SCIENCE AND TECHNOLOGY POLICY IN BRAZIL:
A Review of the Literature*

Fábio Stefano Erber

1. INTRODUCTION

The texts discussed below treat the problem of the relationship between economic and social development and the development of science and technology. The review is not proposed as exhaustive, but concentrates on the manufacturing sector; and it does not deal with specific literature concerning such important topics as agriculture, energy, transportation, and the relationship between science and technology policy and education (however, the first of these is treated in a complementary study [Albuquerque and Nascimento 1978]). Also, the description of science and technology policy measures and of the institutional apparatus that implements them is reduced to a minimum, although bibliographic sources in which more detailed descriptions can be found are indicated. Given these constraints, an attempt has been made to take into account the complexity of the topic and the variety of research that it has inspired. In this sense, contributions from noneconomists, notably sociologists and political scientists, are incorporated; we refrain, however, from any evaluation of the theoretical framework that guides such contributions.[1]

Section 2 presents works that discuss the role of science and technology in the process of capitalist development, which tend to focus

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principally on the central countries of the world system. Of the studies that focus more specifically on Brazil, section 3 treats those that (1) discuss the problem of technological dependency and its ramifications, (2) discuss the diffusion of innovation in the country, and (3) analyze the role of the state in the generation and diffusion of science and technology in Brazil. Section 4 deals with works that emphasize the consequences of the use of technology for Brazilian development—its role in industrial growth, in the balance of payments, and in employment and income distribution. Finally, an attempt is made to assess the state of the arts (as of the end of 1978). One of the purposes of this review is to suggest topics for future research and, although suggestions appear throughout the text, section 5 concludes with additional areas that should be researched.

2. SCIENCE AND TECHNOLOGY IN THE PROCESS OF CAPITALIST DEVELOPMENT

The role played by scientific and technological production in the process of capitalist development was discussed in detail by the classical economists (notably Ricardo and Marx); after a long neoclassical interruption (with the brilliant exception of Schumpeter), it was "rediscovered" after the Second World War (see, for example, Rosenberg 1976). Beginning in the 1950s, an extensive literature was produced in the advanced countries, discussing the effects of technical and scientific progress on the process of growth and the economic and social conditions that influence that progress (see, for instance, Heertje 1977).

A substantial part of the neoclassical literature of the advanced countries has analyzed the role of technical progress in economic growth using aggregate production functions, in which the contributions of "capital" and "labor" to the total growth of the product are evaluated, with the portion of growth not explained by those two factors (the "residual") being attributed to technical progress. In Brazilian research, Bonelli (1976) presents a detailed review and critique of such literature. He deals mainly with the "internal" problems of this approach—the level of aggregation, estimation problems, etc.—but also comments upon the restrictions that the "Cambridge controversy" imposed on the neoclassical approach (notably the question of how to measure "capital").

Another approach, which has greater explanatory power but is less preoccupied with measurement, considers the questions raised by the classical economists—looking at technical progress through its role in capitalist accumulation, and distinguishing the different parts it plays under different historical and competitive conditions. Within this perspective, Tolipan (1974) and Erber (1977a) call attention to the historical nature of technical progress (an important aspect lost in the neoclassical treatment that tends to see it as "natural" and, to a considerable extent, autonomous) and discuss it on two levels: first by comparing different modes of production, each mode being characterized by specific labor processes and a different technical structure; and second, within the capitalist mode of production, by noting the changes in the role played by technical progress according to the relationship between workers and capitalists and according to changes in the conditions of competition.[2]

In two recent studies, Barbosa (1978a, b) analyzes the evolution of technology as a commodity, showing how the legal forms of such a commodity and the commodity itself are modified as a result of the transformation of conditions of production and commerce within the capitalist system.[3] Several authors (Rattner 1973, Pena 1976) stress that technology and science can serve to maintain power structures: within the productive units this is accomplished through the organization of the labor process; at a broader level of society, this is achieved through the depoliticization of economic and social questions (giving them a technical and "neutral" nature), as well as through the use of technology and science to predict and manipulate society. Moreover, by valuing science and technology as intrinsically good and a benefit to everyone, scientific and technological achievements can be used as legitimizing elements for the economic and political structure in force.

At the level of the firm, Erber (1977a) discusses in detail the role that technical progress can have in the expansion of the surplus of a capitalist enterprise through reductions in the constant and variable costs, modifications in the market prices, and growth of sales. That analysis is complemented by a discussion of the conditions that induce a company to invest in research and development (R and D), with an indication that companies invest in science and technology only when they have no other alternative. In a later work (1977b), Erber returns to some of the points raised by Nelson (1971) and Arrow (1971), applying them to the specific case of the capital goods industry. He argues that, from a social point of view, the characteristics of property and decision-making in the capitalist system lead to an underinvestment in R and D by private business, largely because of externalities (the inability of the investing company to fully appropriate the results of its research) and differences between the perspectives of the private company and society with respect to risks and time—which serve to justify state support of investments in R and D.[4]

In discussing the conditions favorable to investment in R and D, the international literature often links the increase of concentration and size of companies to the increase of innovations in the capitalist system following the Second World War (the "Schumpeterian hypothesis").[5]

Until recently, the Brazilian literature on technical progress (Rattner 1974, for example) also tended to accept the acceleration of the introduction of innovations as a fact. Those ideas are countered by Castro and Araujo (1978), who point out (1) that there is a concentration of innovations in key sectors (petrochemicals, electronics, and computers), from which they spread to the rest of the economy, and (2) that "despite the great expenditures on R and D, a kind of saturation in the development of the same ideas has apparently been reached" (p. 156). When they point out that innovations are not a linear function of R and D expenditures and deny the correlation between the size of the enterprise and its success as an innovator, they suggest several theoretical and empirical questions with important economic and political implications. At a general level, one such question stands out: that of the relation between capital and technology.[6] Castro and Araujo imply that capital has only partial control over technical knowledge; that it has more influence over the moment of its introduction into the productive apparatus than over the generation of such knowledge itself.

The relationship between capital and the generation of knowledge has been treated in more detailed and explicit form in the texts dedicated exclusively to scientific policy. Franken (1978), for example, points to two characteristics of the scientific community—its social specificity (a community that "neither overcomes the underlying class structure nor allows itself to be submerged by that structure") and its operational specificity (the legitimization by peers). He argues that to demand "useful" results from science is not only ineffective, given the autonomous character of the evolution of knowledge and the unpredictability of its results, but also counterproductive, since it jeopardizes proper scientific work.

In contrast, Pena (1976) concludes that scientific activity is closely linked to the production of surplus and constitutes a large investment. "For this reason, investment and control of science become the responsibility of the state. Tied to the state, science is transformed into a political and productive activity" (p. 24). Nevertheless, Pena recognizes that by incorporating science as an instrument of power, a "new contradiction is inserted into the apparatus of the state": between the necessity of state financial support of science and the fact that science is "above all a non-plannable activity" (p. 32).

According to Castro and Araujo, technical progress is highly differentiated by sector. The same is true of scientific progress—the process of producing knowledge and the mediations between the generation of knowledge and its utilization by society are differentiated according to the scientific fields (Schwartzman et al. 1979). More specific analyses are necessary to detail such connections. The questions raised by Castro and Araujo also point out the need for a deeper theoretical and empirical examination of the relationship between technical and economic cycles. Their work raises the issues of the bargaining power of developing countries vis-à-vis the rest of the system (notably multinational companies), due to the relative "shortening" of the technological lag, and of the appropriate scientific and technological policy at the periphery. They argue it would not be sensible to emulate the experience of the advanced countries when the latter are at a "true technological intersection" (p. 160). Such questions remain little explored in our literature.

3. SPECIFIC CONDITIONS IN BRAZIL

An important achievement of social theory since the Second World War has been the better understanding of the situation of countries originally integrated into the capitalist system as suppliers of primary goods, the "underdeveloped" countries. This understanding involves recognizing that the situation of such countries is historically specific; that their development is not a temporarily dephased repetition of that of the central countries of the system; and that the international division of labor in its present form does not necessarily lead to their development.

Until approximately the beginning of the 1960s, literature on scientific and technological development stressed the advantage to the underdeveloped countries of relying upon the large stock of knowledge from the advanced countries, so that they need not compromise scarce resources in costly and risky undertakings such as the development of new techniques.[7] There were exceptions for cases involving labor-intensive activities and the appropriate use of natural resources, but it was generally supposed that these problems would be solved through adapting the products and processes developed in the center, eventually by the adoption of "vintage" equipment and processes from a time when the central economies were more labor-intensive. In spite of the exceptions, there was widespread belief that investment in scientific and technological capability was not a priority for underdeveloped countries and that this capability would develop naturally along with economic growth. The same approach emphasized the role to be played by foreign investment—as a carrier of "technological modernization" and an "engine of growth"—and, consequently, the importance of policies creating a "favorable environment" for such investment. The optimistic perspective that economic growth would be accompanied by a blossoming of scientific activity was echoed in the pioneer work of Azevedo (1955) on the history of science in Brazil.

Around the 1960s, accompanying the emphasis on technical progress as an instrument of growth and capitalist competition, many

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authors (often scientists) began to question the benefits arising from the international division of technical and scientific work, and indicated the possibility that underdeveloped countries might not develop their own technical and scientific capacity unless deliberate measures were taken to that end (Leite Lopes 1964, 1969; Herrera, 1971). Thus, especially in Latin America, "technological dependency" became an element in the relationship linking the periphery to the center under the economic and political hegemony of the latter.

Two studies by the IPEA, on technological research conducted in Brazil and technology transfer from abroad (Biato et al. 1971, 1973), can be taken as the landmark of economic research on the specific conditions in Brazil.[8] Following an approach common in Latin American literature, the authors start with a model of the articulation of flows between the national productive system and (1) the technological, scientific, and educational system of the country, and (2) the "rest of the world." Biato et al. (1971) contrast the "efficient" functioning of this model (based on the experience of the central countries), where there is a constant interaction between the "productive system" and the local "scientific and technological systems," with the results of an investigation of the technological production of 46 research institutes and 454 industrial companies selected from the 500 largest in Brazil. The deviation from this efficient functioning that they observed in Brazil had "as a consequence an insufficiency of internal technology and a dependency on external know-how . . . pointing out the aspects to be focused upon by the national technological development policy" (pp. 137, 138). Although Biato et al. (1973) intended to study technology imports as a "real flow," corresponding to the incorporation by the national productive systems of technical knowledge developed abroad, and as a "nominal flow" of payments for imported technology, the data available (Central Bank contracts) led them to concentrate on the latter.

The data generated by Biato et al. (1971) show that in Brazil, activities of low technological complexity (notably tests) predominate in the research institutes, which maintain a precarious link with the productive system—scarcely a third of their activity is conducted in response to requests by third parties. The weak relationship between research institutes and the manufacturing sector could suggest that the industrial companies are self-sufficient, producing internally the technology that they require. However, the data show not only a great dependency upon foreign technology but a deepening of this dependency as well. The results indicated that 62 percent of the 454 companies in the survey utilized imported know-how, and showed an increase in the importance of foreign technology among companies founded more recently: 58 percent for those established before 1930 and 72 percent for those that began operations after 1965.

Information gathered from the 282 companies that resorted to imported technology when they were established reveals that, in general, such incorporation was not accompanied by internal efforts toward adaptation. This picture was supported by examination of the technological activity of the industrial companies in the period 1967–69: all research was restricted to adaptations of existing know-how. Although at times such activities involved improvements, in most cases this did not imply substantial modifications of the original technology. Biato et al. (1971) indicate that, although the percentage of foreign companies carrying out technological activities was greater than that of national companies, the latter tended to perform more complex activities. This was probably due to the fact that such activities required by foreign companies were carried out in their parent laboratories, abroad. Both studies by Biato et al. call attention to the heterogeneity of behavior within the industry—within industrial branches as well as between national or foreign ownership.

Thus, the five branches that lead industrial growth in Brazil were responsible for two-thirds of the technological activities of the sample and for the majority of import contracts. As regards ownership, local enterprises tended to be relatively more important than foreign firms in the realization of more complex technological activities and in imports of technology, which the authors argue is due to the special relationship between foreign subsidiaries and parent companies (see below).

