like Digitel (modems, multiplexers, etc.), STI (data communication, chip development, etc.), Altus (numerically controlled computers, programmable controllers), and Parks (alarm systems, signal digital processing), and Sid, Elebra and Itaucom (integrated circuits) (Damasio, 1989; Rímoli, 1987).

Minas Gerais: A similar pole is planned in Minas Gerais. Minas Gerais is a region rich in minerals, especially quartz (Brazil possesses 90% of the world's quartz reserves and accounts for 95% of the world's exports), and is planning to increase production of silicon used in chips. Called electronic quartz when processed, a group of firms in the region hope to be exporting processed quartz by 1990. Research from the Technology Center Foundation (Cetec) of Minas Gerais is currently oriented to develop the technology necessary to process the mineral (Informática Hoje, 1987c). Sid Microelectrônica is located in Minas, and is the country's principal producer of circuits.

The Federal University of Minas Gerais (UFMG) has a large computer science department. Of the 40 professors 22 have Ph.Ds from universities in the U.S., Canada, France and England. The university currently has about 50 R&D projects in areas such as data banks, computer architecture, microelectronics, networks, industrial automation, and telecommunications Janeiro. Financing projects are governmental organization and contracts with private firms (INFO, 1988k), including CNPq, FAPEMIG, the Bank of Brazil Foundation, TELEBRAS, Sid Informatica (project ESTRA), IBM, etc (Bras-net message from Alberto Laender - May 2, 1990).

Santa Catarina: The Regional Center for Informatics Technology (Certi) was initiated in 1982 as part of the Federal University of Santa Catarina to tie university research to local industry needs in the area of industrial automation. Firms may use the university for problem solving and improvement of specific industry problems. Certi has worked with several informatics firms, including Sid and Elebra. An important component of Certi is the incubator park located within a mile of the campus. The park, called the High Technology Industrial District, offers a rich infrastructure and access to university facilities for new informatics firms (Rímoli, 1987b).

Other Regions: Other regions are attempting to 'decentralize' the information industry concentrated in the Rio-São Paulo region. According to Fleury (1988), the northeast region possesses 20% of Brazil's industrial establishments, 8.3% of industrial production, and 11.1% of industrial employment, but in the informatics sector less than 5% of firms. The lack of investment capital in many of these regions limits entrepreneurial activity. Firms locating in these regions must compete with producers from other states with a well developed S&T infrastructure. For example, in Bahia there are no suppliers of informatics components and the market is not well developed (Paula, 1986).

Conin has developed policy to stimulate some information activities in peripheral regions and utilize what Fleury (1988) calls the 'latent possibilities' of the region. Firms in the Sudene (Northeast) and Sudam (Amazon) regions may apply 50% of their income taxes for research in conjunction with universities and research centers. The Bahian government has used this tax incentive to initiate an information district to promote the development of small and medium sized firms in the area of software, automation, telecommunications applications, and quartz processing. Human resources will come from the Federal University of Bahia (UFBA) (Paula, 1986). Maranhão and Ceará have also increased hopes for more informatics firms in their states, and both have examples of university generated spin-offs that have achieved success nationally (Paula, 1986d).

These case studies illustrate that the development of several high-technology centers have been based on university/industry linkages. State and local governments have supported these centers with measures ranging from tax breaks to investment financing. Cases exist of new firm generation to high level joint research programs with large firms. The centers are primarily based around universities with strong informatics and computer science departments. Peripheral regions, with federal government incentives, have shown great interest in attracting and generating high-technology industries, but these programs face problems of limited infrastructures and distance from market and suppliers.

Foreign Technology

Foreign technology has a strong role in the Brazilian computer industry. According to the 1984 informatics law, foreign technology may be purchased and is allowed when such technology is necessary for the present stage of Brazilian development, when it is not available locally, and when it complements Brazilian R&D (Viegas, 1987a). Many licensing agreements to transfer technology have been signed by Brazilian firms. These agreements, however, are restricted by SEI as onetime technology licenses in an attempt to reduce technological dependence and stimulate the licensee to learn and improve the technology. The potential risk is that without local technological efforts, the licensee's products will become outdated in two or three years. SEI has also shown some flexibility in allowing firms to import restricted technologies, especially for firms with large export markets (Marques, 1987; Moad, 1989).

Table 6.30 Technology Transfer Agreements by Brazilian Firms by 1980.

Firm	Year	Product	Technology
Cobra	1974	Minicomputer	Ferranti Ltd (UK)
Cobra	1976	Minicomputer	Sycor Inc. (USA)
Labo Eletrônica	1977	Minicomputer	Nixdorf (Germany)
Sid	1978	Minicomputer	Logabax (France)
Edisa	1978	Minicomputer	Fujitsu (Japan)
ICC-Coencisa	1976	Modem	Racal Milgo (USA)
OZ Eletrônica	1977	Modem	NEC (Japan)
Elebra Eletrônica	1978	Modem	Codex (USA)
Elebra Informatica	1977	Printer	Honeywell (USA)
Digilab	1978	Printer	NEC (Japan)
Globus	1979	Printer	Data Products (USA)
Microlab	1978	Disk and tape drive	Ampex Corporation (USA)
Elebra Informatica	1978	Disk drive	Control Data (USA)
Multidigit	1979	Disk drive	PCC-Pertec (USA)
Cobra	1978	Floppy-disk drive	Calcomp (USA)
Flexidisk	1979	Floppy-disk drive	Shugart Associates (USA)
Globus	1978	Tape drive	PCC-Pertec (USA)
Compart	1980	Tape drive	Parkin Elmer (USA)

Source: Tigre, 1983: 144

During the initial stages of the Brazilian computer industry, national firms licensed technology from firms in Europe, Japan and the U.S. that were either not industry leaders, or technologies not considered state-of-the-art. Tigre's (1983) research found that medium-sized foreign firms that did not directly compete in foreign markets were more prone to license technology to Brazilian firms to help recuperate R&D expenditures.

