Revista de Economia Política das Tecnologias da Informação e Comunicação
www.eptic.he.com.br Vol.III, n.1, Ene/Abr 2001

Relatos de Investigación

Technological change and Development: Conceptual considerations

Dean Lee Hansen[49]

Abstract

This paper studies technological change in Developing Country contexts. Notions of technological dependence, transfers of technology, technological capability, and the spatial manifestation of these variables are discussed. Processes of technological advance are analyzed conceptually and theoretically, by questioning how firms acquire the capability to use technology more efficiently. Developing regional technological capabilities, it is argued, is a necessary condition for steady and continuing processes of technological change in peripheral areas, and arises through the technological efforts of people, firms, and regions.

Introduction

Technological advances have set in motion a powerful combination of processes and forces of change. Analyses of the varied impacts, both positive and negative, of global processes based on new technologies in Developing Country contexts, distinguishes an important area of research. Within the literature one may find many contrasting views on the impact of new technologies in developing regions.

On one hand, there are those who argue that new technologies have globalized economic activities, decentralized of production, and thus spread the benefits of industrialization to Developing Countries. That use of new technologies will allow for better cost-effective services, even in isolated rural areas, such as health assistance, and, in general, increase access to information and thus promoting development. Moreover, that the adoption of new technologies provides Developing Countries the potential to leapfrog up the technological trajectory without costly research expenditures (World Bank, 1997; Azzoni, 1995).

[49] Ph.D em Economia pela Universidade de Washington (EUA) do Departamento de Economia da Universidade Federal de Sergipe.

On the other hand, there are convincing arguments that new technologies lead to increased dependence on Industrialized Countries- where the technology is developed - and relegate their position in the new global economy to simple activities such as assembly production (Bhalla and James, 1988; Kaplinsky, 1984). 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.

Due to the paucity of empirical research on the role of new technologies in developing economies, many arguments largely rest on speculation. Moreover, much of the current debate on the impact of new technologies in developing economies treats the 'Developing Country' as a single entity, rather than examining the varied regional effects *within* the country. Structural changes associated with global technological changes have profound spatial influences, with varied and complex reactions among each region within a country. Technological development, dependent on regional technological and socioeconomic structures ('local' as opposed to 'country'), more accurately create new patterns and hierarchies of wealth creation, presenting opportunities for some regions and threats to others. However, not only regional economic growth and dynamism are affected. The implications of new technologies are far reaching, including transformations, both direct and indirect, that are social, cultural, political, and urban in nature (Geiger, 1995). It is not clearly understood, for example, to what extent new technologies solidify (or diminish) the dominant economic position of current urban/industrial centers. Much less understood are the economic, social, cultural, political and urban changes that are presently occurring in peripheral regions (such as the Northeast of Brazil) as a result of globalization processes (Jaramillo and Cuervo, 1990; Gonçalves, 1994; Guimarães and Castro, 1990). Development issues, such as the dependency-inducing tendencies of new technologies and possible avenues for technological development, are not only of vital importance in the present global economy, but also demand attention from academic researchers.

Processes of globalization, or the internationalization of 'activities,' include a powerful set of forces and changes that are not geographically uniform; likewise, when cities, regions, or countries interact with larger-scale global processes specific outcomes are often difficult to predict (Dicken, 1992). Globalization itself is not a new phenomenon, colonialism being a case in point. What distinguishes the present global economy is the extent that capitalism has expanded, transformed, and even determined economic conditions in most parts of the world. Based on scientific-technological innovations in areas such computers, communications, robotics, and genetic engineering, capitalism, through globalization, has left its imprint on virtually all regions of the world. Sassen (1991) characterizes the global economy as a complex duality: geographic dispersal of economic activity, yet an organization that is globally integrated. In other words, and international division of labor continues, although perhaps more accurately labeled a regional division of technological capabilities (Hansen, 1990). Storper (1994) reminds us that the trajectory of technology goes on regardless; while some regions will gain - *learning regions*, others will be bypassed. Those regions *apparently* bypassed, however, yet still face profound modifications (Leborgne and Lipietz, 1990). Processes of globalization, as such, threaten to increase regional inequalities, principally those regions lacking technological capabilities to adjust to new advances in economic activities.