Based upon an historical analysis, showing the evolution of the forms of incorporation of technology in Brazilian development, Biato et al. argue that the situation is the result of a combination of factors. In the *demand* for technology, consumers—who adopt consumption patterns from the more developed countries—induce a demand for external technology; the demands of foreign capital, especially in sectors that use advanced technology, are met predominantly by their headquarters abroad; and the "requirements of efficiency, orientation of internal demand, and of opening to the external market" force the more dynamic national companies to resort to "imported know-how" (Biato et al. 1971, p. 30). In the internal *supply* of technology, deficiencies in the scientific and technological system, coupled with the characteristics of demand, lead to a "process of circular causation, in which the absence of response in the past inspires few requests in the present, which, in turn, impedes stimulation of . . . any internal demand for know-how" (p. 139). This generates a double technological gap—the "absolute gap" separating the technology used internally from the latest innovations, and the "relative gap" corresponding to the imbalance between the internal demand for and the internal supply of technology.

For Biato et al., there are no inherent automatic corrective mechanisms that would lead to an effective articulation of the parts of the system. Therefore, there must be an intervention of "factors exogenous to the [scientific and technological] complex and to the productive system to determine a trajectory distinct from that actually observed. Such a possibility would depend on the action chosen by governmental agencies . . ." (p. 141). Since the authors were pessimistic about the medium-term possibilities for stimulating research activity in industrial companies, they suggested that government intervention should be oriented toward research institutes and universities.

Therefore, for Biato et al. (as for others, such as Stepan [1976], who approach the problem from a "systems analysis" viewpoint), technological dependency is both the cause and the consequence of the lack of articulation between the productive system and the scientific and technological complex. However, by assuming the efficacy of a model based on the experience of the advanced countries, they see the situation in Brazil as a "functional anomaly." This treatment reduces the importance of the specificity of the pattern of dependent development; it does not question the need for or the possibility of reproducing, within such a pattern of development, a specific system of economic and social relationships developed under substantially different conditions. Moreover, regarding the state as an element exogenous to the system tends to confer upon the state an autonomy of action that it does not possess while losing sight of the role that it does play in structuring these relationships.

The questions raised by Biato et al. were treated in more detail in a series of studies done principally at FINEP (Financiadora de Estudos e Projetos), to be discussed below. However, it should first be asked why any modification of the technological dependency would be desirable, and then, since there appears to be a consensus among authors that the intervention of the state would be necessary for such a modification, upon what basis this intervention would be justifiable.

Technological Dependency

For some authors who deal with technical progress in Brazil (Moura 1974, for example), technological dependency in industry is not a problem: since the country is "essentially agricultural, [that] sector must receive *priority one* in the allocation of resources devoted to research and development . . . the question of national technology developed through the private industrial sector must be postponed for some years,

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until minimum conditions . . . begin to appear'' (pp. 108–9). The priority of science and technology policy should be the diffusion of more modern techniques imported from abroad, complemented by local applied research in agriculture. Even those who see dependency as a problem (such as Biato et al. 1971) do not raise the question explicitly—it is answered a priori by assuming that the only efficient model of technical progress is that of the advanced countries, where there is a predominance of technology generated locally, and that deviations from this pattern are, by definition, inefficient.

Authors who discuss the question explicitly vary their answer according to their perception of the role that technology plays in the process of economic development. Thus, for Figueiredo (1972, 1974), who sees the introduction of technical progress in the economy as contributing mainly to a rational ''distribution of productive resources—investment resources especially—reflecting national, regional, and sectorial aptitudes for development, the economic requirements of scale of production, etc.'' (1974, p. 39), the objective should be to increase the incorporation of technical knowledge from abroad in order to increase the integration of the national economy with the world economy (p. 36). Within this perspective, the concern with technological autonomy should be postponed until the economy, in part through the import of technology, has achieved the conditions that lead to the endogenous generation of technology. The protectionist ''inefficiency'' of the pattern of import-substituting industrialization and the underdevelopment of the scientific and technological system are obstacles to this strategy, and the responsibility of the state should be to reorient industrial policy according to ''clear sectorial priorities,'' as well as to support the development of the scientific and technological system. This vision can be contrasted to that of Rattner (1973) and others (Tigre 1978, for example), for whom ''technological changes are equivalent to cultural changes, and their consequences can affect not only habits, customs, and patterns of behavior, but the actual social structure and the distribution of power, wealth, and social prestige'' (p. 23). Thus, Rattner objects to the ''ideology of the transfer of technology'' from developed countries, based principally on the action of multinational companies, arguing that such ''transfer'' has negative consequences for the balance of payments, employment of skilled and unskilled labor (because, respectively, of brain-drain and capital intensity), rate of growth (because of import of obsolete technology), and national sovereignty. Coupled to other types of cultural imports (e.g., education models), the import of technology would be instrumental in structuring political and economic alliances and in preserving the economic and political status quo.

One of the epistemological characteristics of debate in the social sciences is the opportunity it offers its participants for ignoring the arguments of their opponents supported by different paradigms; the debate about transfer of technology is no exception. However, when extreme alternatives—technological autarky, on the one hand, and total dependency, on the other—are rejected (the former because it is economically inefficient and, in practice, not feasible; the latter because a minimum of local technical capacity is indispensable, if only to adapt imported technology to local production and market conditions), the main issue becomes that of determining the proper combination of imported and locally developed technology.

Erber (1977b) develops this line of reasoning for the capital goods industry, discussing the reasons that could lead the state to support greater technological autonomy (understood mainly as the ability to develop the basic design of capital goods) in an underdeveloped country, instead of licensing from abroad. Beyond the "classical" reasons for this support (the lack, or precariousness, of technological solutions from abroad for fuller employment of human and natural resources in peripheral economies; the necessity of reducing foreign exchange constraints; the external control of national decisions) and their repercussions on economic growth, Erber emphasizes the differences between the private and social assessment of the consequences of greater technological autonomy. Thus, from the point of view of long-term growth, the best strategy would be a "mixed" one combining licensing and self-development, using one or the other in certain cases, and using them "in parallel" in others, sometimes geared to a future substitution of local development for licensing. However, the costs and benefits of increased technological autonomy tend to fall upon different groups in society; therefore, the evaluation of the desirability of state support and the determination of policy priorities are linked to value judgments and specific social projects.

The intervention of the state in favor of greater technological autonomy is frequently defended by pointing to the example in central countries of state support given to innovators and indicating that technological dependency fosters control of decisions by foreign entities (Rattner 1973, Erber 1977b, Tigre 1978). Thus, a nationalist ideology would favor a strategy of relative technological autonomy. Moreover, it is probable, due to the long term of maturation of this strategy, as well as to the collective nature of technical work, that a "national project" would be a *necessary condition* for the substantial growth of technological autonomy in a peripheral country in the capitalist system. Within the framework of this system, a nationalist ideology would be the only basis of articulation between the state, private enterprise, and the scientific and technological system that would allow simultaneously (1) the establishment of a joint long-term action (eventually overcoming immediate market pressures), (2) respect for private ownership of the means of production, and (3) the legitimization of this action before the rest of society (Erber 1977b). Given the functions of the state, it is probable that nationalism will be strong within state apparatuses, which may explain why policies of greater technological autonomy have been initiated by government agencies. However, it is precisely in the peripheral countries that the objective conditions of development are least favorable for the effective translation of this ideology into economic action. In such countries, the pattern of dependent development tends to build a powerful block of interests, strongly represented within the state, which does not favor a policy of greater technological autonomy or even opposes it altogether.

Studies of the Scientific and Technological System

Scientific Production and Science Policy / Information on Brazilian scientific production is still somewhat limited, both in terms of inputs (e.g., the scientists employed) and in terms of products (e.g., publications), despite the yearly "evaluation and perspectives" reports on different scientific fields by the Conselho Nacional de Pesquisas (begun in 1974), and despite some bibliometric studies, such as Morel (1977). In a quantitative analysis of scientific papers published in journals indexed by the Institute for Scientific Information, Morel shows that, although between 1967 and 1974 the number of Brazilian authors indexed had practically quintupled, the number was still insignificant in the world total—0.3 percent. In relation to the total population of the country, the number of authors is small—"around six authors per one million inhabitants; countries such as Kenya, Uganda, Zambia, Uruguay, Rhodesia, etc., surpass this ratio." Thus, Morel concludes that "at least with respect to the development of scientific authors of international recognition, the Brazilian system has been inefficient, even though graduate courses have been expanded and research activities have been significantly increased" (p. 100).

Studies of scientific production in Brazil have dealt mainly with the institutionalization of scientific activity, essentially through the study of relatively successful cases such as the Instituto Oswaldo Cruz (Stepan 1975, Sant'Ana 1978) and the Escola de Minas de Ouro Preto (Carvalho 1978), and unsuccessful cases such as atomic research (Morel 1975). Schwartzman et al. (1978) present a detailed analysis of the formation of the Brazilian scientific community from colonial times to the post-World War II period and provide an extensive bibliography that includes work on this topic published in Brazil (among these, it is valuable to consult

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Azevedo [1955]). There seems to be a consensus that the economic, social, and cultural conditions in Brazil during the phase of primary export-led growth and during the first stage of import substitution were, as a rule, unfavorable to a broad institutionalization of scientific activity.[9] Even the exceptions confirm the rule: the main efforts toward institutionalization of scientific activity were largely in response to specific economic and political conditions (usually geographically concentrated, too)—such as the epidemics of yellow fever in Rio de Janeiro (Instituto Oswaldo Cruz—Stepan 1975, Sant'Ana 1978), the propagation of the *broca* (beetle) in coffee in São Paulo (Instituto Biológico de São Paulo—Rowe 1969), and the reaction of the Paulista elite to the power of the federal government after the unsuccessful São Paulo revolution of 1932 (Faculdade de Filosofia, Ciências e Letras, Universidade de São Paulo—Pereira 1976, Sant'Ana 1978, Franken 1978).

The main controversies in this area involve the interpretation of the present situation and the role of the state, and are intimately linked to different interpretations of scientific activity. Morel, Pereira, Pena, Stepan, and Sant'Ana see scientific and technological activities as closely linked, and they tend to attribute the difficulties in institutionalizing scientific activity primarily to the technological dependency of the economy, which entails a low priority for scientific activity in the allocation of resources and a limited social legitimacy. They underline the fundamental role that the state must play if this situation is to be changed, although they express considerable doubt about the feasibility of a firm state policy with that purpose, precisely because of the economic and political dependency of the country. Moreover, they point out several instances, especially in the recent past, when the state has disrupted scientific activities for political reasons.

On the other hand, Franken (1978) claims an essential distinction between scientific and technological work in terms of the appropriation of results and social legitimization. He is concerned that a "utilitarianism" imposed by the state upon scientific activity would inhibit its role as producer of knowledge as well as limit it in its function of criticizing society. The questions raised by Franken are important: if one accepts that the state will intervene in science, which should be the priorities of this policy; and should the state intervene as a "learned Maecenas," who provides resources but does not question their use, or as a participant in the definition of research priorities? Indeed, the two questions are closely linked: those who believe that scientific progress obeys only the dynamics of the scientific community (Polanyi 1962, 1967) defend the exclusive definition of priorities by that community; the position that emphasizes the interaction of economics and politics with science (Bernal 1965, Cicotti et al. 1976) leads to a more active participation of the state in delineating these priorities.

The connections between scientific activity and economic and political objectives are complex and vary substantially among the different sciences; there is a great need for research, especially in the conditions of a peripheral country such as Brazil. Indeed, it is frequently pointed out that the problems and work methods of the scientific community in a peripheral country are imported from the center (Herrera 1971). If one believes that science in the central countries is permeated by the specific political and military objectives of those societies (e.g., the arms race—Leite Lopes 1969), then the consequences of a state policy of a peripheral country of just providing the financial resources but keeping at arms length as regards priorities might imply an (at least partial) subordination of its national scientific efforts to the objectives of the central countries. Such questions, which, again, are directly related to the heterogeneity of scientific activities, emphasize the need for investigation in this area.