Brazilian firms found that large MNCs would licensed technology only under very restrictive conditions or at best for peripheral equipment. The technology was necessary to establish initial product lines for more technological complex equipment like minicomputers and some peripherals such as printers, modems, and disk drives. Less sophisticated products, including microcomputers from Apple, Radio-shack, and IBM, were more accessible to Brazilian firms via imitation or reverse engineering.

The situation in the middle and late 80s has brought the technological participation of international industry leaders and technologies near or at the state-of-the-art. As with all technology transferred, local firms must nationalize production of equipment. For example, in 1988, Sid signed a technology transfer contract with IBM for the production of communication centers, a type of computer that permits the interlinking of data processing centers in diverse areas of the country. Initially the centers will be manufactured in the U.S. and assembled in Brazil. After three years Sid plans to manufacture 85% of the equipment in Brazil. For IBM, this contract represents its first in Brazil. For Sid, the agreement represents access to state-of-the-art technology; it will be the only firm outside the U.S. manufacturing this equipment (Veja, 1988).

Gwynne (1985) argues that Brazil's technological strategy has close comparisons with the Japanese model of technological development. It is based on the importation of new technologies, with domestic adaptation and improvement vigorously promoted.

Licensing of technology is common for more technologically sophisticated products where technological complexity is prohibitive or the local market would not compensate development costs, such as superminis or peripherals like laser printers. Licensing permits savings in R&D costs and access to 'proven' products, although licensed products are likely to be at the mature stage. For technological development to occur, licensed products must be adapted and improved and provide a technological base to develop new products. When the transfer of technology enables the licensee to produce the technologies and to continue development along the technological trajectory, there is a greater accumulation of technological capability (Unger, 1988).

Table 6.31 Technology Transfer Agreements between Brazilian Firms and Foreign Suppliers up to 1986.

Firm	Product	Supplier
Moddata	mainframe	Control Data
Elebra Comp	supermini	Digital
Edisa	supermini	Hewlett Packard
Cobra	supermini	Data General
Itautec	supermini	Formation
ABC	supermini	Honeywell Bull
Cobra	mini	Ferranti
Cobra	mini	Sycor
Labo	mini	Nixdorf
Sid	mini	Logabax
Edisa	mini	Fujitsu
Elebra Elet.	modem	Codex
Elebra Inf.	printer	Honeywell
Digilab	printer	NEC
Expansão	printer	Data Products
Microlab	disks and tapes	Ampex
Elebra Inf.	disk units	Control Data
Multidigit	disk units	PCC-Pertec
Conpart	tape units	Perkin-Elmer
Ensec	process. commun.	CMC
Intralab	spectrophotometer	Varian
Intralab	chromograph	Varian
Vandem	chromograph	G.P.
Romi	numeral controler	Comicron
CTL	numeral command	PLC
Sistema	Programmable logic controls	Reliance
Engeletro	Programmable logic controls	Modicon (Gould)
Metal Leve	Programmable logic controls	Allen-Bradley
Digicon	Programmable logic controls	ISSC (Honeywell)
Elebra Micr	SDCD	Leeds-Northrup
Unicontrol	SDCD	Fisher Controls
Villares	CAD	Control Data
Sysgraph	CAD	Intergraf
Compugraf	CAD	Hewlett Packard
Multitel	CAD	Scientific Calculation
Multitel	CAD	TRW
Exacta	CAD	CLM
Prólogo	micro/development	Intel
Multitel	PABX digital	ITT
Elebra Telecom	multiplexer	Codex
Vandem	spectrophotometer	Hewlett Packard
Micronal	chromograph	Millipore
WGB	oscilloscope	Tektronix
Conpart	tape unit	Cipher
Cobra	flexible disk actionater	Caldisk
Digirede	Winchester disk	Maxtor
Elebra Inf.	Winchester drive	Control Data
Elgin	line printer	Centronics
Expansão	line and serial printer	Data Products
Flexidisk	Winchester drive	Priam
Microlab	tape	Rosscomp
Microlab	disk	Ampex/Atasi
Tecnocoop	line printer	STC
Muldigit	Winchester drive	Pertec

Source: Abicomp, cited in Furiati, 1986.

As the industry develops and firms manufacture a more varied line of informatics equipment, more sophisticated technology is required. When firms make the decision to license technology, according to Machado (1985), Brazilian firms are able to sit at the negotiating table with greater bargaining power because of their technological capacity. Those national firms that pursue technological capacity through continued R&D investment, will, when required to license, enjoy more 'favorable' contracts for sophisticated technology from foreign sources (Machado, 1985). Guinle (1988), president of Elebra, adds that firms are able to license technology because of the increased bargaining power derived from the reserva. Foreign firms wishing to enter the large Brazilian market has prompted them to license their technology, otherwise Brazilian firms have little to offer foreign firms.

The licensing of foreign technology might become more important if proprietary chips are to be used more in the future, since reverse engineering, based on generic chips, would entail a significantly greater technological effort. For example, the DEC and Elebra technology agreement for the production of the MicroVax II, which is based on a proprietary chip, means that future advancements of the computer will require Elebra either to license for access to the new generation of components or develop its own chip system from generic components (Tigre, 1986). The apparent trend toward open architectures and the continued use of generic microprocessors should ensure Brazilian manufacturers, for the time being, access to 'learning' technologies rather than 'dependency inducing' technologies.

Entrepreneurs in developing countries must choose technologies from a variety of sources. The learning process and acquisition of technological knowledge in a firm is improved from a pool of intangibles gained as a firm goes through several generations of products, such as past work, current investment in R&D, marketing experience and market feedback, and firm reputation. Accumulated technological knowledge and past experience, combined with sufficient investment in R&D and strong interaction with customers contributes to successful technological performance.