This present work analyses conceptual processes of developing technological capabilities. Notions of technological change and development will be reviewed. It is argued that economic activity and a general economic infrastructure broadly define the initial parameters of technological capability. 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. 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). Local structures such as research universities, institutions and organizations figure prominently in defining a regional human infrastructure. They employ and generate human resources and provide an environment for work, 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). Regional technological capacity is dependent on educational and research facilities, and a network of information linkages within the general economic environment.

Regional characteristics, broadly based on technological capabilities, are significant in understanding how localities interact with larger-scale global processes. Regions with technological capabilities, or regions that institute local policies to promote technological capabilities, are more likely to successfully adapt to global changes, regions without are more likely to stagnate. Local resources and skills are, more than ever before, vital if regions are to adjust to global processes (Storper, 1990; Boisier, 1996). The dilemma for peripheral regions is that global forces of change are pervasive, with the ability to directly and indirectly affect them, regardless, and thus pressuring them to change. How will peripheral regions without technological capabilities survive with current standards of economic success that are based on, for example, flexibility and automation.

Regional changes based on globalization process are currently in evidence. Clearly, new technologies have led to the creation of new regions of economic growth in the Industrialized Countries, for example, the Southern region of the U.S.A. (similar, relatively, to Brazil's Northeast region). Trends in the Industrialized Countries, however, may not be reflected in Developing Countries. Although new systems of production create new centers of growth, often secondary cities, and thus may reduce spatial economic polarization, the task for peripheral regions is to create the necessary policies to attract these new activities and promote indigenous growth.

In this work theoretical concepts are combined to shed light on the development of technology capability. The first section identifies concepts and processes that are integral to an analysis of technology in Developing Country contexts, begins by defining technological dependence. The second section treats the issue of transfers of technology, and how development may be derived from transfers of technology. The final section discusses 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.

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 Developing Country 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, 1988).

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 common side affect of *inhibiting local technological efforts* (Alschuler, 1988: 18).

The central indicator of technological dependence 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).

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 Science and Technology system (S&T) ➔ 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 transnational corporations (TNCs).

Many authors have emphasized the negative effects of technological dependence related to reliance on transnational corporation technology 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, let alone adapt.

Developing Countries have traditionally relied on transnational corporations 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). 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 *inhibit* indigenous R&D and technology capabilities.

Allowing for technological dependence to occur in the short-run, however, may complement the long-run objective of technological self-reliance (Watanabe, 1985). Note the heavy use of foreign technologies by Japan in the 1950s and 1960s and subsequent rapid rise of an indigenous technological capacity. Other 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).

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 pursue a strategy of 'catch up' to more technologically advanced countries, presupposes an indigenous technological capacity.

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. Indigenous technology is less clear, and is a relative concept. In some 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[50].

[50]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.

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 a number of potential suppliers of technology, including individuals, corporations, government agencies, universities, and research institutes (Smith, 1981).

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

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).

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[51] 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[52] 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.

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).

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

Education abroad is, historically, 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 *et al*, 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:

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). Transferors of technology commonly impose a variety of restrictions or conditions regarding the use of the technology transferred, including, for example, tied-buying provisions that require the technology recipient to buy certain inputs from the transferring firm, not in the open market, or export restrictions (Robinson, 1988: 74-76).

---

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

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 often helps 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. 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 may 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 steps from the consideration of a foreign technology to the point where it has been indigenously mastered. 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 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. (UNIDO, 1984). When products, processes, and other firm activities are enhanced, this is referred to as improvement (Enos and Park, 1988).

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. Firm imitation and adoption during the process of diffusion make many improvements and innovations. User experience, competition between suppliers, and applying the innovation in a new environment stimulate recipient technological improvements and innovation (Thomas, 1985; Freeman, 1988a). The different types of complexities associated with each technology may intensify these processes:

> *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 significantly depends on the diffusion of new technologies at the international and national level. For example, a new 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 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 regions (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 the previous section pointed out the dangers and limitations of technology transfers, 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.

An important cause 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 practice, time, and mistakes must train people, which may make innovation costly, and too risky. It is important to remember that regional infrastructure variations result in differential costs for firms to acquire scientific and technical knowledge for otherwise equally endowed firms.