Even accepting the participation of the state in the definition of priorities, there remains the question of what form this participation should take. The international literature suggests different specific characteristics of scientific work that could serve as a normative basis for this intervention; for example, the long-term maturation of investment in research and the uncertainty of basic research results (Nelson 1971).[10] Different planning methods have also been suggested (OEA 1971, Weinberg 1963, Cetron and Goldhar 1970) to link science policy priorities to economic and social objectives. In Brazil, literature of this normative character has been followed infrequently, with the main exception of Paulinyi (1977), who examines in detail one of these methods—the relevance of decision matrices. Probably more serious is the lack of studies that investigate in depth the present relations between the state and the scientific community, for example, in the preparation of plans for scientific development and in the decisions regarding the allocation of resources.[11]

Technological Research Institutes / Research institutes in Brazil have been the object of several studies, with the same point of departure as that of Biato et al. (1971)—the need to establish links between research institutes and the productive sector, to create continuous flows between demand for and supply of services that would ultimately lead to the generation of innovations within the Brazilian economy. The slight demand by the manufacturing sector for research institute services and the concentration of this demand in activities of little technological complexity (mainly tests and quality control) was confirmed in sectorial studies on the capital goods industry (Erber et al. 1974b), the food products industry (Poppe de Figueiredo 1978, Marcovitch 1978), and the wood-processing and iron and steel industries (Marcovitch 1978). A more comprehensive study of the demand for the services of research institutes (Erber et al. 1974a)[12] shows that other sectors are important users of such services—notably the construction industry and infrastructure government agencies (mainly electric power and sanitation). Although most of the services supplied are of a routine nature, some more complex activities are performed, especially for government agencies. Nonetheless, the study suggested that this was due to the difficulty of importing such services rather than to any deliberate policy of fostering the institutes.

Erber et al. (1974b) and Marcovitch (1978) show the dissatisfaction of management regarding research institutes' services. They confirm that the poor connection between businesses and institutes cannot be attributed simply to the technological dependency of the former, because the latter have serious operational deficiencies that frequently limit their ability to perform more complex services, even if companies commissioned them. More detailed examination of research institutions, conducted from within them and to some extent confirming the claims of management, is found in Carneiro et al. (1971), Ministério de Planejamento e Coordenação Geral (1971), Sant'Ana (1978), Poppe de Figueiredo (1978), and Marcovitch (1978). The contrast between the first two studies and the last is especially enlightening since it indicates the persistence of some of the more serious problems, such as the inability to maintain highly qualified technical staffs, the lack of appropriate legal-administrative structures, and the lack of financial resources. These problems are especially acute for the older research institutes, some of which have recently undergone a process of modernization. Such a process, and its results, as well as the experience of some of the newer and more specialized institutes, deserve further research.

Technological Infrastructure / "Scientific and technological support services," among which are systems of technological information and technical assistance, trademarks and patents, and technical standards and certification procedures, have been little studied in Brazil. Deficiencies in the Brazilian technological infrastructure, especially with regard to the generation and diffusion of national standards, are discussed by Pereira de Castro (1974). He argues that "to produce technology is to produce standards of operation," and that a system of national standards could be used to increase technology transfer and to protect local enterprises from foreign competition, especially if coupled with proper purchasing policies by the state. Few enterprises in Brazil use national standards or other available infrastructure services, generating a vicious circle similar to that previously discussed for research institutes. Unfortunately, there is a dearth of studies concerning such services, in spite of their importance. A related question is the quality of industrial production—how far it conforms to international technical standards. This issue was raised by IPEA (1974) for machine tool production; it ought to be further researched.

Consulting Engineering Firms / Consulting engineering firms play an important role in the incorporation and diffusion of technical progress.[13] In processing industries, they act as a link between the suppliers of technology and the producers of the equipment and their buyers. They are also often responsible for supervising construction and start-up operations, as well as for technical assistance during operation. Although their role in generating new technologies is, in general, limited, consulting firms are a locus of engineering capability that can be used later in the generation of technology.[14]

In Brazil, Alves and Ford (1975) analyze the use of consulting firms by state companies in three sectors (iron and steel, petroleum refining, and generation of electric power), and Ford et al. (1977) discuss the overall evolution of the consulting sector and investigate the technological, administrative, and financial capability of the companies acting for the sectors of hydroelectric generation, mining, petroleum refining, petrochemicals, iron and steel, and railroad transport.[15] Ford et al. concluded that the consulting sector is highly concentrated and that there is a significant link between the position of the companies in the sector and their experience. Most firms are nationally controlled, but the participation of local firms is limited to "the least complex phases of project preparation: the feasibility study, detail engineering, and the design of the 'utilities' of the project (off-site). The critical phases of industrial projects, i.e., those steps where technical choices of a definitive character are made (basic design or basic engineering phase), generally continue to be carried out under the leadership of foreign companies" (pp. 6–7). According to these two works, such technological dependency will tend to be maintained unless explicit measures are taken to increase the participation of national companies in the main activities of engineering.

The studies also show that, to a considerable extent, the situation is a consequence of the policies of the companies that purchase consulting services (especially state companies) due to poor planning in the contracting of services, requirements of previous experience (partly to reduce risk but thereby preventing national companies from doing more complex work), not differentiating between national companies and foreign affiliates, and the lack of standards for contracting services. Moreover, Alves and Ford point out that the financial structure of the projects of state companies influences the choice of consulting firms, since international financing agencies require the participation of foreign consulting firms.

In spite of the weight attributed to external factors, the two studies also point out the role played by the consulting firms in the maintenance of technological dependency, notably through "attempting to reduce their risk by diversification of their activity and by increasing the volume of projects planned" (Alves and Ford, p. 73) and by the "reduced commitment of some of these companies to make a commercial, financial, and technical effort in the training of their teams, absorption of technology, setting up technical archives, etc." (Ford et al., p. 8). This vicious circle between state policies and entrepreneurial strategy is another feature that consulting firms share with the capital goods industry, as we shall see below.

Studies of the Productive System

The Choice between Licensing and Local Development / The majority of the studies of technological dependency concern the behavior of Brazilian companies, private and state-owned. The topic has been dealt with comprehensively (Politzer and Araoz 1975, Pastore 1976, Cerqueira Leite 1976, Longo 1978, Rangel 1978) and in studies treating in detail the following sectors: capital goods (custom-built and mass-produced) (Erber et al. 1974a, Erber 1977b); machine tools (Vidossich 1970, IPEA 1974, Bastos 1976, Versiani and Bastos 1976, Magalhães 1976); computers (Erber 1977b, Tigre 1978); mechanical equipment, food-processing, and metallurgy (Fung and Cassiolato 1976); petrochemicals (Araujo and Dick 1974, Wasserman et al. 1976, Jorge 1978, Silva Filho 1978); petroleum, iron and steel, and wood (Reis and Redinger 1975, Marcovitch 1978, Leuschner 1971, Dahlman 1978); textiles and clothing (Spreafico 1970); and pharmaceuticals (Bertero 1972, Frenkel et al. 1978).[16]

Although the studies confirmed the technological dependency found at the beginning of the decade by Biato et al., and that this dependency appears to be deepening, they show that it varies significantly among and within sectors.[17] As a result of such studies, we know more about the determinants of dependency and, consequently, about the characteristics and limits of a policy of greater technological autonomy—including the need to think at a disaggregated level. Notwithstanding the heterogeneity of the literature and the specificity of the sectors' conditions (a point that deserves stressing), the studies have an analytical problem in common: the rationale underlying the choice between local development of technology and the use of imported technology (henceforth—licensing).

The Technical Basis of Dependency / Abandoning the tradition of viewing R and D as a homogeneous and indivisible production factor, Erber, Tigre, Wasserman et al., Jorge, and Frenkel et al. analyze the different activities (research, design, etc.) that lead to technical progress, establish important distinctions regarding the relative weight such activities have for technological autonomy, and analyze the resources necessary for carrying out such activities in the country.[18] Their analysis focused on an important point—the discontinuity of technical knowledge: although interrelated, each technological activity requires specific knowledge and skills, and proficiency in one activity does not necessarily lead to mastery of the others. Thus, being skilled in operation procedures may allow the introduction of technical improvements that increase production and improve products, but it does not necessarily foster the ability to design a new plant or a new product.[19]

This discontinuity is important in explaining the coincidence of two phenomena in the transfer of technology: national firms acquire certain technical capabilities (production technology and detailed design), but the innovation process, based upon the activities of research and basic design, whose knowledge is not transferred, remains under foreign control. For instance, to the extent that the income of the owner of technology depends upon the sale of licensed products, it has an interest in the licensee producing such products properly. To do so, a local firm must master production technology and, often, must be able to detail production specifications consonant with availability of raw materials, components, etc. But by retaining the knowledge of those activities where innovations are introduced, the owner of technology maintains technical control over the innovation process, which, coupled to the legal control given by the contract, assures dependency over time and, consequently, the maintenance of income flow and other benefits arising from the relationship.[20]

The studies suggest that although the transfer of technology can be an instrument of learning for future autonomy, technological dependency will tend to be maintained unless national firms invest in their own R and D capability. It should be noted, however, that the discontinuity is not always uniform. There are sectors in which progress from one activity to another is feasible, through copying and adapting the original product. Nonetheless, copying (frequently, and significantly, called "reverse engineering" in the international literature) is controlled by the patent system; it may also require that the copier have technical knowledge that, depending on the product copied, may need to be substantial.

Assuming for the sake of argument that the suggestions of developing national capability for basic R and D were accepted, what resources would be necessary for that expansion? Or, inversely, what limits are placed upon a policy of greater autonomy by the existing human and material resources in the country? In this regard the studies show important industrial differences that are closely related to the relative importance of different technological activities. In process industries (petrochemicals, iron and steel, pharmaceuticals), technical work rests on research activities performed in laboratories, which often requires a sizeable minimum scale of the firms.[21] In contrast, in some capital goods industries, there is relatively little research, and innovations are introduced mainly at the basic (or "preliminary") design stage; they depend a great deal upon the talent of specific individuals, and can be carried out by firms of a relatively small size. In other words, although in some sectors technological autonomy is seriously limited by the size of national companies or the size of the local markets, such conclusions cannot be generalized for the whole industry.

The organization of the technical labor process has another important consequence for a policy of technological autonomy: since technical knowledge is person-embodied (as in the case of basic design for capital goods) and since such persons exchange information informally and move from one enterprise to another, the full appropriation of the results of the development of technical capability by the enterprise is impossible. Moreover, since such capacity is developed mainly through learning by doing, what is in the short run a cost for the enterprise is, in the long run, an investment for the society. Therefore, there are differences between the entrepreneurial and societal benefits of the development of technical capability, in which the latter are greater than the former.

Technical progress can be characterized as a collective process in which there is a strong intersector interaction, and, when all the sectors invest in their own technological capacity, there is a synergic effect produced through learning-by-doing, circulation of personnel, informal exchanges of information, copying, etc. However, the technological dependency of one sector also has "linkage effects" upon the others, which can deepen the general dependency. In terms of policy, viewing technical progress as a collective process suggests a sectorial approach, in which a "sector" would be composed of technically similar industries in which maximization of the synergic effects should be attempted.[22] To articulate such collective work, the deliberate intervention of the state would be required, especially where the processes of circular causation leading to dependency are already established, as is the case in Brazil.

Costs / Although entrepreneurs tend to give it considerable importance, it is difficult to compare directly the costs of licensing with those of the local development of technology, partly because they are not exactly separate. In the bargaining process to establish the cost of a license and the conditions to be imposed in the contract, the cost of producing the technology will play a different role for the licensor if it must be especially developed for the licensee or if it already exists. In the first case, the cost of production probably establishes the minimum payment for the license; in the second case, it may carry little weight since it will already have been covered by previous sales of the product or process, and since the cost of adaptation normally falls on the licensee[23] (see Hufbauer 1966; Vaitsos 1970, 1974; Sercovitch 1974; Erber 1977b; Tigre 1978). Conditions imposed by the licensor can be influenced by his fear that the licensee may develop the technology himself or obtain it from another supplier (and in this way become a competitor), as well as by the possibility of reciprocity, i.e., that the licensee may become a licensor of other products. As a result, contracts between similar firms tend to have less stringent conditions than those between unequal firms, and thus, the technical capacity of the licensee is an important element in reducing the licensing cost of imported technology.

Studies have shown that the supply of "technological inputs" in Brazil is precarious, and some evidence suggests that their cost—especially for university-trained personnel—is close to international levels. In some industries, the cost of producing the technology is feasible only for relatively large companies; but even when the requirement of scale is surmounted, the cost of producing the technology instead of using licensing becomes the upper limit of payment for the license by the licensee, only under the restrictive hypotheses that the risks and benefits of the two alternatives are equivalent and that there are no other investment alternatives. Since such assumptions are not realistic (see below), the importance of the cost of production of technology per se is reduced as a determinant of the bargaining position of the licensee, too.