Finance

One of the amazing features of the informatics industry, is that its growth has occurred concurrently with a decade of severe economic problems in Brazil. The Brazilian economy began to decline at the start of the 1980s, when the informatics industry was launched. High rates of inflation have meant high costs for capital and high interest rates. The debt problem has meant foreign exchange problems which makes difficult importation of electronic components. Computer firms have had to face higher costs from supplier firms. Firms must monthly readjust final prices on their equipment by indexation, however suppliers are argued to change prices daily (INFO, 1988n). All this leads to firms without secure sources of capital to shy away from new investments. Firms unable to generate their own capital are in a difficult position, so lack forces them to rely on government provided capital.

While the informatics law allows firms to take a variety of deductions on new investments and projects, there are basically two agencies that support the financing of long-term projects in these firms: the Brazilian Economic and Social Development Bank (BNDES) and the Fund for Financing Studies and Projects (Finep). Financing for research activities comes predominantly from Finep, CNPq, and Capes. CNPq and Finep invest in research projects through specific programs. In general, however, the government is attempting to move from its past direct financing of research projects to more indirect methods, specifically by providing attractive incentives for industry to directly invest in R&D activities (Morals, 1989).

In the private sector there are only a few venture capital firms. These include Brasilpar, Investec, Arbi Participaçãoes, Acel, Capital Tc, Campanhia Rio-grande de Participaçãoes, Sociedade de Capital de Risco, and Partbank. Rather than seed financing, Brazilian venture capitalists in high technology invest more in 'start tape' financing, where both the product and market already exist and the venture money is used elevate the product's potential growth (INFO, 1988j). Unfortunately, the level of venture capital participation is low. Banks participate, but their loans tend to be in the short-run, limiting entrepreneurial ventures (Guimarães, 1987).

The Brazilian Economic and Social Development Bank (BNDES) has a long history of support for the computer industry, back to its participation with the GTE, Capre, and Cobra. The bank has sponsored many projects in the informatics sector, especially in R&D, and 'intends' to increase its investment in this area, although as the following table illustrates funding for informatics has declined relative to other sectors. BNDES financing is important, especially for long-term projects. The principal beneficiaries of BNDES financing, since 1984, have been firms which are working on state-of-the-art technology. The most recent focus of BNDES is to help finance the infant microelectronics industry.

Table 6.32 Disbursements by BNDES in Informatics.

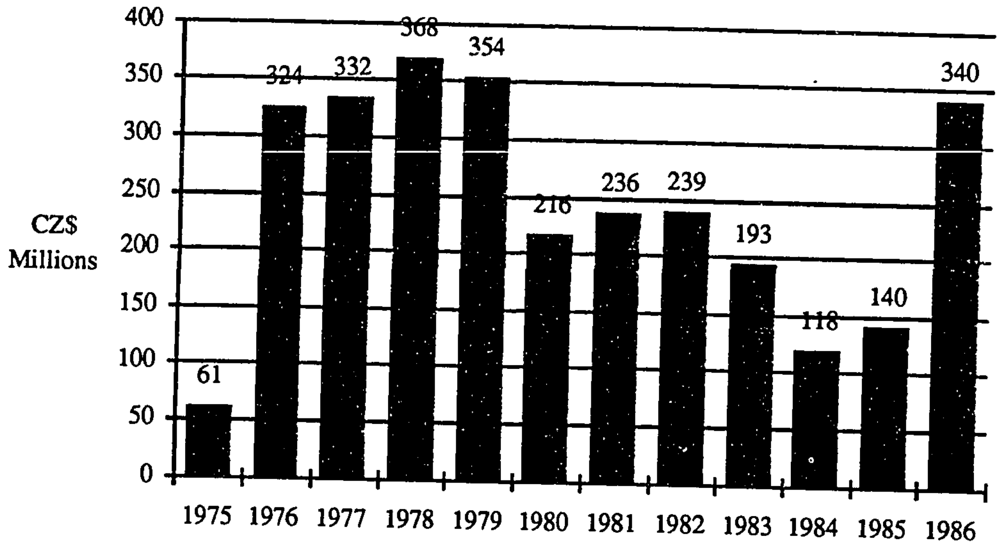
Year	Percentage
1984	0.7
1985	1.8
1986	2.7
1987	4.5
1988	1.2

Source: INFO, 1988d; Maços, 1989.

In 1988, the actual request for funds by informatics firms fell significantly. The decline in funding petitions demonstrates that firms are hesitant to invest in technology during the current economic problems. More importantly, the decline reflects new bank requirements that firms use loans for technological development rather than survival. BNDES conditioned funding to firms with positive bank accounts and primarily for development projects either in association with other local firms or those that use their own indigenous technologies, rather than imported technologies (INFO, 1988d).

Projects approved for 1988 include two lines of superminis (Elebra and Labo); four lines of supermicros (Digirede, Edisa, Sid and Cobra); the AT microcomputer by Scopus; a public communications center (Elebra and PHT); a CASE (computer aided software engineering) software system called Mosaico by the firm Iesa/TS; research for the encapsulation of integrated circuits (Itaucom); production of pressing circuit boards ((Adiboard); and the importation of equipment and technology for the production of large scale printers form Japan (Itaucom and Tecnocop) (INFO, 1988d). As the list illustrates, large and established firms with strong technological capabilities were generally the major participants of BNDES loans.

Finep, a government organization that draws its money from the FNDCT, funds projects for the development of new technologies. Finep aims its funding to both universities and firms. In addition to funding research projects in universities, Finep attempts to facilitate the transfer of university technology to firms (Oliveira, 1989). Firms normally have five years to pay back the loans beginning two years after the loan. Funded firms must be national and be investing in technological capability rather than licensing. The major areas of interest are informatics, biotechnology, new materials, precision machines, and fine chemicals, and areas where new industries are beginning to form.