The process of using more indigenous technologies may be gradual and depends in part on how technology is imported. As shown in Table 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.

Table 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).

To obtain more indigenous innovation, or a capacity for more sophisticated industrialization, developing regions are forced to create local R&D capabilities. While several Developing Countries are actively attempting to shift the origin of technologies from foreign to more indigenous, it is recognized that foreign technologies are, and will continue to be, imported either formally or informally. Imported technology often limits learning-by-doing by the local labor force, and, if the technology *could* have been produced locally, employment opportunities are lost and valuable hard currencies are be needlessly spent (Britton, 1985; Benson and Lloyd, 1983). As a result, technology transfer agreements that maximize the know-how transferred should be fundamental to justify purchases of foreign technology.

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). When firms have R&D capacities, the licensing of foreign technology may be very beneficial, with an added benefit of reducing the disadvantages of costly R&D expenditures by spreading risks. R&D capacities allow firms to obtain better conditions from licensing, to increase learning and to reduce risk (Erber, 1981). The option most favorable to Developing Countries is to get the most from imported technology and import only when it contributes to the 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).

Transfers of technology contribute to technological capability when recipient firms learn how to change or adapt the 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 discussed in the following section.

Technological Capability

Technological change, which results from innovation, plays a significant role in increasing economic growth and productivity (Thomas, 1987; DeBresson, 1989). 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).

The study of technological change in Developing Countries 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 beyond its own relative technological limits, even though the technical problem has already been solved by other firms and is well within the technological frontier.

Accordingly, technological change in Developing Countries includes 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; and 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 and 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 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 capabilities 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[53]. While a

[53]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

technological capability refers to the necessary modifications and adaptations of technology transferred from foreign sources, a growing technological 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 regardless of whether or not the firm (or region, or country) is at the international frontier of technology, and 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 (covered later).

The acquisition of technological capabilities, for this work, is compartmentalized 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

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).

demands. A fourth stage, or the 'improvement stage,' refers to achieving 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 distinguish 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 generally have a more highly developed capital goods sector, and greater experience with different forms of industrial activity, including that of assimilating technology, but also organizational and managerial experience.

Further refinement of 'technological capability' forces us to look deeper into the nature of industrial activity. Technological capacity, according to Ranis (1984), is identified through its functionality; as 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, one may delineate 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 that requires applied R&D, or the knowledge of why it works the way it does and involves 'learning' of products. 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[54], 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 analyses 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

[54]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.

mechanism linking 'doing' and 'learning' with technical change (Bell, 1984; Fransman, 1985).

Technical change through learning involves explicit effort and investment; the accumulation of knowledge only sets the stage for technical change to take place (Bell, 1984). 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 to 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, 1981). Hence, protectionist policies may not be enough to promote explicit learning.

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. 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, make small, perhaps, but important technology changes. As engineers, technicians, managers, and manufacturers gain knowledge of industrial processes, equipment and industrial processes formally imported 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 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 processes suggest an active role for the firm, as well as the presence of uncertainty (Fransman, 1985). The search process 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: 171), 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 technologies, which 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." 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 a 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., the 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, 1991). 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. The first three technological activities listed below involve know-how knowledge (1-3), and the last two require know-why knowledge (4-5). 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 regions involve steps 1 through 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 genetic engineering industry.

Regardless of these ambiguities, 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 new technology tends to 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 is significantly affected by geography. 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 technological progress. Figure 1 depicts elements of technological capability by differing geographical scales. Of particular importance are the system of technology-related structures and the linkages between them, that tend to concentrate spatially within a country, or regionally, rather than equally throughout a country.

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 education and entrepreneurship. These technological features of a region are not easily transferable to others (Malecki, 1988). Hence, the region, or, as used in this work, the regional technological infrastructure, is a key variable and dimension of technological capability.