In practice, the conditions of licensing are set in between the opportunity costs of the two parties. Usually there is an element of rent paid to the licensor, equivalent to the difference between its opportunity cost and the actual income received. The latter generally comes explicitly as a lump-sum payment plus a percentage of sales, but it is often increased by sales of raw materials and components, frequently charged at monopolistic prices. In such cases, the true cost of licensing is, of course, difficult to determine. The cost comparison between licensing and self-reliance becomes even more complex if certain long-term effects of the latter are taken into account, such as the relative reduction of future costs of local technology, the reduction of future licensing costs due to an increase in bargaining power, and the fact that the technical knowledge produced for one process or product is often applicable to others that are not covered by a license contract.

Development Time and Entry in the Market / Requirements for performance and reliability of capital goods and engineering services become more stringent as the economy expands and diversifies and technical capability becomes increasingly important. Also, a timely arrival on the market is a major factor in competition, especially during phases of rapid expansion and diversification. In the capital goods industry, delivery time is an especially important factor in choosing technology sources (see Bastos 1976, Erber 1977b). In Brazil, to a considerable extent due to lack of governmental policy, state investment projects are frequently decided upon only when strong pressure exists for their immediate realization, which entails requests for rapid delivery by the suppliers. Thus, when technological development tends to be time-consuming, licensing, which uses greater foreign experience and/or already existing designs, can allow an easier and faster entry into the market, giving the licensee a competitive advantage.

The difference in timing between the two strategies has financial implications, too: while in local development expenditures tend to precede receipts, the inverse happens in licensing, where expenditures as a percentage of sales are subsequent to receipts. The less efficient the resources used for local technological development, the greater the difference will be.

In Brazil, the precariousness of the local inputs for technological production is aggravated by the limitations of the long-term credit market and by the almost complete lack of instruments of risk capital.[24] Also, the maturation time for investments in technology demands a long-term strategy by companies with respect to their investment and product mix. In their studies of the Brazilian capital goods and iron and steel firms, Erber (1977b) and Dahlman (1978) single out a long-term strategy as one of the distinguishing traits of firms pursuing relative technological autonomy; they also show the difficulties encountered by these companies in following such a strategy, especially due to the lack of any clear industrial policy with well-defined priorities under which the several governmental institutions acted. Thus, the existing financial system and the pattern of Brazilian policymaking has encouraged the use of licensing and has inhibited the development of technological autonomy.

Demand and Competition Constraints / The size of the market may favor the use of licensing, especially when the ratio between the investment scale in R and D and the size of the market is high (notably in process industries), or in cases in which technical capability depends upon experience, and when the number of experiments that the market will sanction is restricted (notably in capital goods). In this sense, certain characteristics of the pattern of Brazilian industrialization (strongly influenced by governmental policies) aggravated the structural restrictions imposed by the size of the national market. Among these, for example, was the lack of control over the entry of companies (especially foreign firms) into certain markets, making more difficult any specialization or achievement of minimum scales of production compatible with investments in R and D and the thrust of industrialization toward the internal market.

The nature of the demand for consumer and capital goods in Brazil also encourages the tendency toward licensing. Various authors (Biato et al. 1971, Rattner 1973) point out that the demand for products similar to those of central countries leads to technological dependency through the imitation of production techniques and design patterns. In Brazil this is compounded by the predominance in the area of durable consumer goods of multinational companies interested in supplying the country with models developed abroad. However, the sectorial studies of technological dependency have been oriented primarily toward capital goods and intermediary goods, partly due to the role played by these sectors in the introduction and diffusion of technical progress, and partly due to the role of national companies, both private and state-owned, in these sectors, since these companies, presumably, would be the primary beneficiaries of any policy of greater technological autonomy.

Studies of the selection processes of some of the major purchasers of custom-built capital goods—the state-owned iron and steel, electric, and petroleum companies (Erber 1974, 1977b; Alves and Ford 1975)[25]—show frequent requests for foreign technology. In some markets, the use of foreign technology is a *conditio sine qua non* for the entry of a national firm; but even when it is not, purchasers often look favorably upon its use in a product. This is especially true for those capital goods that form the "core" of the productive processes of the state companies and which have stricter requirements for performance and reliability that depend on the experience of their suppliers.

The interaction of these factors leads to a vicious circle: since the suppliers of capital goods and engineering services to state enterprises do not have the product design experience or the plants required, they are obliged to use licensing. This, however, does not teach them basic design skills and, because of the characteristics of demand, the investment that would lead to such learning becomes too risky; thus, dependency from abroad is renewed. Since these state enterprises are suppliers of inputs that are essential to the rest of the economy (e.g., steel, electric power, etc.), they tend to minimize risks. But the studies also show that, in response to the classic dilemma of being both business and state, these enterprises have tended to emphasize their "entrepreneurial" side, and concern over their own growth has ruled over considerations of the consequences of their decisions for the rest of the economy.[26] Moreover, they stress that the criteria for evaluating the risks of using local technology are permeated by political considerations that often go unrecognized by the decision-makers of these enterprises. State enterprises also give low priority to R and D, even their own (Reis and Redinger 1975). Although there is a consensus among authors concerning the potential use of state demand to encourage technological autonomy in the capital goods industry and engineering services, they also warn that for some products, such a goal would be difficult to justify, either in terms of the risks imposed on the rest of society or in terms of the size of the market that would warrant the investment in research and basic design.

In most sectors, competition also adds to the pressures that arise from demand, thus encouraging national firms to increase their use of foreign technology. A major role is played by the competition of foreign capital, which, when internalized in the country, makes the import of technology by national companies often inevitable. More generally, the studies show that the industrial policy followed by the Brazilian governments in the second postwar period had, by and large, an inhibiting effect upon local technological activities by fostering the import of technology—capital goods, foreign investment, and use of licensing by national firms—without a countervailing protection for local technological activities already existant or which could be developed.

The analyses of sectors in which a certain degree of technological autonomy has been achieved (e.g., universal machine-tools) or in which there is an explicit policy with that objective (e.g., mini-computers) point out that in such sectors the inhibiting factors mentioned above are absent or have been overcome by a political decision. The case of minicomputers deserves special notice as a sector in which the policy adopted was not only opposed to the interests of large international firms which wanted to enter this market but also to the preferences of the consumers.

Autonomy and Survival / International studies of innovations (Freeman 1974, for example) argue that the main inhibitor of R and D activities is risk.[27] The risk of technical failure is substantially less in licensing, not only due to the greater experience of the manufacturers but also because the imported technology has often already been tested in other countries. In the same way, the financial risks of a strategy of national development tend to be greater than those of licensing. Nevertheless, according to the same studies, the advantages conferred by licensing are accompanied by risks in terms of autonomy, expansion, and even the survival of the licensed firms in these markets.

Licensing is only one of several strategies that can be used by the holder of technology. It can also establish a subsidiary, if the conditions of the local market are favorable; licensing a local firm can be an intermediary step, to the extent that the licensee tests the market and establishes the name of the licensor. If the licensor does establish a subsidiary in the market previously occupied by a licensed national firm, the latter will have to find another licensor or abandon the market. If the licensed firm depends substantially on its profits from licensed products, its survival will be threatened. The cases studied by Erber (1977b) of the entry of former licensors into the Brazilian market show that previously licensed Brazilian firms were strongly affected.

The proprietor of technology may also become a partner of his licensee; according to Erber et al. (1977b), this seemed to be a growing tendency in the capital goods industry. National entrepreneurs were, although unwillingly, prepared to accept this, frequently under the threat of the establishment of a subsidiary in the country. As shown by Araujo and Dick (1974), the entry of foreign partners as technology suppliers was widely used in the Northeastern petrochemical pole. The control of technology by a foreign partner not only requires a division of the total profits with this partner, based on a capital of uncertain value, but can also have the effect of subordinating the expansion of the national firm (markets, product mix, etc.) to the broader interests of the foreign firm (especially if this firm is multinational); it can also restrict the access of the national firm to technology from international competitors of the foreign partner.

Therefore, the studies suggest that a trade-off exists between the risks of local development of technology and the risks of licensing, between the risks of short-term technical and economic failure and the loss of autonomy and longer term growth limitation. One way of minimizing the risks of the two strategies is via a combination in which locally developed products play a large part. Nevertheless, the feasibility of a mixed strategy varies in accordance with the specific market conditions under which the companies operate, as well as with the characteristics of national enterprises, notably their inclination to take risks, their time horizon, and the value they place upon a greater or lesser autonomy in decision-making; that is, it depends upon political as well as economic criteria. The fact that a mixed strategy has not been adopted by the majority of Brazilian companies appears to be the result not only of structural deficiencies in the economy and the pattern of industrial policy, but also of the political outlook of local entrepreneurs—especially their short-term horizon and the low value placed on autonomy.

Legal Constraints / The Brazilian literature has concentrated on the laws and regulations governing the import of technology. Until 1975, such legislation had as its main objective to restrict payments abroad by imposing limits upon the percentage of the value of production that could be expatriated without paying income tax and by forbidding payments for patents and trademarks between foreign subsidiaries and parent companies. Several authors (Figueiredo 1972, Biato et al. 1973, Fung and Cassiolato 1976, Barbosa 1978a and b) have pointed out the inefficiency of such rules, especially as regards foreign enterprises, which can shift the legal form under which they pay their parent companies. Although in 1975 the INPI lay down new rules for the import of technology, which emphasize the absorption of technology, their effect has not yet been fully appraised. However, some preliminary assessments were skeptical of their effectiveness, largely because of their lack of coherence with the general industrial policy and the difficulties of INPI controlling their implementation (Fung and Cassiolato 1976, Erber 1977b).

As regards patents, a rich and polemic approach is found in Barbosa (1978a) where it is argued—contrary to a considerable international literature—that peripheral countries such as Brazil should adhere to international patent agreements, but not to "know-how" agreements. This issue deserves further research, as well as the effects that other laws, directed to more general industrial policy, have upon local technological development.

Studies of Foreign Enterprises

Biato et al. (1971) showed that, among the largest enterprises in Brazil, those that were foreign-owned tended to perform more technological activities than those that were nationally owned, although the latter tended to do the majority of the more complex technological activities.

They argued that this was because the foreign subsidiaries used the laboratories of their parent companies to do the more complex activities and performed locally only minor adaptations to local conditions. Figueiredo (1972) explained this behavior of the international companies as "a logical consequence of national policies . . . directed only to import substitution in a highly protected national market" (p. 55), and he supposed that such behavior would be changed by an opening up of the Brazilian economy.

However, the pattern found by Biato et al. was confirmed by Erber et al. (1974b) for the capital goods industry and by Frenkel et al. (1978) for the pharmaceutical industry. The evidence available suggests that where more complex activities have been established in the country (as in the case of cellulosis), this was the result of a combination of great comparative advantages in terms of natural resources with a highly permissive legislation in terms of environmental protection. Although the explicit science and technology policy includes as an objective the performance of R and D by foreign subsidiaries within the country, there is considerable controversy about this. First, there are doubts whether such an objective is compatible with the global strategy of such companies since, as argued by Fajnzylber (1977), "in their home countries the leading enterprises of the oligopolies generate the process of technological innovation, in Latin America the leaders of the local oligopolies, subsidiaries of the former, use such innovations and contribute in this way to pay for the research costs of the parent companies" (p. 22).

Even if economic incentives could change such behavior, the benefits arising from such R and D (exports, training of personnel) have to be weighed against the alternative cost of such incentives and the consequences of such R and D upon the local technological and scientific system and upon the technological activities of local enterprises. Thus, the subordination of the subsidiaries' R and D to the overall strategy of their group could lead to an "internal brain-drain," tying up scarce local technical and scientific personnel in activities unrelated to national problems—thus reducing the importance of the training received, too. As for the second point, there is a consensus among the studies of technological dependency that one of the main reasons that national enterprises have such limited technological activities is the pressure of competition from foreign subsidiaries (see above), which not only establishes a pattern of competition in which quick access to foreign technology is necessary to survival, but also occupies segments of the market that otherwise could give local firms the necessary scale for investing in R and D (Frenkel et al. 1978). As shown by Wanderley et al. (1976), in their study of exports of services of engineering firms, such competition may be extended abroad as well.

Finally, it is regrettable that the studies on the diffusion of innovations (see below) have not detailed the role played by foreign companies, since the international literature often suggests that they should have a pioneer role in this process.