Source: Thimoteo, 1986, cited from Finep.

Figure 6.17 Loans from Finep for Firm Financing for Technological Development. (in millions of Cruzados, 1986 constant Cruzados).

In 1987 Finep's funding increased 4 times (real increase) over 1986 to 2.5 billion cruzados[1] with a significant share of the money going to informatics (Informática Hoje, 1987b). Informatics industries are funded in areas for new projects (especially where the industry does not want to be dependent on sophisticated items, and where firms want to diversify their activities and enter more segments in informatics), and where firms need financing to increase their productivity and technological development. While in 1978 the demand for financing was estimated at Cz$370 million (in 1986 constant Cruzados) it is estimated that in 1986 the demand would be Cz$ 1.7 billion, or much greater than actual dispensations (Thimoteo, 1986).

As Figure 6.17 indicates, in 1986, Finep investments finally rebounded after several years of decline, and for informatics, this specifically meant more funding to support universities, microelectronics, software, and industrial automation. By 1987,

[1]Of that quantity Cz$ 422 million goes to amortize its external debt, administrative expenses take up Cz$ 144 million, the rest is distributed to various programs, with a large part going to research institutions and universities: informatics -Cz$ 394 million, Chemicals and petrochemicals -Cz$ 311 million, minerals and metallurgical -Cz$ 243 million, Metal mechanics industry - Cz$ 103 million, and transport -Cz$ 108 million (Thimoteo, 1986).

Finep's investment in informatics technology jumped by $450 million dollars from 1986 (Aquino, 1987)

Finep's most important project was the Program to Integrate Research in Computer Science (Programa Integrado de Pesquisas em Computação - PIC/C) to support universities and research centers in computer sciences. All institutions involved in training at the university level will receive funding to purchase equipment produced by national firms. The major projects funded were in the areas of artificial intelligence, local networks, robotics, CAD/CAM, and dedicated and semidedicated integrated circuits (INFO, 1987d). Other Finep programs, based on realizing the goals outlined in the Planin, include industrial automation, software and microelectronics. The Program of Process Control and Manufacturing Automation (PAI) provides incentives for the production of hardware and software for industrial automation. For hardware this includes: CAD/CAM work stations, robotics, programmable logic controls, numerically commanded computerization, digital control systems, and single loops. Software development was funded in real time to control, superviser systems, and Computer Integrated Manufacturing (CIM). Small and medium sized software houses will receive the bulk of the funding. Microelectronic firms producing chips will receive incentives to further their technological capacity (INFO, 1987d).

The programs and projects identified by BNDES and Finep indicate areas where Brazil is focusing on acquiring technological capability. Projects support both firm and university research, and joint projects that include both firms and universities. Projects focus on research that develops indigenous technology, and firms that are actively pursuing technological advancements are favored. With these seemingly numerous and ambitious projects identified, the lingering problem remains that financing of Brazilian firms is limited and insufficient. The lack of capital is acute for those small and potentially innovative new firms with good ideas but no venture capital to turn ideas into products.

General Comments on the Brazilian Pathway

There are many factors that support of the argument that Brazil is developing technology through its industry: the existence of a substantial industrial park, a rapidly growing of S&T labor force, more intensive competition in the internal market, and experience gained by all aspects of operating a high-technology industry. The Brazilian computer industry has good channels of distribution throughout the country, although maintenance is better around the Rio/São Paulo axis. Certainly Brazil has an informatics base already installed and a technology culture. Cases suggest that multinationals are increasingly respecting Brazilian technological capabilities. For example, Motorola chose Edisa as one of the few firms in the world to test their chips, and IBM now develops disks in Campinas.

As a consequence of the market reserve policy, Brazilian firms have had to develop their own administration and operational structure, and gain the capability to develop products. According to Tigre (1984), licensing technology was sufficient to gain access to know-how necessary to manufacture equipment. However, in some cases, indigenous development of new products was necessary particularly in niche markets. Overall, Brazilian computer firms have learned to develop, manufacture, maintain and commercialize products. This has entailed significant investment in technological efforts and human resource development.

In summation, some firms are making some technological strides, gaining increases in productivity, and managing cost reductions. By avoiding reliance on direct investment for technology, as Pavitt (1988) reminds us, they break the pattern of weak technological accumulation in developing countries. This is not to say that firms have developed frontier technology, but they are moving along the frontier. Indeed, in comparison with other Latin American countries Oliveira (1988) argues that that Brazil is at least five years ahead of Mexico and Argentina. A technological gap still exists between Brazil and the U.S. but it is diminishing. This brings some advantages; a follower role allows Brazilian firms to invest in proven technologies, without wasting precious capital in risky projects that might have little potential.

CHAPTER 7

CONCLUSIONS

In spite of significant global economic growth, the gap between the developing and industrialized countries has widened, measured by national income, industrial output, or trade. Even more pronounced, however, is the uneven distribution of technology, which has increased in magnitude with the appearance of new informatics technologies. Unfortunately, the likelihood of self-generated 'informatics development' in most developing countries is questionable. These new industries are science-based and require significant R&D inputs. Developing countries fail badly in these areas. R&D activities generally do not exist, or are limited to the adaptation of products to new environments; and industrial production, based on foreign technologies, has created little demand for the science generated from local university research. A further concern for developing countries is the potential industrializing effect new informatics technologies may have on other economic sectors in industrialized countries. The 're-industrialization' of traditional industries in industrialized countries, like textiles, through the incorporation of informatics production techniques, might reduce cheap labor advantages in developing countries. Developing countries, then, not only face the prospect of increased technological dependence, but also a loss of competitiveness in many industrial sectors.