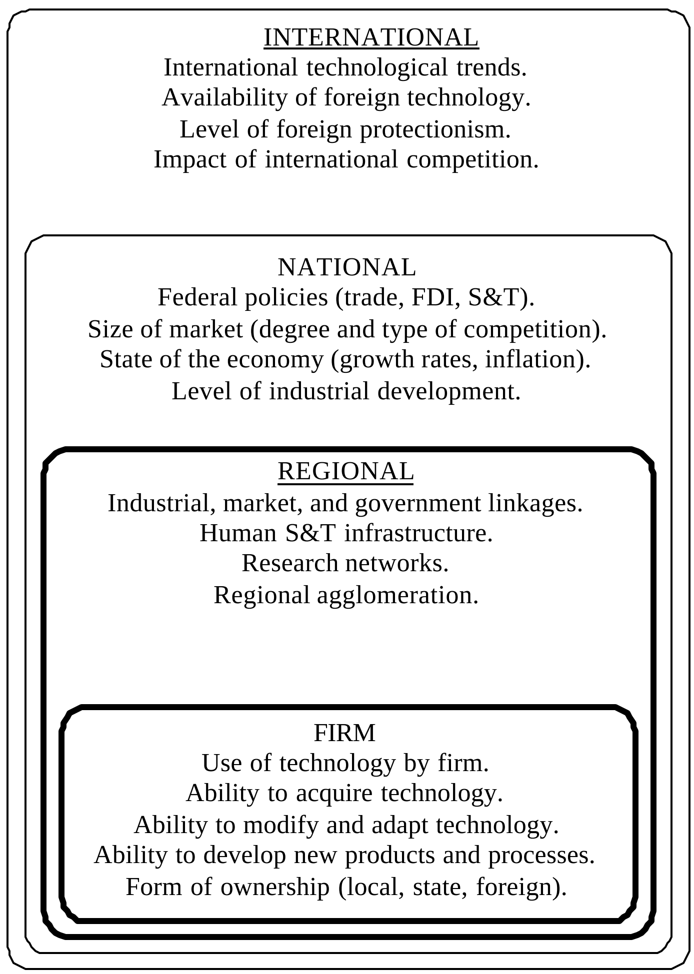

Figure 1 Factors Defined by Spatial Scales that Influence and stimulate the Development of Technological Capability.

The use of 'linkage' goes beyond the traditional concept of industrial linkages. As Krumme (1984: 112) suggests, "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."

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 illustrates that learning and technological accumulation takes place in people, firms, and regions.

Conclusions

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.

Focus on the implications of importing foreign technologies gave way from the late 1970s to analysis which examined 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; 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, it includes the ability to choose, acquire, generate and apply technologies that are most advantageous to that particular firm or country.

Technological capability, although its benefits are difficult to determine quantitatively or even describe with statistical precision, is a fundamental component of industrialization. It benefits industrialization by effectively regulating and reducing the cost of technology imports, leading to the development and production of more 'appropriate' technologies, stimulating the creation of vital backward linking industries, increasing the use of local raw materials and the formation of new skills, and creating a stronger sense of self-reliance and confidence. Not surprisingly, a key constraint for the indigenous development of technology (as for importing and assimilating foreign technology) is the lack of requisite S&T regional capabilities; or knowledge and skills embodied in people and localities.

References

ALSCHULER, Lawrence (1988) *Multinationals and Maldevelopment*, London: The MacMillan Press Ltd.

AZZONI, Carlos Roberto (1995) *Formação Sócio-Espacial Metropolitana: Novas Tendências ou Novas Evidências?.* In:– Maria Flora Gonçalves (organizadora) *O Novo Brasil Urbano: Impasses, Dilemas, Perspectivas*, Porto Alegre: Mercado Aberto.

BARANSON, Jack and ROARK, Robin, (1985) *Trends in North-South Transfer of High Technology.* In:– Nathan Rosenberg and Claudio Frischtak (eds) *International Technology Transfer: Concepts, Measures, and Comparisons,* New York: Praeger Special Studies.

BEHRMAN, Jack N. and FISCHER, William A. (1980) *Science and Technology for Development*, Cambridge: Oelgeschlager, Gunn and Hain Publishers, Inc..

BELL, Martin (1984) *'Learning' and the Accumulation of Industrial Technological Capacity in Developing Countries*, In:– Martin Fransman and Kenneth King (eds) *Technological Capability in the Third World*, London: Macmillan Press.