Studies of Diffusion

As we have seen, much of the Brazilian literature has concentrated on the problems of technological dependency. However, emphasizing the sources—external or internal—of technology runs the risk of underestimating the question of change in productive techniques, which "in any industrial system, dependent or not, is the basic element maintaining its dynamism" (Araujo et al. 1976, p. 3). Thus, more recent sectorial studies have investigated the diffusion of innovations—in the textile, paper, and cement industries (Araujo et al. 1976), dairy products (Bielchowsky and Pires 1978), and textiles and footwear (Cruz and Barros 1978). Although they agree the topic is important, the studies differ in its treatment. In those done at FINEP, the analysis of technological progress is geared to ". . . [understanding] it as an instrument of intercapitalist competition . . . an element that acquires distinct meaning in each market structure" (Araujo et al. 1976, p. 5; see also Araujo 1975). Centering their analysis of the diffusion process upon characteristics of the industrial structure, the authors articulate "three levels of questions that are relevant to the discussion of technological change: the market, the firm, and the productive techniques" (p. 6).

After extensive review of the work of Mansfield and the National Institute of Economic and Social Research of England,[28] Guimarães (1975) presents an important theoretical contribution to the study of diffusion, although it is limited to process innovations that do not affect the quality of the product and to markets of concentrated oligopoly: assuming that the innovator is not an inventor (that is, without considering the stages of research and development), he discusses the technical and economic features that characterize innovation; examines the principal factors that influence the capacity for innovation within a firm (size, information, etc.); and, within the theoretical framework of oligopoly proposed by Labini (1969), discusses the reasons and pressures that encourage the firm to innovate. With coauthor L. Reis, he examines empirically the case of diffusion of the dry process in the cement industry (summarized in Araujo et al. 1976).

The work of Cruz and Barros, in turn, is linked to the tradition established especially by Mansfield in which, through extensive use of econometric models, the characteristics of the innovations and of the firms that eventually introduce them are taken as the explanatory factors in diffusion. Thus, the "groups of users and nonusers of innovation could be distinguished by three basic characteristics: (a) the profitability of the innovation (in relation to the risk); (b) the size of the firm; and (c) the quality of management" (pp. 398–99).

Although the difference in approach has deep paradigmatic roots, the two groups of authors tend to qualify it, acknowledging the usefulness of the alternative approach. Such qualification probably reflects the lack of a more general theory, further evidenced by the case-by-case conclusions drawn by the authors. Nonetheless, they reiterate two important points: first, the role played in diffusion by other agents, such as the producers of capital goods and engineering firms; and second, the role of technical progress in capitalist competition—as the study on shuttleless looms in Araujo et al. shows, there are situations in which the renewal of productive techniques may be unimportant as a mechanism of competition. In the same way, it is impossible to deduce from these studies any general policy suggestions—these tend to be made with reference to the specific sector studied. Nevertheless, they raise important implications for the formulation of policy by, again, calling attention to industrial heterogeneity and, consequently, to the need for differentiated and flexible policies at the sectorial level. At the same time, by confirming the collective character of technical progress, seen now in its diffusion stage, these studies show the need for an integrated treatment.

It is important to note another facet of the studies of diffusion that differentiates them from studies of dependency: in the latter, the historic specificity of the peripheral situation appears in the foreground; in the former, the dependent situation constitutes the backdrop against which the processes of diffusion unfold. While dependency analysis attempts to identify the singularity of the Brazilian condition in terms of capitalist development, the diffusion analysis helps to identify the elements that Brazilian capitalist development and the development of the central countries hold in common. This can be seen not only in the theoretical framework used in the two types of studies discussed, but also in the preoccupation (especially in Cruz and Barros) with finding in Brazil a pattern of diffusion homologous to the patterns of the central countries. A theoretical work yet to be done is an attempt to synthesize the two treatments—for example, to bring the specificity of dependency to the foreground in the analysis of diffusion—to view diffusion from the perspective of dependency, and vice versa.

Finally, although the studies of technological dependency show the relationships existing between the market structure and the dynamics of dependency and between dependency and the growth, survival, and autonomy of national firms, the approach proposed by Araujo et al.

(expanded later in other works of the FINEP, such as Frenkel et al. 1978, and Tavares et al. 1978) focuses more directly upon the relationships that exist among growth, competition, and technical progress. This opens up a significant field of research in theoretical terms and for economic policy, including at the macroeconomic level—points to be taken up in section 4.

The Role of the State: Explicit and Implicit Policies of Science and Technology[29]

Among the authors who defend the idea that Brazil, like other peripheral countries, needs its own technical and scientific capability, there is a consensus that the intervention of the state is necessary for the development of this capability; that is, that the present dynamics of economic and social forces lead to insufficient development of internal scientific and technological capability, requiring the intervention of the state to modify these forces.

The different historical analyses of the participation of the state in science and technology in Brazil (Morel 1975, Guimarães and Ford 1975, Pereira 1976, Romani 1977) show that beginning in the late 1960s there is a noticeable modification of this participation; one can take as a watershed the Programa Estratégico de Desenvolvimento—PED—which, in 1968, for the first time defined at the federal government level an explicit policy for science and technology, with objectives and a program of action that would to a considerable degree be maintained in later plans. The studies show that a science and technology policy as an objective of the state had not existed previously. Although there was intervention in these areas, for example, through the institutionalization of certain scientific activities (e.g., in the area of health) and in establishing policy-making institutions for science and technology (such as the National Research Council [Conselho Nacional de Pesquisas]), this intervention was markedly fragmented and lacked continuity.

Taken together, the studies suggest that when there was state support of scientific and technological activity, it was granted for specific occasions (yellow fever in Rio, coffee beetle in São Paulo, excess centralization of power of the federal government in São Paulo, etc.). Once these immediate interests were served, state support became rarefied and the institutions and their activities languished. When, as in the case of atomic policy (Morel 1975), the implications of state intervention were greater, involving modifications in the structure of internal or external relations, the groups concerned lacked the strength to give them the continuity and force necessary, even though state intervention had been initiated in the area. In other words, the studies of scientific activity and technology dependency suggest that until recently the pattern of accumulation of capital in Brazil, the characteristics of the political system, and the nature of the country's participation in the international system did not offer the state sufficient and necessary economic and political reasons for greater intervention in science and technology, except in specific cases of limited scope.

In the period beginning in 1968, scientific and technological development became a specific object of policy. At the same time, special financial mechanisms were established for scientific and technological activities and an institutional structure was established for planning in the area, which produced two Planos Básicos para Desenvolvimento da Ciência e Tecnologia (PBDCT I and II), encompassing the periods 1973–74 and 1975–79, respectively. These activities of the federal government, described in detail in Romani (1977) and Erber (1977b), are mirrored on a smaller scale at the level of some state governments, especially in São Paulo (Marcovich 1978).[30]

Although all the plans emphasize creating a greater scientific and technological capability, as well as increasing the incorporation of knowledge from abroad, there are important differences between the priorities of the PED and of the other plans. While in the PED the priority was to develop technologies more appropriate to the supply of production factors of the country, in order to assure greater absorption of manpower and to create a mass market to guarantee self-sustained growth, in the other plans the emphasis fell on increasing the international competitive power of Brazilian industry and strengthening national enterprises (Guimarães and Ford 1975).[31]

In practice, the emphasis on federal government investments in science and technology, as shown by the budgets of the PBDCTs and by the activity of the financial institutions of the system, has fallen on basic research and the training of postgraduate personnel and on the establishment of the institutional infrastructure of research and development, although the financing of technological activities by national companies (private and state) has recently been expanded—apparently with relative success. At the end of 1975 this policy was complemented by modifications in the regulation of transfer of technology, which made this transfer conditional upon absorption of technology by recipient companies, especially by the imposition of clauses demanding full disclosure of technical knowledge by the proprietors of the technology, and the presentation of plans for the absorption of imported technology by the licensed companies. Finally, through the Núcleos de Articulação com a Industria (NAIs), established in the state companies with the main objective of increasing the local content of their purchases, more favorable conditions are being sought for those suppliers of capital goods who develop their technology locally.

It is estimated that the federal government spends about 0.5 percent of the GNP on science and technology (as defined in the PBDCT). Although lower than what is considered desirable internationally, this figure is not insignificant internationally in terms of absolute value (Erber 1977b).[32] There are few studies that evaluate the results of this science and technology policy in more detail. Although the policy has, perhaps, been in effect for too short a time for any results to be felt fully, the literature points out some of its limitations.

Several authors (Morel 1975, Pereira 1976, Sant'Ana 1978, for example) argue that, since technological dependency is part of a broader complex of relationships, to overcome this dependency it would be necessary to effect profound changes in the country's economic and political structures and in its relations with foreign countries. According to this analysis, without such changes the explicit science and technology policy would run counter to the "dependent" pattern of development followed in Brazil. Other analyses (Guimarães and Ford 1975; Bastos 1976; Erber 1977b, 1978) show a contradiction between the explicit science and technology policy and the other economic policies carried out by the state. They show that while the explicit policy tried to increase the technological autonomy of national companies, the other policies (among which stands out the favorable conditions given to foreign capital) induced national companies to use more and more technology from abroad.

Several authors (e.g., Schwartzman et al. 1979) suggest that the policy of science and technology responded, at least in part, to the needs of the economy for higher level manpower which, given the problems of personnel training at the university level, would have to be supplied by the graduate system. Erber (1977b) argues that the expansion of the graduate and research systems created a politically vocal interest group that presses the state for continuity in science and technology policy. Others have suggested that science and technology policy responded to the need for reducing the deficit in the balance of payments by cutting down costs for technology and capital goods imports (Tigre 1978).

The contradiction between the explicit and implicit scientific and technological policies and the role played in explicit policy by advanced science and technology (atomic energy, space research, etc.) leads some authors (Morel 1975, Pereira 1976, Romani 1977, Sant'Ana 1978) to suggest that the main function of the explicit policy of science and technology was to legitimize internally a regime supposedly based on "technical and scientific knowledge," and to enhance its international prestige.

Erber (1977b), although agreeing with the legitimizing function of the science and technology policy, searches for the root of this policy in the internal divisions of the Brazilian state, where a nationalistic segment of the bureaucracy, in alliance with military segments of similar ideology and with specific professional interests in science and technology, probably had the autonomy necessary to initiate the explicit policy. This study examines the role played by institutions initiating explicit policy, as compared to the technological strategy followed by national companies, as well as the composition of interests underlying those cases in which a policy of greater technological autonomy is being pursued (mini-computers and aeronautical engines). There is also an analysis of the priorities of the PBDCT budgets, where projects of military interest play a relevant role, which emphasizes that the initiative for science and technology policy came from certain state apparatuses; the national bourgeoisie had a passive role until recently, when it began to use more intensively the financial incentives (mainly subsidized loans) available under the science and technology policy. Erber points out that although the recent crisis in the balance of payments has probably expanded support for the science and technology policy, the policy and its institutionalization through the PBDCT Plan I preceded that crisis.

The policy suggestions in the national literature vary regarding the role to be played by scientific and technological development in the process of economic, social, and political development—that is, they vary according to the "social projects" of the various authors, and are concentrated in the area of technology, reflecting in part the "state of the art" of knowledge in these two areas. Even among authors with apparently similar projects, there are large differences in the suggestions, depending on the relative emphasis they attribute to the determining factors of the present situation and their evaluation of the margin of maneuver existing to carry out policy measures.[33]

In spite of these differences, a consensus seems to exist: the explicit science and technology policy will be effective only if it is coherent and integrated with the implicit policy. There appears to be a consensus that both policies must be designed at a rather disaggregated level in order to take into account the specificity of technical progress and the role it plays in each industry. There also seems to be agreement that the integration of explicit and implicit policy should encompass intersectorial connections; in other words, it seems to be necessary to conceive sectorial policy "packages" that embrace not only the relationships between the productive and technical-scientific systems but the relevant interindustrial relations as well. Similarly, there seems to be a consensus that the time dimension is crucial—a science and technology policy has a long maturation time and, therefore, must have a long anticipatory element in it.

It seems unnecessary to insist here upon the discrepancy between the type of recommendation and the actual policymaking process in

Brazil. As a rule, the authors had a clear perception of this; they probably did not expect to see it eliminated in the short term, but wished to contribute to the improvement of the actual policies.

4. CONSEQUENCES OF TECHNOLOGY FOR DEVELOPMENT

Technology and Industrial Growth

As we saw in section 1, different schools of economic thought agree that technological (and scientific) development is relevant to the recent growth of capitalist economies. What role would it play in Brazil, where conditions are structurally different from those of the central countries that serve as a base for these analyses?