While it is important to understand the many negative outcomes of technological dependence, the focus of this dissertation lies elsewhere. The present work challenges the notion of inevitable 'technological dependency' by suggesting frameworks and policy strategies for developing countries to acquire high-technology capabilities, and to increase our understanding of the development processes of high-technology industrialization. The approach is eclectic and meta-disciplinary in order to treat the many issues and complexities associated with technological development. It also avoids the use of a specific paradigm[1] which may influence the nature of empirical findings. With the burgeoning of a small number of developing countries expanding their technological capabilities, new horizons of inquiry arise.

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[1]A paradigm by definition entails a significant degree of generalization. Theories and hypotheses that spin-off from the paradigm attempt to understand the more unique and specific situations. These theories are then substantiated or disproven by empirical research. The main paradigms for development geography may be divided into three broad categories: the first category is the diffusionist paradigm (positive economic theory and modernization theory); the second category is the dependency paradigm (dependency theory and world-system theory); the third category is the Marxist paradigm (socio-spatial dialectic theory, fundamental Marxist theory, and "articulation" theory).

This dissertation uses concepts drawn from development literature on technological capability and current empirical research on high-technology in industrialized countries. Literature on technological capability has demonstrated the importance of indigenous technological efforts by developing country firms, the need to learn from foreign technologies rather than just using them, and how policy helps the generation of these capabilities. This research, however, is based on the capital goods sector, and much attention has been placed on transfers of technology. For high-technology industrialization, a more appropriate focus is the development of a local research and innovative capability. Moreover, the literature on technological capability has rarely considered, conceptualized, or researched the spatial dimensions of technological development, which, it was suggested, are particularly important to high-technology firms. Previous geographical research on high-technology industries has provided us with a set of spatial characteristics that are instrumental for and evident in high-technology regions (see chapter 3). Important as this work is, it is based almost entirely on examples from the industrialized countries, and the 'development' process is not yet well understood. The conceptualization used in this dissertation aims at introducing major geographical problems that developing countries face in high-technology, in particular locational, spatial linkage, and regional development considerations.

Specifically, high-technology capability in developing countries requires the development of two interdependent components: technological capabilities and supporting technological infrastructures. Stages have been identified in chapter 2 to describe the growth of technological capability - from reliance on transfers of technology to an indigenous innovation capability. Several conditions and processes are important in the growth of technological capability, e.g., protecting firms to stimulate technological efforts, learning, and technological accumulation, and selectively importing technology. Technological change, then, results from explicit efforts by firms to accumulate and learn technological know-how. Along with these efforts comes an increase in firm demand for quality personnel from the higher education system and the increased ability to innovate locally. Government policies may help to promote or stimulate technological efforts by regulating transfers of technology. In order to develop this capability a nation needs not only some history of industrial activity but also the development of a technological infrastructure, permitting a greater ability to assimilate, adopt, and improve foreign technology.

The development of the second component, technological infrastructures, is vital for increasing technological capabilities. These infrastructures, highly interdependent and overlapping, are based on supporting institutional structures, such as universities, firms, markets, and suppliers, and on the spatial linkages that connect these structures.

The evolution of infrastructures has been viewed from three perspectives: human resources, research linkages, and high technology regional agglomerations. The human element of infrastructure is based on the generation of quality human resources to promote research and technological advance. The productivity of the infrastructure is dependent on educational and research structures, including physical facilities in research universities and institutions (e.g., laboratories, research equipment, libraries), and a network of linkages to diffuse knowledge (e.g., consulting and engineering services).

A research linkage view facilitates an understanding of indigenous research and innovation. Successful research and innovation necessitates strong linkages between science, technology, production, markets, and governmental planning. Government policies guide research efforts toward national goals and stimulate R&D activities by creating markets and regulating the importation of foreign technologies. University and research institutions conduct basic and applied research, and supply qualified and skilled labor. Research activities in firms provide the opportunity for people to utilize scientific and technological knowledge for specific results. A market demands and utilizes research results and pulls indigenous knowledge and technology to product innovation.

A third perspective focusses on the spatial dimension of high-technology. An apparent condition for high-technology development and sophisticated innovative activities is the necessity for regional agglomerations of infrastructural resources, networks, and linkages, including: 1) a quality labor supply with particular emphasis on highly skilled human resources from universities and research institutes; 2) access to research from universities, government institutes, and industry; 3) backward and forward industrial linkages, 4) market linkages; 5) access to investment capital; and 6) basic physical resources such as efficient transportation.

A high-technology capability derives from the sequential development of infrastructures, and the advancement to higher stages of technological capability. The learning from transfers of technology and the development of an indigenous innovative and research ability are fostered by the development of human resources, research networks, and infrastructural spatial agglomerations. In addition, policies may be needed that, 1) control technology transfers and promote learning from foreign technologies, 2) improve indigenous innovation and research capabilities through support for local industries and research institutes, 3) promote infrastructural development, and 4) stimulate new industries through trade and foreign investment regulations. The case of the Brazilian informatics industry illustrates the interplay of policy, capabilities, and infrastructure.

Several criteria consistent with this framework were used to determine to what extent Brazil has developed a high-technology capability , including: (1) the successful contribution to and intensification of the human infrastructure; (2) the linking and deepening of research and development capabilities in industry, government and university centers and the connections between the actors that comprise the research infrastructure; (3) the creation of a regional high-technology infrastructure; (4) the industry's ability to advance new generations of products, lower prices and improve productivity, and effectively select and bargain for foreign technology; (5) the nature of technological importation or firm links with foreign sources of technology, either direct (licenses or joint ventures) or indirect (reverse engineering), and the 'learning,' and improving foreign technology; and (6) the gradual utilization of locally sourced technology and components.