BENSON, Ian and LLOYD, John (1983) *New Technology and Industrial Change*, New York: Nichols Publishing Company.

BHALLA, A. S. and JAMES, D. (1988) *Some Conceptual and Policy Issues*, In:– A. S. Bhalla and D. James (eds) *New Technologies and Development*, Boulder: Lynne Rienner Publishers.

BOISIER, Sergio. (1996) *Em Busca do Esquivo Desenvolvimento Regional; Entre a Caixa-Preta e o Projeto Político. Planejamento e Políticas Públicas*. N° 13, p. 111-145,.

BRITTON, John N. H. (1985) *Research and Development in the Canadian Economy: Sectoral, Ownership, Locational and Policy Issues*,, In:– A. T. Thwaites, and R. P. Oakey (eds) *The Regional Economic Impact of Technological Change*, London: Frances Pinter Publishers.

CHOI, Hyung Sup (1988) *Science Policy Mechanism and Technology Development Strategy in the Developing Countries*. In *Technological Forecasting and Social Change*, 33, pp. 279-292.

CIMOLI, M. and DOSI, Giovanni (1988) *Technology and Development: Some Implications of Recent Advances in the Economics of Innovation for the Process of Development*, In:– Atul Wad (ed) *Science, Technology and Development*, Boulder: Westview Press, Inc.

DAHLMAN, Carl and WESTFALL, Larry (1982) *Technological Effort in Industrial Development - An Interpretative Survey of Recent Research*, In:– Frances Stewart and Jeffrey James (eds) *The Economics of New Technology in Developing Countries*, London: Frances Pinter Publishers.

DAHLMAN, Carl J. (1984) *Foreign Technology and Indigenous Technological Capability in Brazil*, In:– Martin Fransman and Kenneth King (eds) *Technological Capability in the Third World*, London: Macmillan Press.

DEBRESSON, Chris (1989) *Breeding Innovation Clusters: A Source of Dynamic Development*, In *World Development*, January, pp. 1-16.

DICKEN, Peter (1992) *Global Shift*, New York: The Guilford Press.

DOSI, Giovanni and ORSENIGO, Luigi (1988) *Industrial Structure and Technical Change*, In:– Arnold Heertje (ed) *Innovation, Technology, and Finance*, Oxford: Basil Blackwell.

ENOS, J. L. and PARK ,W. -H. (1988) *The Adoption and Diffusion of Imported Technology: The Case of Korea*, London: Croom Helm.

ERBER, Fabio (1981) *Science and Technology Policy: A View from the Periphery*, In:– Joseph S. Szliowicz (ed) *Technology and International Affairs*, New York: Praeger Publishers.

ERNST, Dieter (1981) *Technology Policy for Self-Reliance: Some Major Issues*, In *International Social Science Journal*, No. 3, pp. 466-480.

EVANS, Peter (1979) *Dependent Development*. Princeton: Princeton University Press

FRAME, J. Davidson (1983) *International Business and Global Technology*, Lexington: Lexington Books.

FRANSMAN, Martin (1985) *Conceptualising Technical Change in the Third World in the 1980s: An Interpretive Survey*. In *The Journal of Development Studies*, July, pp. 572-652.

FRANSMAN, Martin (1984) *Technological Capability in the Third World: an Overview and Introduction to some of the Issues Raised in this Book*, In:– Martin Fransman and Kenneth King (eds) *Technological Capability in the Third World*, London: Macmillan Press.

FREEMAN, Chris (1988a) *Diffusion: The Spread of New Technology to Firms, Sectors, and Nations*, In:– Arnold Heertje (ed) *Innovation, Technology, and Finance*, Oxford: Basil Blackwell.

FREEMAN, Christopher (1988b) *Japan: A New National System of Innovation?*; In:– Giovann Dosi, Christopher Freeman, Richard Nelson, Gerald Silverberg, and Luc Soete (eds) *Technical Change and Economic Theory,* London: Printer Publishers.

GEIGER, Pedro P. (1995) *A Urbanização Brasileira nos Novos Contextos Contemporâneos,* In:– Maria Flora Gonçalves (organizadora) *O Novo Brasil Urbano: Impasses, Dilemas, Perspectivas,* Porto Alegre: Mercado Aberto.