In contrast to the authors previously discussed, Bonelli (1976) analyzes Brazilian industry of the 1960s within a neoclassical paradigm, using production functions. He posits the equivalence of value added and profits-plus-payroll, thereby taking the rate of growth of production as the weighted sum of the growth rates of its components—labor and capital—plus a residual growth rate, i.e., that part of the growth rate that exceeds the contribution of those basic factors.[34] The model is not causal in the sense that it cannot be used for prediction, since it does not assume a constant production function. Although its type of analysis may be formally likened to the studies of neoclassical authors (e.g., Denison 1974), it has a somewhat different meaning: the residual cannot be identified with technological change since it is not assumed that the prices of the factors correspond to their marginal productivity. The study concludes that "the residual's contribution to increased production in the manufacturing industry . . . in the 1960s varies from 22.5% when gross income is used to 29.7% for net income. The contributions of capital are calculated to be 66.4% and 54.5%, respectively, while the amounts due to increases in manpower employed are estimated at 11.5% and 15.8%, respectively. According to such values, the rapid accumulation of capital was the principal 'cause' of growth" (p. 172).

As Bonelli points out, the relative magnitude of the residual in calculating the growth rate is substantially less than that found by similar studies for the central countries. It is possible that this difference is due to a different pattern of development, but the author does not explore this hypothesis. He does, however, attribute "at least part of the differences . . . to the fact that our estimations of the participation of capital in income . . . are higher than those employed in similar work" (p. 173). The analysis indicates that the residual grew slowly in the "traditional" industries (leather, furniture, food, etc.) and at higher-than-average rates in dynamic industries.

Since the residual can include causes and factors other than technological advancement, Bonelli attempts to identify and evaluate the factors responsible for growth and variation of the residual by using a factor-analysis model, with fifteen possible variables identified a priori from the literature. The two principal factors identified, which explain approximately 80 percent of the variance of the residual, are seen to have a common characteristic: "both are related to the process of technological change imported from abroad, and represent two aspects of this process. Thus Factor 1 describes the industrial structure conducive to the introduction and diffusion of new products and processes in the manufacturing sector. Factor 2 in turn represents the mechanisms through which new productive processes and products are incorporated by the internal productive structure" (p. 176).[35]

By controlling for two types of industry—fast growth and slow growth—there are important differences in the significance of the factors. Although the more dynamic industries present a structure similar to that of the industrial average, Factor 2 (representing the transfer of technology) becomes more important and appears associated with the presence of foreign firms, "suggesting, therefore, that during the period under examination these firms were responsible for introducing into the country new goods and techniques developed abroad" (p. 177). By contrast, in slower growth industries the technological changes due to qualitative improvement of the processes and equipment used in production and, to a lesser degree, due to economies of scale appear to be more important.[36]

Bonelli's analysis, especialty that part which deals with the elements responsible for the residual in which the peculiarities of Brazil are revealed more clearly, represents an interesting confirmation of the results obtained by the studies of technological dependency, using a different theoretical matrix and different methods of empirical verification. However, in his conclusions, Bonelli emphasizes the speculative nature of his work, not only because of statistical deficiencies, but also ". . . due to the fact that either the concepts used are nothing more than proxies for effects we would want to grasp or due to the fact that no theory exists which deals with the special problems we studied" (p. 178).

Furthermore, Bonelli's approach suffers from the problems inherent in its theoretical framework: although it goes beyond the traditional studies that identify technical progress with the "residual" (e.g., Maneschi and Nunes 1970), the relationships existing between the movement of capital accumulation and technical progress remain unclarified, essentially due to the treatment of "capital" and "technical progress" as distinct and autonomous production factors, even if the analysis of growth and variance of the residual suggests some of the possible relationships between the two.

The relationships between technical progress and industrial growth are, in our opinion, better understood and greater possibilities for technological policy suggestions (implicit and explicit) are opened by the explicit treatment of these relations in the light of theories that deal with industrial organization, notably with oligopoly (for example, Steindl 1952, Bain 1959, Labini 1969) and with the dynamics of capitalist accumulation (for example, the above and Kalecki 1956). This approach, which treats technical progress essentially as an instrument of capitalist competition and market control that accompanies the movement of accumulated capital, was adopted in the studies of diffusion done by the FINEP (see section 3). It was further detailed in its application to Brazil in Tavares et al. (1978) and Tavares (1978). These two studies (1) discuss the recent movement in Brazilian industrialization, especially during the expansion of 1967–73; (2) examine the process of capital accumulation and concentration in the several industrial branches (grouped by types and uses), the evolution of their profitability (prices and mark-up) and employment, and their competitive dynamics; and (3) distinguish the behavior of the industrial branches from that of their leading companies, differentiated between national (public and private) and foreign-owned.

It is beyond the scope of this study to summarize the general results of such research. As for the role of technical progress, it is treated as an integral element of a broader process, serving as a technical base for production and as an instrument of accumulation and competition. The results obtained point once more to industrial heterogeneity: not only does technical progress play different roles in industrial growth, from one industrial branch to another, but in several cases it is hardly relevant. For example, in the intermediary goods branches, industrial concentration is strongly based on the technical dimensions of production, while in durable consumer goods the characteristics of technical progress impinge most strongly upon the competitive dynamics through differentiation of products. In certain branches of nondurable consumer goods, in turn, technical progress plays a secondary role in growth.

The studies cited offer interesting hypotheses and valuable empirical material for further research focusing on the role of technical progress in the growth process in a given industry and, comparatively, between industries. Additional research is needed for the period already studied and, especially, to cover the current phase of the cycle, in which the role of technical progress will presumably be different from that observed in the recent period of expansion.[37]

As we have seen, a substantial part of the Brazilian literature concentrates on the problem of technological dependency. Taken together, the works reviewed here, in addition to pointing out important sectorial differences in the forms in which the technical process is introduced and the role it plays in the growth of these sectors, show that the pattern of dependent technological development was compatible with the rather rapid growth rates experienced by Brazilian industry in the recent past. According to the arguments, greater technological autonomy would have offered greater growth opportunities, especially for the long term, and could foster a somewhat different development pattern, especially in terms of the relative weight of national capital in comparison to foreign capital and, perhaps, in terms of growth-cum-equity, if it were used to reduce unemployment and thus expanded the internal consumer market.

However, in our view, the main concern should not be an attempt to rewrite history, investigating what would have occurred had there been greater technological autonomy, but, to the extent such autonomy is deemed necessary to meet given economic and political objectives, to question its feasibility. The answers to this question vary according to the margin of maneuver available for a policy of greater technological autonomy. All observers seem to agree that this margin is not large under present Brazilian conditions, so their answers to the question of feasibility differ only as to the degree of difficulty perceived.

Technology and Balance of Payments

Policies of greater technological autonomy are often justified by their beneficial effect on the balance of payments of peripheral countries. In Brazil this is an important aspect, given the recurring limitations on growth imposed by the stranglehold of the external balance of payments and the important consequences of the measures taken to overcome this constraint. Pastore (1976) argues that national research contributed positively to the production of traditional primary products (coffee, cotton, and sugar cane) and he suggests that the investment in research on such products was a consequence of their role in Brazilian exports; by contrast, research in products for the internal market has been meager or inefficient.

The work of Fajnzylber (1971) is apparently still the most complete study of exports of manufactured products, which are becoming increasingly important for Brazil. Comparing the structure of imported technology (based on data of Biato et al. 1973) with Brazilian exports, Fajnzylber observes:

(I) The sectors that show greater intensity of imported technology contribute to only a small fraction of exports. (II) The sectors with a greater-than-average openness to foreign trade absorb only a small amount of imported "know-how" and, (III) given the reduced technological development performed by industry in Brazil, this implies that the large majority of industrial exports from the country rely upon use of diffused technical knowledge. This implies a fragile competitive situation in a market such as manufactured products, characterized by rapid innovations in products and processes. (P. 169)

In analyzing the relationship between the behavior of the firms which import technology and those which export manufactured products, Fajnzylber established that:

(I) The exports of the companies which import technology are destined primarily for countries with a similar or lesser degree of industrial development [notably of the ALALC]. (II) Manufactured products are exported from Brazil to developed countries fundamentally by companies which do not import technology but which apparently also do not achieve any autonomous development. (III) The majority of exports destined for developed countries made by national companies which do import technology are products which utilize the comparative advantage of Brazil, primarily the availability of natural resources which serve as a base for manufacturing [mainly iron and steel]. (IV) The majority of the exports from international companies to developed countries are the less complex items of their product line, i.e., those which are partially technologically obsolete, those destined for the replacement market, and those based on processing abundant natural resources. (P. 197)

Comparing the relative importance of international and Brazilian companies, Fajnzylber shows that in the period studied (1967–69) exports from international companies predominated in the majority of the sectors and that the technological content of the products exported by international companies appeared greater than the corresponding technological content of the exports of national companies.[38] Although restricted to the initial period of Brazilian exports of manufactured products, the conclusions of Fajnzylber are confirmed by more recent studies (Von Doellinger et al. 1974). Nonetheless, a more detailed evaluation of Brazilian exports during the decade after the period examined by Fajnzylber seems highly advisable.

The studies mentioned argue that future expansion of manufactured exports will depend heavily upon an increase of technological complexity in order to enter more dynamic markets and to avoid the competition of the less developed countries. For national companies, this implies an internal R and D effort, since licensing often includes restrictions on exports by the licensee. Such restrictions are empirically confirmed by the studies of clauses of licensing contracts signed by Brazilian companies (Erber et al. 1974b, Fung and Cassiolato 1976).[39]

More recently, partly because of the role played by engineering companies in capital goods exports, a FINEP study investigated exports of engineering and architectural services (Wanderly et al. 1976), which showed a geographic orientation analogous to that of manufactured products: in terms of either proposals or contracts, they were concentrated in countries of lesser development than Brazil—two-thirds of the contracts were in Latin America and the remainder in Africa. Of the eighteen projects done, eight were related to transportation.

The authors concentrate on the difficulties encountered by the Brazilian firms in exporting their services. Part of these difficulties derive from the intangible nature of these services; they probably require greater sales efforts than manufactured products because they do not receive support from the governmental system for information, financing, etc. Despite emphasis on the deficiencies of Brazilian export policy for these services (in contrast to the support given by governments of advanced countries to exports by their consulting firms), followed by policy suggestions, the authors also point out several characteristics of the enterprises that limit their exports. These include the lack of any international tradition and their size, which is insufficient to meet the commercial and financial costs of the projects. As previously discussed, the authors also point out the presence of affiliates of foreign companies in the Brazilian market as an important element restricting exports by the national firms.[40]

The common problem in economic analysis in identifying real with monetary flows is conspicuous in the case of international payments for the transfer of technology. First, when the transactions are among independent firms, the price paid for the technology transferred results from a bargaining process with limits determined by the opportunity costs of the two parties, one of whom (the licensee) necessarily does not fully know what he is receiving. In this context, the technological content of that being negotiated is but one element in the negotiation, and is frequently secondary.

When the transfer is made among companies of the same group, payment for the transferred technology through a contract is not necessary—this document is fundamentally related to legal requirements of either a fiscal nature or regarding remittance of resources by the affiliate to the parent company. Nevertheless, even when contracts are signed between affiliates and parent companies, they do not necessarily reflect flows of technology. As Biato et al. (1973) observe for Brazil: "The company installed in the country is linked to the international organization through the capital invested (in the form of financial resources and capital goods) and through the use of the technology." From the viewpoint of the international company, what matters is only the amount of overall receipts for its "assets."[41] In this sense, remittances in the form of profits on the capital invested and in the form of payments for the transfer of technology depends mainly on the institutional and legal handling of foreign capital and the transfer of technology by the receiving and exporting countries.

In the case of foreign companies in which there is investment of national capital, the international group seems to prefer to be paid for the imported technology since such payment constitutes a production cost, which reduces the profits of the local company and reduces the national stockholders' income to the benefit of the foreign headquarters. Also, payments are received in the same year as the production itself, while profits are realized later. Due to changes in the exchange rates, the headquarters benefit more if payment is made for the importation of "know-how" (Biato et al. 1973, p. 12).[42] Such analysis of the contracts of foreign firms is especially relevant for Brazil when one considers that, in the period 1965–70, foreign firms were responsible for three-quarters of the payments for the transformation industry (excluding contracts for oil products) and more than 50 percent of the total resulted from contracts signed between parent companies and subsidiaries and/or associates (Biato et al. 1973).[43]

In the case of Brazil, it is worthwhile to recall the often deprecated quality of statistical data. The data prior to 1965 for payments made for technology appear questionable, due to loss of information; and even for the period after that date, Biato et al. suggest that the data are probably underestimated. Thus, the conclusions of the studies reviewed below must be taken cautiously, and this area demands considerable additional research.