The evolution of the Brazilian informatics industry illustrates many of the problems developing countries face in acquiring high-technology capability. High technology is not a simple development tool nor is it easy to devise a simple industrial policy to promote it. The Brazilian informatics industry, in terms of price or export indicators, demonstrates the limitations and high costs of Brazilian informatics policy. Prices of Brazilian equipment, especially more sophisticated products, may reach up to twice the price of similar equipment found in the U.S.. These higher costs limit the computerization of various sectors of the Brazilian economy and the development of an export market.

An evaluation based only on price or export indicators, however, does not do justice to the more positive aspects of the Brazilian industry, namely the creation of an indigenous R&D base, R&D linkages between university, industrial and government, human resource development, and firm technological accumulation, product development, and production experience. Furthermore, domestic firms have demonstrated that production experience and technological accumulation, especially in market segments facing a high degree of internal competition, have led to price reductions. Although the informatics trade balance remains unfavorable, firms have been exporting on an increasing scale, and these exports represent products based on local design and engineering. Yet, there are significant limitations associated with Brazilian high-technology capability. In particular there is insufficient funding available for firm and university R&D activities, lack of venture capital available for new and existing firms, and limited funding for advanced and foreign education. Additionally, Federal policies have suffered 'unintended' results. For example, industry protection has led to increased contraband or black market activity and high prices for final products.

More specifically, how has the Brazilian industry fared in developing a high-technology capability? One of the primary contributions of the industry has been the development and utilization of quality human resources. The industry has employed, on a rapidly increasing scale, scientists, engineers, and other personnel in areas such as administration or production. These employees have accumulated technical knowledge from R&D activities and gained valuable business experience in the high-technology sector. Comparisons between multinational and national firms operating in Brazil show that the former are a limited source of technical training for Brazilian personnel. In terms of human resource development, the Brazilian computer industry has significantly contributed to national technological capabilities in Brazil. Unfortunately, the limited capacity of the higher education system has hindered the development of future faculty.

A further contribution of the industry is the development of a research capability. For all Brazilian industrial sectors, R&D investment averages only 0.6% of revenues. Informatics firms, by contrast, have R&D departments and invest an average of 9% in R&D. The informatics law allows firms to take a variety of deductions on new investments and projects, and government funding for research and development is available to firms with projects that use local technologies. In general, however, the government is attempting to move from direct financing of research projects to more indirect methods, specifically by providing attractive incentives for industry to invest in R&D activities. It is the larger, more financially stable firms that have invested more steadily in R&D. Manufacturers that do not have as secure a financial backing are not able to invest significantly in R&D. Many of these firms resort to imitating computers from the US and Japan.

Firms which have invested heavily in technologies can either produce unique solutions or closely follow international technological trends. In the case of microcomputers, the time gap between international releases and subsequent Brazilian releases of compatible equipment has occasionally been reduced to less than a year. These firms have accumulated the technological know-how to adapt to changing technological frontiers. In other more sophisticated market segments national firms were less capable of following international technological developments, with delays of up to three years, significantly higher prices, and greater reliance on licensed technology.

The efforts by firms to acquire their own technologies have greatly increased the demand for technical know-how in universities. For example, the first prototype computers were developed in universities at Rio and São Paulo, and the technology was later transferred to the state firm Cobra. As the informatics industry evolves, firms have engaged in more R&D cooperation with universities and joint R&D projects with other firms. The geographical patterns of these linkages are concentrated in the Southeast, especially along the Rio-São Paulo axis. These regions, with a well developed technological infrastructure, have witnessed several cases of new firm generation and an increasing number of academic researchers that have created spin-off firms. State and local governments have created high-technology centers based on university and industry linkages, and have enticed firms with fiscal incentives and investment financing. Campinas, in the state of São Paulo, is the best example of such a center. Peripheral regions, assisted by federal government incentives, have shown great interest in attracting and generating high-technology industries, but these programs face problems of limited infrastructures and distance from market and suppliers.

The local production of components has been stimulated by import restrictions and policies that encourage computer manufacturers to buy locally. As a result, strong industrial linkages have been created and indigenous manufacturing processes developed and learned (rather than simple assembly operations). Import restrictions, however, have meant that local manufacturers must pay for the higher priced local components, elevating the final price of Brazilian computers. Restricted access to the best and cheapest components worldwide has hindered the ability of firms to compete in export markets, limiting economies of scale and a potential means of lowering final prices. Furthermore, computer manufacturers have cited the lack of reliability of national component suppliers in terms of insufficient supply, time delays, price, and quality, and the difficulty of acquiring imported components as major problems for the Brazilian computer industry. A positive side effect has been the increased pressure on computer manufacturers to increase production efficiency and thereby lower final prices of their equipment. Recent policy statements indicate that the government is considering adjusting domestic content requirements and removing certain key components from market reserve protection.

Brazil's strategy for acquiring technology has been very similar to that of Japan, where the importation of new technologies with domestic adaptation and improvement was vigorously promoted. Federal policy has protected infant industries and adopted specifications for technology licensing agreements. Initially, national firms were forced to license technology to establish product lines for technologically more complex equipment. This technology was either 'outdated' or from firms that were not industry leaders. Large MNCs would only license technology with restrictive conditions. Less sophisticated products were accessible to Brazilian firms via imitation or reverse engineering. Industrial development, however, has increased the technological participation of industry leaders worldwide and transfer of technologies to near state-of-the-art levels. As with most technology transferred, local firms must produce the equipment using a high proportion of domestic inputs, leading to more local linkages but higher final prices. This is also the case for multinational production in Brazil. In a positive sense, however, there has been an increase of local learning and technological accumulation as a result of these restrictions. In many market segments, local firm bargaining power for foreign technology has significantly increased, leading to a greater number of interested licensees and the transfer of more state-of-the-art technologies. Those national firms that pursue technological capacity through continued R&D investment are able to negotiate more 'favorable' contracts for sophisticated technologies. The large Brazilian market has also prompted foreign firms to license their technology.