GONÇALVES, Maria Flora (1994) *Uma de Muitas Facetas da Paradoxal Urbanização Brasileira*, In:– Francisco Capuano Scarlato, Milton Santos, Maria Adélia A. de Souza, e Monica Arroyo (organizadores) *Globalização e Espaço latino-americano*, São Paulo: Editora HUCITEC.

GUIMARÃES, Antônio Sérgio Alfredo e CASTRO, Nadya A. (1990) *Classes, Regimes Fabris e Mudança Social no Nordeste Brasileiro*, In:– Licia Valladares e Edmond Preteceille (organizadores) *Reestruturação Urbana: Tendências e Desafios*, São Paulo: Livraria Nobel, S. A.

HANSEN, Dean L. (1990) *Acquiring High-Technology Capability: The Case of the Brazilian Informatics Industry,* The University of Washington, Ph.D. dissertation.

HALTY-CARRERE, Maximo (1979) *Technological Development Strategies for Developing Countries*, Montreal: Institute for Research on Public Policy.

HAYTER, Roger (1988) *Technology and the Canadian Forest-Product Industries: A Policy Perspective*, Background Study 54.

HEERTJE, Arnold (1988) *Technical and Financial Innovation,* In:– Arnold Heertje (ed) *Innovation, Technology, and Finance*, Oxford: Basil Blackwell.

HELLEINER, G.K. (1977) *International Technology Issues: Southern Needs and Northern Responses*, In:– Jagdish N. Bhugwati (ed) *The New International Economic Order: The North-South Debate* Cambridge: The MIT Press.

JACOBSEN, John Kurt (1987) *Peripheral "Postindustrialization": Ideology, High Technology, and Dependent Development*, In:– James A. Caporaso (ed) *A Changing International Division of Labor*, Boulder; Lynne Rienner Publishers.

JAMES, Jeffrey and WATANABE, Susumu (1985) *Introduction*, In:– Jeffrey James and Susumu Watanabe (eds) *Technology, Institutions and Government Policies*, London: Macmillan.

JARAMILLO, Samuel e CUERVO, Luis Mauricio (1990) *Tendências Recentes e Principais Mudanças na Estrutura Espacial dos Países Latino-Americanos*, In:– Licia Valladares e Edmond Preteceille (organizadores) *Reestruturação Urbana: Tendências e Desafios*, São Paulo: Livraria Nobel, S. A.

KAMENETZKY, Mario (1979) *Preinvestment Work and Engineering as Links Between Supply and Demand of Knowledge*, In:– D. Babatunde Thomas and Miguel S. Wionczek (eds) *Integration of Science and Technology with Development*, New York: Pergamon Press.

KAPLINSKY, Raphael (1984) *Automation: The Technology and Society*, Essex: Longman Group Limited.

KNG, Chng Meng; LOW, Linda, NGA, Tay Boon; and TYABJI, Amina (1986) *Technology and Skills in Singapore*, Singapore: Institute of Southeast Asian Studies.

KOBRIN, Stephen J. (1979) *Multinational Corporations, Sociocultural Dependence, and Industrialization: Need Satisfaction or Want Creation?*, Journal of Developing Areas, January, pp. 109-125.

KRUMME, Günter (1984) *Turbulent Environments, Corporate Strategies and Local Employment Perspectives*, GeoJournal, 9.2, pp. 111-119.

LALL, Sanjaya (1987) *Learning to Industrialize: The Acquisition of Technological Capability by India*, London: Macmillan Press.

LALL, Sanjaya (1982) *Technological Learning in the Third World: Some Implications of Technology Exports*, In:– Frances Stewart and Jeffrey James (eds) *The Economics of New Technology in Developing Countries*, London: Frances Pinter Publishers.

LALL, Sanjaya (1980) *Developing Countries as Exporters of Industrial Technology*, Research Policy, 9, pp. 24-52.

LEBORGNE, Danielle e LIPIETZ, Alain (1990) *Flexibilidade Defensiva ou Flexibilidade Ofensiva: Os Desafios das Novas Tecnologias e da Competição Mundial*, In:– Licia Valladares e Edmond Preteceille (organizadores) Reestruturação Urbana: Tendências e Desafios, São Paulo: Livraria Nobel, S. A.