Several authors (Biato et al. 1971, 1973; Pastore 1976) argue that the growing complexity of the Brazilian industrial structure, including the internal production of capital goods, would modify the structure of technology imports and expand the import of technology not incorporated in capital goods. The data from the Banco Central show that imports of technology indeed grew substantially in terms of absolute values (Biato et al. 1973, Tigre 1978). Nevertheless, in relation to the imports of capital goods, the payments for technology increased between the postwar period and 1965 but declined after 1965 (see Tigre 1978), which suggests that the main form of incorporation of foreign technology is still embodied in capital goods. Tigre shows that the costs of technology had maintained a practically constant relationship with the gross national product in the last decade (about 0.2 percent) and they represent a very small part of the total imports of the country—slightly more than 2 percent in the period 1970–76.[44]

The ratio of technology imports to Brazilian GNP is not substantially greater than in the central countries: the main difference is in the ratio between internal costs for R and D and imports—while the central countries (France, for example) spend more than ten times the amount for technology imports on local R and D, in Brazil the ratio is less than three (Tigre 1978). However, while Figueirido (1962) has reservations regarding the capacity of Brazilian industry to absorb technology and warns against expansion of local R and D since it could divert scarce human resources from industrial activities and thereby inhibit economic development, Tigre recommends precisely the contrary—expanded local expenditure on R and D, based on the inadequacy of imported technology for greater growth, combined with greater economic and political autonomy.

Two studies present a more disaggregated analysis of payments for technology—Biato et al. (1973) for 1965–70 and Fung and Cassiolato (1976) for 1972–75.[45] Their results are difficult to compare due to the procedures utilized. Biato et al. use the exchange contracts at the Banco Central for technology payments, and concentrate on the transformation industry (excluding petroleum product derivatives), which corresponds to 55 percent of the total payments recorded by the Banco Central. Fung and Cassiolato use INPI data on the transfer agreements for all sectors and concentrate on those agreements in which the amount of payment is specified (82 percent of the total number of contracts). Although Fung and Cassiolato offer greater coverage in terms of sectors, the reliability of their data is poor since they use INPI's ex-ante estimates of payments.[46] Nevertheless, they show some aspects not studied by Biato et al., such as the insignificance of the agricultural sector as an importer of technology, and the importance of state imports (notably for the petroleum and electrical power companies).

The two studies agree as to the concentration of payments at the branch level and at the company level. They also agree when comparing the behavior of Brazilian and foreign companies: Biato et al. point out that "the average payment between the parent office and the subsidiary and/or associate is 8.7 times greater than that of national companies, and 4.8 times greater than that of foreign companies which have no property link with the external supplier of technology" (p. 127); Fung and Cassiolato find that the value for "foreign companies paying related suppliers is approximately four times that of nonrelated companies and approximately three times that of Brazilian companies" (p. 53). Thus, although using different data sources, both studies conclude that payments for technology may be a possible area of profit remittances for foreign companies.

The proverbial tip-of-the-iceberg image is applied frequently to the direct costs for importing technology. As shown by the studies of Vaitsos (1970, 1974) for the Andean Pact, contracts for technology transfer often have tied-in imports of raw materials, components, services, etc., which are frequently overpriced; this increases the cost of the transferred technology and tends to concentrate income in the hands of the owners of technology in the central countries. Though no study in Brazil has matched the scope of Vaitsos' work, sectorial data concerning custom-built capital goods (Erber 1977b) and pharmaceutical products (Frenkel et al. 1978) suggest that the same phenomenon happens in Brazil.[47] Nevertheless, a more comprehensive study that would examine the question in detail would be very useful.

Imports of capital goods still appear to be the main form of incorporation of technology from abroad. Given the role they played in the Brazilian balance of payments, recent economic policy has emphasized the internal production of goods previously imported. Although it is probably a minor cause of imports, there seems to be a technological gap between local production and imports (Magalhães 1976), which may have given additional support to the policy of greater technological autonomy in this industry.[48]

Fung and Cassiolato (1976) describe the institutional apparatus for the control of payments for technology, and analyze its operation at the time of the study. Several deficiencies are pointed out, especially the lack of resources (notably human) and the weak integration of the government institutions in charge of technology imports. The present policy of transfer of technology, following the changes introduced in 1975, is characterized by two related objectives: the reduction of expenditures in foreign currency and the stimulation of internal technological activity.

Although an empirical evaluation of the results of this policy is still lacking, the data suggest that even substantial reductions in direct costs for technology would have a limited effect in terms of reducing the constraints on foreign exchange. Nevertheless, direct costs for technology are not the only way technological dependency affects the balance of payments, and it is possible that by helping to change the relative prices of imported technology and local technology in favor of the latter, the present policy had other indirect positive effects on the balance of payments.

It is also possible that the combination of restrictions on direct imports and on payments for technology stimulated the entry of foreign firms into the Brazilian market through subsidiaries and/or joint ventures, especially in the capital goods industry. If this is true, in addition to its questionable effect on the distribution of ownership in industry, this policy would have uncertain effects upon the balance of payments, too, by stimulating in the long term a greater flow of resources to foreign countries in the form of repatriation of profits. The speculative nature of these comments suggests, once more, the need for expanded research in this area.

Technology, Employment, and Distribution of Income

Unemployment, whether open or hidden, is frequently pointed out as the "most marked symptom of inadequate development" in peripheral countries (Jolly et al. 1973, p. 9), and the import of technology is often named a cause of unemployment in such countries (Moravetz 1974). It is argued that imports of capital-intensive, labor-saving techniques for new industries would directly aggravate the structural problem of unemployment, producing too few jobs to meet the growth of the labor force. This effect would be compounded by the modernization of traditional industries through relatively labor-saving techniques. Indirectly, through its effect on capitalist competition, imports of technology would contribute to the elimination of craftsmen and small and medium-size businesses, which employ more labor. Such effects on employment aggravate the inequality of the income distribution of peripheral countries. In addition, imports of technology worsen income distribution through the establishment of labor markets that are segmented and highly differentiated in terms of income, with a small, highly paid group of "technical-management" jobs and a large, "unskilled," low-income group. From this angle, imports of technology would limit the rhythm and autonomy of growth in peripheral countries by inhibiting the growth of a mass market that would serve as a basis for self-sustained expansion.

The question of whether technical progress in central countries tends to be labor-saving for the economy as a whole is theoretically and empirically debated in international literature (e.g., Blaug 1963, Bowen and Mangun 1966, Braverman 1974). Nevertheless, the evidence available for industry indicates that the reduction of labor directly employed in production is only partially compensated by the expansion of indirect labor (maintenance, planning, etc.).[49] Some authors argue (sometimes implicitly) that although that historical analysis may be correct, there is at any given moment a range of available techniques of varying degrees of labor intensity, and that even so the tendency in peripheral countries would be to select less labor-intensive techniques. Goodman et al. (1972) and Bacha et al. (1974), following a line of reasoning common in international literature (e.g., Ranis 1973) and inspired to a large extent by the dual model of Lewis (1963), argue that in Brazil the preference of management for capital-intensive techniques is in good part due to the excessively high price of labor in relation to capital, due to social security costs that burden the former and the state subsidies granted the latter. They suggest policy measures to modify the relative prices and estimate that such modification would substantially increase labor absorption in industry.

In criticizing this approach, Erber (1972) argues that the range of available technology is, in reality, quite small, limited mainly to the nondurable consumer goods sectors. Although empirical evidence from international literature shows that often there is a range of *technically* efficient procedures in many industries (e.g., Jenkins 1975), in Brazil, the conditions of income distribution, the behavior of multinational companies, and the technological dependency of national companies restrict the range of *economically* feasible techniques.

This same trio of factors also accounts for a process of selection of technologies that is not too sensitive to variations in the costs of the production factors. In addition to the indirect evidence from studies of technological dependency and diffusion, which suggest that this choice has other stronger determinants (see the preceding section), some studies that discuss the topic directly show the minor role that the relative costs of production factors play in the selection of technologies; see, for instance, Versiani (1972) on the retooling of the textile industry in the 1950s,[50] and Morely and Smith (1977) on the behavior of multinational firms in Brazil.[51]

In the same study, Erber also argues against treating capital and labor as homogeneous production factors. Subsidies to capital had been mainly for fixed capital, and if, following a reduction in labor costs, management changed the production function by employing more labor, it would increase working capital requirements, whose additional financial costs could be greater than the reduction in manpower costs. Erber points out the need to differentiate the labor factor according to training, suggesting that the lack of skilled workers and technicians in Brazil would be a reason for choosing capital-intensive techniques that would more intensively use unskilled manpower on the one hand and university-level personnel on the other.

This last issue, deficiencies in the supply of trained manpower, is taken up and expanded by Almeida (1973) who grants it a fundamental role in the low absorption of manpower by industry. Almeida also argues that the use of labor-intensive techniques tends to perpetuate underdevelopment and dependency to the extent to which such techniques are obsolete and do not foster the structural transformations that are characteristic of development. Thus, the training of personnel and the absorption of imported technology are granted priority in science and technology policy.

As an alternative to labor absorption through manipulation of factor prices, Almeida (1973) and Rattner (1974) propose a "planned technological dualism" in which the labor-intensive techniques of some economic activities would be combined with the capital-intensive techniques of others. This dual structure would include the transformation industry but would be oriented above all toward agricultural activities, the construction industry, and public works, where it is assumed there would be greater opportunity for the use of labor-intensive techniques. There does seem to be disagreement among those authors about the availability of techniques to implement a policy of technological dualism and regarding the resulting technological policy. Although Almeida does not discuss the topic explicitly, he seems to believe that dual techniques could be imported or that at least they would not demand a great national scientific and technological effort. In contrast, Rattner argues that imported techniques would be inappropriate and that R and D facilities of the country should develop "intermediary technologies." Even if a dual system is desirable and technological problems can be solved, it would still be necessary to examine in detail whether this dual system is compatible with the present Brazilian economic and political structure. This crucial topic is only rarely discussed in the national literature.

The topic of dualism is elaborated further by Cunha (1978). After a criticism of "dualism *cum* distortions in the factor prices," in which he expands the points mentioned above, Cunha reintroduces dualism as a manifestation of a heterogeneous production structure in which "archaic" forms of labor organization (the "informal" sector) are continually reproduced in the process of capitalist expansion and are a function of such expansion. In his final section, Cunha focuses on the segmentation of job markets and productive techniques according to the market structure, arguing that they are being fragmented increasingly by the development of oligopolies.

The important theoretical survey by Cunha can serve as the backdrop for several studies of the relationships between technique and employment, for example, Ozório de Almeida (1978) and Schmitz and Camargo (1977), as well as for the evidence pointed out by Bacha (1973) and Cunha and Bonelli (1978) on the dispersion of wages. This fruitful line of theoretical work and empirical investigation would be enriched by specific studies of current labor processes in Brazil, exploring the validity for Brazil of the theses raised in the international literature on the labor process for the central countries (e.g., Braverman 1974, Gorz et al. 1974).

5. CONCLUSIONS

The relationship among science, technology, and society now appears to have a place of its own as a specific topic of research in Brazil. A considerable portion of the literature also seems to recognize the complexity of the field and its importance as the locus of critical decision-making junctions for the economy, while at the same time cautioning against overrating this importance. Dealing with this complexity, even through partial analyses (recognized as such), is, in our view, one of the main achievements of Brazilian literature on the topic.

This complexity warns against the generalizations so much to the taste of our culture, although efforts to synthesize the results are clearly necessary. Since a broad theoretical capacity does not seem to have developed as yet, the easier and more productive route is to continue with the studies of specific situations that have not only proved to be fruitful but have also served as a basis for some of the more creative generalizations, such as the recent discussion of the exhaustion of innovation (see section 2). In the same way, the study of multiple determinations of phenomena in this field suggests the opportunity and even the need for multidisciplinary analysis, combining knowledge from the several social sciences with that from other sciences and engineering. We are not suggesting that the available analyses exhaust the topic. Nevertheless, it is important to recognize the progress made in understanding the social and economic environment for the generation and diffusion of science and technology in Brazilian society. In the areas studied, the level of research is, in our view, often comparable to the best of the international literature.