In general, the acquisition of technological knowledge has been improved from production experience (i.e., manufacturing several generations of products). The accumulation of experience through intangibles such as past product development and production, investments in R&D, marketing experience and market feedback, and firm reputation, has meant an increased ability to search for and select the most appropriate technology at the most favorable price, either internally or externally.

In response to the current high cost of capital, many informatics firms have formed alliances with large financial or industrial groups, or even other informatics firms. Such associations may be viewed as a maturation and consolidation of the industry. They have brought informatics firms financial stability, a greater ability to diversify product lines and finance technological development, and greater access to foreign technologies. The large domestic informatics market and significant potential for forward linkages have enticed large banks and economic groups to acquire informatics firms.

The lack of capital has limited the number of technologies and market segments within the grasp of the industry. It was found that in the private sector there are only a few venture capital firms, and they invest more in areas where both the product and market already exist. Capital 'unavailability' has seriously restrained the innovative potential of many firms. Some form of venture capital is essential for financing high-technology firms and costly R&D activities. It seems that the government needs to increase the availability of venture capital and direct loans for infant high technology firms, or offer more financial arrangements such as grants, subsidies, tax breaks, financial sharing arrangements, or the provision of equipment or buildings or services.

Brazilian firms have demonstrated a significant amount of learning: increased skill in production, an entrepreneurial potential, the ability to reverse engineer, cost-reductions through improved maintenance and reliability, technological improvements, and growing infrastructures. The high cost of equipment, however, continually plagues Brazilian manufacturers. In addition, the inability to enter international markets limits industry potential. When the market reserve policy ends in 1992, some firms will survive, and with access to cheaper components, begin exporting on a larger scale. Other firms, with few indigenous capabilities, face a much dimmer future.

The dissertation has proposed a framework for analyzing the evolution of high-technologies to developing countries. The framework has shed light on the conditions and possibilities of high-technology development, and contributed rich empirical detail on the technological capability of Brazil's informatics industry. Conceptual and empirical findings have attempted to improve our understanding of the developmental processes associated with, and required for, high-technology industrialization. The framework has broad application to other nations considering high-technology developmental pathways; these countries, however, must evaluate the effectiveness of the restrictive Brazilian policies, and their own particular national endowments to determine policy strategies and appropriate degrees of closure to develop these capabilities. As a Third World country, Brazil is unique in its large domestic market, demand for informatics goods by other economic sectors, regulation of foreign technology, strong computer-related university departments, and an absence of foreign competitors. Thus, comparisons of the Brazilian computer industry to countries at similar stages, yet with more open strategies would be particularly illuminating, like South Korea. It is hoped, however, that this dissertation provides both conceptual tools for the analysis of high-technology development, and an empirical benchmark for further exploration of high-technology industrialization.

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APPENDIX A

THE INTERNATIONAL INFORMATICS INDUSTRY

The evolution of the international informatics industry has been controlled by both changing technologies and changing markets. The development of microelectronic technology permitted new entrants and other high growth firms to challenge established oligopolistic market leaders. The early 1960s marked the start of microelectronics proper. At that time transistors began to be grouped together on the same semi-conductor chip (usually of silicon) with other parts of electric circuitry (e.g., capacitors and resistors) forming an 'integrated circuit.' The 'microprocessor' appeared a decade later (in 1971, by Intel), with the gathering together of all the functions of an electric calculator on a single 'chip' (Johnston and Sasson, 1986).

The semiconductor industry has undergone three major innovations: the transistor (1957), the integrated circuit (IC) (1961), and the microprocessor (1971)[1]. The adoption of the chip in computers within the last 15 years has greatly lowered the cost of computers, with smaller computers becoming more feasible and progressively more powerful, even rivaling old mainframe computers. Increased miniaturization and dramatic price reductions have led to the use of electronic components in a diverse number and range of products from consumer-oriented products (like pocket calculators) to highly complex computers (Dicken, 1986).

Computer markets and users have also changed. In the fifties and sixties, the major market for computers was led by large institutions and firms, each with specialized staffs to develop software according to their needs. In 1963, when the first minicomputer was produced by Digital Equipment, the computer market has been regarded as a single market consisting only of mainframes. Currently, the market has rapidly expanded to include more unsophisticated users that use microcomputers in diverse locations with off-the-shelf software. With computer systems becoming more diverse, complicated, and powerful, firms have been forced to concentrate more on markets and new users, with more emphasis placed on marketing, sales and user support. As a result, it is common for well over half the employees of computer firms to be in marketing, sales, service and support (Morgan and Sayer, 1988).

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[1]ICs combine several transistors and different functions on a single chip of silicon; very large scale integration (VLSI) combines a million different functions on a single chip. Two major types of chips are microprocessors and memories. Microprocessors combine the basic information processing functions of a computer on a single chip.

Table 4.1 illustrates the global market for information technology products based on data from the top 100 companies. An overall growth rate of 16.3% was registered for the top 100 companies in 1988. The size of the market, US$ 243.1 billion in 1988, indicates the strength of the sector on a worldwide scale.

Table Appendix A.1 The International Market for Information Technology in 1988.

Market Type	US$ Billion	Share of Market
Mainframes	30.3	12.5%
Minicomputers	24.1	10.0%
Microcomputers	28.4	11.7%
Data Communications	16.0	6.6%
Peripherals	61.8	25.4%
Software	20.8	8.6%
Services	19.8	8.1%
Maintenance	28.8	11.8%
Other	13.1	5.4%
Total	**243.1**	100.1%

Source: Kelly, 1989.