LYONS, Bruce (1987) *International Trade and Technology Policy*, In:– Partha Dasgupta and Paul Stoneman (eds) Economic Policy and Technological Performance, Cambridge: Cambridge University Press.

MALECKI, Edward J. (1991) *Technology and Economic Development: The Dynamics of Local, Regional, and National Change*, Essex: Longman Scientific and Technical.

MALECKI, Edward J. (1988) *Research and Development and Technology Transfer in Economic Development: The Role of Regional Technological Capability*, Paper prepared for the 1988 European Summer Institute of the Regional Science Association, Arco, Italy.

MALECKI, Edward J. (1981a) *Product Cycles, Innovation Cycles, and Regional Economic Change*, Technological Forecasting and Social Change, 19, pp. 291-306.

MALECKI, Edward J. (1981b) *Science, Technology, and Regional Economic Development: Review and Prospects*, Research Policy, 10, pp. 313-334.

MASSEY, Doreen (1984) *Spatial Divisions of Labour*, London: Macmillan.

MCNAMARA, Kevin T.; KRIESEL, Warren P.; and DEATON, Brady J. (1988) *Human Capital Stock and Flow and Economic Growth Analysis: Note*, Growth and Change, Winter, pp. 61-66.

MYTELKA, Lynn K. (1979) *Regional Development in a Global Economy: The Multinational Corporation, Technology, and Andean Integration*, New Haven: Yale University Press.

MÜLLER, Ronald (1979) *Poverty is the Product*, In:– George Modelski (ed) Transnational Corporations and World Order, San Francisco: W.H. Freeman and Company.

NICHOLS, Rodney W. (1984) *Linking R&D with Production in the Third World, Technology in Society*, Vol. 6, pp. 95-108.

OAKEY, R.P., THWAITES, A.T. and NASH, P.A. (1982) *Technological Change and Regional Development: Some Evidence on Regional Variations in Product and Process Innovation*, Environment and Planning A, 14, pp. 1073-86.

PEREZ, Carlota and SOETE, Luc (1988) *Catching Up in Technology: Entry Barriers and Windows of Opportunity*, In:– Giovann Dosi, Christopher Freeman, Richard Nelson, Gerald Silverberg, and Luc Soete (eds) *Technical Change and Economic Theory*, London: Pinter Publishers.

RANIS, Gustav (1984) *Determinants and Consequences of Indigenous Technological Activity*," In:– Martin Fransman and Kenneth King (eds) *Technological Capability in the Third World*, London: Macmillan Press.

ROBINSON, Richard D. (1988) *The International Transfer of Technology: Theory, Issues, and Practice*, Cambridge: Ballinger Publishing Company.

ROMAN, Daniel D. and PUETT, Joseph F., Jr. (1983) *International Business and Technological Innovation*, New York: Elsevier Science Publishing Co., Inc.

ROTHWELL, Roy (1986) *Technological Change and Reindustrialization: In Search of a Policy Framework*, In:– Jerry Dermer (ed) Competitiveness through Technology, Lexington: Lexington Books.

SAHAL, Devendra (1983) *Technology, Productivity, and Industry Structure*, Technological Forecasting and Social Change, 24, pp. 1-13.

SASSEN, Saskia (1991) *The Global City*, Princeton; Princeton University Press.

SMITH, Charles H. (1981) *Japanese Technology Transfer to Brazil*, Ann Arbor: UMI Research Press.

STEWART, Frances (1988) "Comments on 'Technology, Productivity Growth, and Economic Development'," In:– Gustav Ranis and T. Paul Schultz (eds) *The State of Development Economics: Progress and Perspectives*, Oxford: Basil Blackwell.

STORPER, Michael (1994) *Desenvolvimento Territorial na Economia Global do Aprendizado: o Desafio dos Países em Desenvolvimento*, In:– Luiz César de Qeiroz Ribeiro e Orlando Alves dos Santos Júnior (organizadores) *Globalização, Fragmentação, e Reforma Urbana: O Futuro das Cidades Brasileiras na Crise*, Rio de Janeiro: Editora Civilização Brasileira S.A..