These studies may be an important aid in the preparation of science and technology policies, not only because they present many specific policy suggestions, but also because they indicate their complexity and their relationship to other policies. For policymaking purposes, the results suggest that the more fruitful approach is that which, without abandoning the use of models and more abstract formal approaches, includes direct investigation of the rationale of the behavior of the agents involved—partly as a consequence of the lack of more general theories for explaining this behavior.

Even the topics already treated, such as technological dependency, diffusion of innovation, institutionalization of scientific activities, the role of the state, etc., need to be examined further at the empirical level and reviewed theoretically. There remain several aspects that are only slightly studied, such as the consequences of modifications of the labor process on the composition and control of the labor force, or the role that technological dependency plays in Brazilian foreign trade. There are also topics that remain virtually unstudied, such as the relationship between technology and the environment in Brazil and the introduction and diffusion of technology in the amalgam that constitutes the "tertiary" sector. National literature also presents a parochial and singularly dependent facet: other than Brazil, the central capitalist countries are studied almost exclusively, and the important cases of scientific and technological policy in the periphery, as, for example, in India and Argentina, are ignored. Likewise, analysis normally concentrates on the larger nations, ignoring important cases such as Sweden, Belgium, and Holland, which are, perhaps, more relevant to the Brazilian situation.

Explanation of why the treatment of subjects is so uneven would require a separate study. Nevertheless, we suggest that the choice of topics probably was not independent of the institutional framework within which the studies were done. In this sense, it is important to note the discontinuous nature of the investigation done in the universities, which is frequently subordinated to the presentation of masters' and doctoral theses; no research tradition in this field was established in these institutions, unlike that which developed in government, especially at FINEP.

It is hoped that with increasing interest in the subject in the university community—recently expressed in a myriad of seminars, by the establishment of an M.A. course on the "economics of technology" (at the Instituto de Economia Industrial of the UFRJ), and by the beginning of research groups studying the subject—that the institutional gap will be filled and with it some of the research lacunae.

NOTES

1. For reasons of time, publications of a sectorial nature, such as the journal *Dados e Idéias*, published by SERPRO or the reports of *Semanas de Tecnologia Industrial* from the Secretaria de Tecnologia Industrial of the MIC, were not reviewed.
2. The question of whether the socialist mode of production requires a different labor process and different production methods, an important debate in the international literature, is only rarely treated in the Brazilian literature.
3. Barbosa analyzes the characteristics of three forms of technology/commodity in detail: patents, know-how, and technical services. He shows that while a patent (as well as a trademark) is an asset of the company—an object of property—know-how and technical services are not legally recognized as property, being considered "quasi-assets," despite attempts to give legal proprietary rights to know-how.
4. This is especially true in those activities offering more uncertain and long-term results, such as basic research.
5. In spite of its popularity, the Schumpeterian hypothesis is widely disputed, at both the theoretical and empirical levels. See, for example, Fischer and Temin (1973) and Freeman (1974) and the survey of Kamien and Schwartz (1975).
6. The "empty shelves" thesis has been vividly countered at the empirical level by technologists, as can be seen in the comments on the study of Castro and Araujo in Gomes (1978) and Nunes et al. (1978).
7. This was presented as one of the great advantages to these countries for being "latecomers" (Rostow 1960). For a conceptual criticism of such supposed advantages regarding technological development, see Ames and Rosenberg (1971).
8. These two works are summarized in Biato and Guimarães (1973). In parallel, an international project with the participation of IPEA and IPE/USP did three sectorial studies on the transfer of technology in the machine tools industry (Vidossich 1970),

textiles and clothing (Spreafico 1970), and iron and steel (Leuschner 1971), summarized in Figueiredo (1972). At a more aggregate level and within a different theoretical perspective, IPE conducted studies of aggregate production functions for Brazil, summarized in Maneschi and Nunes (1970).

9. It is worthwhile to note that while the earlier studies (Azevedo 1955, for example) emphasize cultural tradition, the more recent works give more weight to economic and political conditions.
10. Such economic literature implicitly warns against the adoption of "utilitarian" criteria with narrowly defined, short-term objectives.
11. An analysis of the criteria that rule the appraisal of projects by funding agencies (e.g., FINEP) and of the influence of such criteria upon the decisions of scientists about what to present for funding has still not been made.
12. The study was made with data generated by Biato et al. (1971) but only partially used by them, and shows some important problems arising from the use of mailed questionnaires for research in this area.
13. The role played by consulting firms in the generation and diffusion of technical progress is being studied increasingly in the international literature, partly for its effect on the capital goods industry and the international division of work. See, for example, Roberts (1973), Palloix (1975), and Perrin (1976).
14. Even internationally. In addition to the literature cited above, see Freeman (1974).
15. For petrochemicals also see Wasserman et al. (1976).
16. See the bibliographies of studies cited for additional references, especially for work that deals indirectly with the topic.
17. For example, in machine-tools it is noted that the simplest models tend to be locally designed (often copied), while more complex models tend to be licensed.
18. The main categories used are technology of operation, design (basic and detailed), and research (pure and applied). "R and D," as used internationally, includes basic design but not detailed design or operation technology (see Freeman 1974).
19. It is important to note that the studies, notably those on process industries (Wasserman et al. 1976, Jorge 1978, Dahlman 1978), show that the mastery of production technology leads to substantial increases in production, using the same equipment.
20. Technology is seldom bought. Its property remains with the licensor, who "leases" it to the licensee. A clause frequently found in licensing agreements also requires transfer of ownership to the licensor of any innovation introduced by the licensee. According to the studies cited above, payment of licensing contracts is based on a "lump sum" and a percentage of sales, which provide the bulk of the licensor's income. Other benefits include the sale of raw materials and components, the possibility of becoming a partner in the national firm, control of the international market via restrictions on exports by licensees, etc.
21. Note, however, that in some of these industries, such as petrochemicals, there are instances of research and planning conducted by national companies of a relatively small scale (Jorge 1978).
22. The debate concerning "balanced growth" vs. "unbalanced growth," a classic in the "economics of development," is pertinent here.
23. One of the most frequent criteria in the selection of the licensor is the commercial success of his products.
24. FINEP recently included the supply of risk capital in its support operations for national technology; however, an evaluation of this experiment has not yet been made.
25. The initial study of the FINEP on the capital goods industry (Erber et al. 1974b) led to a study of state companies involved in the areas mentioned, in the context of a multinational research project—the Science and Technology Policy Instruments Project, funded by the IDRC and by the OEA in nine peripheral capitalist countries and one socialist country (Yugoslavia). A comparison of the results is found in Sagasti (1978).
26. See Abranches and Dain (1978) for an extensive discussion of the structural ambiguity of state enterprises, complemented by the two "extreme" case studies—the Companhia Vale do Rio Doce and the Rede Ferroviaria Federal.
27. The difference between technical success—the achievement of a product or process

with the desired features—and economic success—the sale of that product or process—is classic. The first does not imply the second, as the international literature shows (Freeman 1974, Rothwell 1976).

28. The study of diffusion by the National Institute of Economic and Social Research of England (Nasberth and Ray 1974) served as a point of departure for the study by Araujo et al. (1976).
29. To account for the multiplicity of factors that affect the decisions of the various agents involved in the process of scientific and technological development, and to attempt to establish hierarchies among the various policies that affect these decisions, the literature on science and technology policy frequently makes the distinction between explicit and implicit policies. The former are those that have a definite and identified intent to influence the activities and functions of science and technology, while the latter are those that, although designed with other purposes in mind (for example, regulating imports), affect those functions and activities. This distinction was detailed in the text of the STPI project mentioned above (Sagasti 1978), and is summarized in Rattner (1977).
30. Romani (1977) presents a detailed description of the evolution of the activity of the CNPq, BNDE, FINEP, Secretaria de Tecnologia Industrial, and of the recently created FIPEC of the Banco do Brasil. Erber (1977b) discusses the creation of the plans, their priorities, financial mechanisms, and their limitations as plans for action. The two plans were published by the Presidencia da Republica. The institutions involved publish annual reports of activities and produce internal documents evaluating their activities, although access to the latter is normally restricted.
31. Guimarães and Ford (1975) present an analysis of the role attributed to science and technology in the different development plans of the period 1956–73.
32. Comparisons with other countries' expenditures are precarious not only due to the usual problems of exchange rates, remuneration of researchers, etc. (see Freeman 1974), but also because the PBDCT includes expenditures that in other countries are not considered R and D (for example, part of graduate training) and because only federal government expenditures are included.
33. For example, Biato et al. (1971) emphasize policies for research institutions, while Erber et al. (1974a) give more weight to the modification of conditions that affect decisions of the companies.
34. The growth rate of these factors is composed of a "size effect" (of the firms in an industry), a "region-effect," plus a simple rate of change of the factor. Nevertheless, the "size" and "region" effects are not very significant.
35. The most important variables in Factor 1 are: average size of industrial installations, industrial concentration, participation of foreign firms in the markets and in the capital of the industrial sectors. Factor 2 is based on: relative importance of payment for patents, manufacturing licenses and registered trademarks bought from abroad per product unit (proxy for evaluating the effects of new products), purchases of foreign technology per product unit, and differentials of manpower training reflected by the proportion of employees with formal education above a certain level.
36. This is the interpretation given to Factor 3, composed of: long-term savings of intermediary inputs per product unit, gross return rate, and the proportion of males employed in the work force, in decreasing order of importance. Factor 4 includes as the main variable the average growth rate of industrial installations and, secondarily, the variation in the rate of utilization of capital between 1959 and 1970 and the rate of profit on value added, with the latter as a proxy for the capacity for self-financing of costs incurred with the introduction of new techniques.
37. For example, the relationship between the competitive dynamics (including the role played by technical progress) and the qualitative composition of the work force (see section on employment and income distribution).
38. Technological content was estimated by the inspection of products, and, quantitatively, by calculation of the degree of the technology imported (payments for technology) by product unit exported, and by the price/weight ratio of the products exported.

39. The INPI no longer registers contracts in which there are clauses restricting exports. Nevertheless, since exports depend on the initiative of national firms, given their dependency on licensors, the efficacy of this measure is doubtful unless national companies are ready to develop their own capability and face a conflict with their licensors.
40. Technical consultant capability depends to a large extent on experience; thus, the lack of international experience produces a vicious circle in terms of entry into the international market. The authors also note that, "In several cases the client wants financing for preparation of the study plus financing of the work to be suggested by the study" (p. 17), confirming the international evidence regarding the formation of financial-commercial "packages" (Palloix 1975).
41. See the treatment of technology as "assets" of the company in Barbosa (1978a and b).
42. In addition to the differential of the exchange rate, the opportunity cost of these resources while they remain in Brazil is probably important too.
43. The 25 percent of payments made that formally correspond to transactions between affiliates domiciled in the country and nonassociated foreign firms probably includes some triangular transactions, in which the Brazilian subsidiary contracts the import of technology with a company associated with the group but legally distinct from the parent company (Biato et al. 1973).
44. Calculation by the author, using data from Tigre (1978).
45. The only breakdown presented in the reports of the Banco Central—"Administration and Technical Assistance," "Patents," and "Royalties and Rents"—has little usefulness, given the legal framework that prohibits remittances of foreign companies for the last category, thus slanting the distribution in favor of the first category.
46. Such weakness does not impinge on their analysis of the reasons and characteristics of companies that use transfer agreements and the observations regarding policy and policymaking in the area.
47. The pharmaceutical industry was also studied by Vaitsos. Both show tied purchases and overpricing between affiliates and parent companies.
48. Among the main causes are government incentives for the import of capital goods and the role played by foreign financing sources, especially for state government projects (Suzigan et al. 1974).
49. See the studies of Bright (1966) and Bell (1972); also the references in Ozorio de Almeida (1978) on subcontracting.
50. "There are indications that the choice of the investment/employment ratio for new equipment is limited, so that the ratio of the prevailing factor prices could not affect this type of decision significantly" (Versiani 1972, p. 41).
51. "Firms were inclined to duplicate plants which produced on the same scale in different places; it is doubtful that they modified plant plans only as a response to a different set of factor prices" (Morely and Smith 1977, p. 261.)

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