The most recent developments in computer technology focus on networking computers and improving the efficiency of existing hardware through improvements in software development (Kelly, 1987). The birth of a 'software industry' is largely a result of the unbundling of hardware and software by computer manufacturers; a process instigated by the rising cost and diversity of systems software, and the specialized nature of application software. As the needs of computer users became more specific, new opportunities were created for the growth of new software houses (Prakke, 1988). Increased awareness of the software industry became more evident in the 1980s, when hardware advances were limited by corresponding advances in software. With each new hardware release the ability to make use of the full capacity of the machine lagged until software was developed - giving rise to the concern of a software bottleneck.

The U.S. is, by a wide margin, the current leader in software technology. According to Linvill (1984), Japanese computer manufacturers have lagged in building U.S. computer sales because of the manufacturers' difficulty in developing software. In large computers, the Japanese accepted IBM operating systems as the standard, and with personal computers off-the-shelf programs and operating systems that are written by other manufacturers predominate. The Japanese have been particularly unsuccessful in developing software for the rapidly expanding minicomputer where there is little standardization and proprietary software is often developed internally.

With the introduction of microcomputers in the late 1970s there has been a marked decentralization of in-house software development. Mini-and micro-computer manufacturers have tended to concentrate on the production of hardware because of the many divergent applications of these smaller computers and the manufacturer's lack of knowledge concerning the software requirements of diverse users. Hence, new software markets are increasingly satisfied by independent software houses (Prakke, 1988). The hardware-software cost ratio has reversed from being hardware dominated (80:20) to being software dominated (80:20) (OECD, 1985). As hardware design and development have become less important some new computer firms have decided to rely on other firms for almost all their components and have instead concentrated on software development, sales, and service (Linvill, 1984).

The development of a 'software industry' can be seen by the increasing size of software firms, their expansion on the international scale, the rapid growth of a software publishing and distribution sector, and the tendency towards concentration in many segments of the market. Software firms are rapidly increasing investments, employment and sales, and - even though over half of data processing expenditure remains within user firms and organizations - the software industry is now one of the fastest growing sectors in the industrialized countries (OECD, 1985).

Two types of software enterprises have evolved: 1) firms that create individual programs to the order for users of medium-sized or large computers (firms that have computer equipment but not the specialists necessary to produce the programs that they need); and 2) firms that create standard programs for general sale (Johnston and Sasson, 1986).

The rapid pace of technological change in the informatics industry have made firms pursue effective R&D programs to attain market competitiveness. The increasing microcomputer and software sectors have produced market rationalization through mergers and firm failures, resulting in increased market segregation and specialization. At the same time, as the industry diversifies, barriers to entry are lowered- with new microprocessors, and new market openings are created. Fields such as micro-processors, home-computers, software, and biotechnology have experienced dynamic technical change not by large, big-science developments but rather by small and new firms.

Kelly (1987) sums up the new trends:

> Firstly, electronic component miniaturisation has greatly lowered the 'barriers to entry' for new firms. Secondly, the pace of technological change has been extremely rapid and small firms are arguably more flexible and responsive to change than larger units with hierarchical decision-making structures. Thirdly, the introduction of the microcomputer has undercut profit margins and shortened projected life-cycles for existing product ranges such that R&D and capital investment can not be fully redeemed. In this context, longer-established firms are less likely to adopt the 'subversive' technology of microelectronics than new firms which have no past investments to protect. Finally, the lack of standardisation in operating systems, interface protocols and programming languages has created a diversity of market niches where economies of scale do not operate and which can best be exploited by small firms with low overheads and a close contact with changing market requirements (pp. 119-120).

There is a spatial pattern in the distribution of computer manufacturers by type of products and labor required. In the U.S., R&D activities and production of sophisticated equipment are regionally concentrated, predominantly in New England and California. Large scale production of relatively standardized components and routinized assembly activities are more dispersed.

Mainframe manufacturers tend to assemble their products close to headquarters and design facilities. This is largely due to the frequent model changes, relatively small batches of production, and learning-by-doing in production. The manufacture and assembly of small and medium-sized computers are also located near design facilities (Hekman, 1985). Minicomputer production is more dispersed than that of mainframes but design and assemble is relatively close to headquarters, geographically concentrated in Massachusetts and in California, while components and peripherals are made in a variety of locations, for example, North Carolina and Arizona. Microcomputer production is even more dispersed than that of minicomputers. Production of peripheral equipment is also decentralized, with printers and terminals manufactured in large branch plants in states with relatively low labor costs such as Tennessee, South Dakota, and North and South Carolina. Individual computer components are often produced in low-wage developing countries (Flynn, 1988: 14-15). A general conclusion can be drawn: as some products become relatively standardized, they can be produced in peripheral regions to capture lower labor costs, while new products remain close to technological R&D centers.

New growth in high-technology 'regions' occurs through the creation of new firms, the expansion of existing firms, and by the diffusion of branch plant locations. Not all new firm growth in high-technology regions is based on pioneers and early entrants in emerging industries. Most new high-technology firms enter markets where barriers to entry are low, and are followers and imitators that find markets in manufacturing and service industries with knowledge and information obtained from established firms (Miller and Côté, 1987). The diffusion of new technologies has allowed these new firms to avoid costly initial investments in developing technologies.

The majority of firms in high-technology regions are small firms, such as suppliers of parts, components, and services, that are oriented toward the local market. The local market for high-technology products and services is derived from local capital-intensive manufacturing corporations and local commercial financial and service businesses. Only a small number of these locally oriented high-technology firms will eventually develop into externally oriented producers (Miller and Côté, 1987: 49).

Firm size is not a prerequisite for success in high-technology fields. Furthermore, without existing product lines at stake, new firms may have a greater incentive to develop new products than market leaders (Flamm, 1987). With the evolution and diffusion of new technologies based on microelectronics to hardware and later to software, the growth of new firm formation has subsided and industry rationalization has occurred. The cost of innovative and R&D activities in established technology centers has become increasingly expensive and competitive. Regardless of these barriers to entry, many market niches are open to new firms, in developed and developing country locations.

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