STORPER, Michael (1990) *A Industrialização e a Questão Regional no Terceiro Mundo*, In:– Lucia Valladares e Edmond Preteceille (organizadores) Reestruturação Urbana: Tendências e Desafios, São Paulo: Livraria Nobel, S. A.

STORPER, Michael (1984) *Who Benefits from Industrial Decentralization? Social Power in the Labor Market, Income Distribution and Spatial Policy in Brazil*; Regional Studies vol.18.2, pp. 143-164.

TEUBAL, Morris (1987) *Innovation Performance, Learning, and Government Policy*, Madison: The University of Wisconsin Press.

TEUBAL, Morris (1984) *The Role of Technological Learning in the Exports of Manufactured Goods: The Case of Selected Capital Goods in Brazil*, World Development, Vol. 12, No. 8, pp. 849-865.

TIGRE, Paulo Bastos (1983) *Technology and Competition in the Brazilian Computer Industry*, London: Frances Pinter Publishers.

THOMAS, Morgan D. (1987) *The Innovation Factor in the Process of Microeconomic Industrial Change: Conceptual Explorations*, In:– Bert Van Der Knapp and Egbert Wever (eds) New Technology and Regional Development, London: Croom Helm.

THOMAS, Morgan D. (1985) *Regional Economic Development and the Role of Innovation and Technological Change*, In:– A. T. Thwaites, and R. P. Oakey (eds) *The Regional Economic Impact of Technological Change*, London: Frances Pinter Publishers.

THOMAS, Morgan D. (1979) *Economic Development, Technological Change, and the New International Economic Order*, Geoforum, Vol. 10, pp. 129-140.

THOMAS, Morgan D. and LE HERON, Richard B. (1975) *Perspectives on Technological Change and the Process of Diffusion in the Manufacturing Sector*, Economic Geography, 51, pp. 231-251.

TÖDTLING, Franz (1984) *Organizational Characteristics of Plants in Core and Peripheral Regions of Austria*, Regional Studies, Vol. 18.5, pp. 397-412.

UNCTC (1987) *Transnational Corporations and Technology Transfer: Effects and Policy Issues*, ST/CTC/86, United Nations Publication.

UNGER, Kurt (1988) *Industrial Structure, Technical Change and Microeconomic Behaviour in LDCs*, In:– Giovann Dosi, Christopher Freeman, Richard Nelson, Gerald Silverberg, and Luc Soete (eds) Technical Change and Economic Theory, London: Pinter Publishers.

UNIDO (1984) *Technological Self-Reliance of the Developing Countries: Toward Operational Strategies*, In:– Pradip K. Gosh (ed) Technology Policy and Development: A Third World Perspective, Westport: Greenwood Press.

VAITSOS, Constantine V. (1976) *Power, Knowledge and Development Policy: Relations between Transnational Enterprises and Developing Countries*, In:– G.K. Helleiner (ed.) A World Divided, Cambridge: Cambridge University Press.

WATANABE, Susumu (1987) *Technological Capability and Industrialisation: Effects of Aid and Sanctions in the United Republic of Tanzania and Zimbabwe*, International Labour Review, pp. 525-541.

WATANABE, Susumu (1985) *The Patent System and Indigenous Technology Development in the Third World*, In:– Jeffrey James and Susumu Watanabe (eds) Technology, Institutions and Government Policies, London: Macmillan.

WEISS, John (1988) *Industry in Developing Countries: Theory, Policy and Evidence*, London: Croom Helm.

WESTPHAL, Larry E. (1982) *Fostering Technological Mastery by Means of Selective Infant-Industry Protection*, In:– Moshé Syrquin and Simón Teitel (eds) *Trade, Stability, Technology, and Equity in Latin America*, New York: Academic Press.

WORLD BANK (1997) *Global Knowledge Conference – 1997*, http://www.worldbank.org.

YOUNG, S.; Hood, N. and DUNLOP, S. (1988) *Global Strategies, Multinational Subsidiary Roles and Economic Impact in Scotland*, Regional Studies, Vol. 22.6, pp. 487-497.