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Innovation and the Dynamic Competitiveness of Brazilian Industry: the Role of Technology Imports and Local Capabilities

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SUMMARY

The recent Brazilian industrial and technology policy seems to be anchored in the idea that, as part of the so-called globalisation process, technology has also become 'global' and that, like a commodity, technology could be acquired internationally under market conditions. Under such view, policies geared to attract foreign investment and pressures on local firms to achieve better quality and improve productivity that would suffice in order for the Brazilian industry to increase competitiveness. Recent research, however, has extensively clarified the 'globalisation of technology' thesis.

A detailed analysis of the thesis shows, however, that 'global exploitation of technology' is the only strong case for 'techno-globalism'. Technologies are increasingly been exploited in foreign markets both embodied in products and disembodied, for example via transfer of licences and know-how. The willingness of firms to exploit their innovations in foreign market does not necessarily mean that they will be successful. As for disembodied technologies this depends on policies by national governments and firms which can facilitate and foster the import of technology.

Analysing the Brazilian case, the papaer argues that the main problem is not about the 'quantity' of technology acquired from abroad; it is about <u>how</u> that technology is acquired. If increased volumes of imported technology are to play their full potential role in enhancing competitiveness in the 1990s, it will be totally inadequate just to go back to the typical ways of acquiring technology in the past. Those approaches must be radically altered. Some of the new understanding about the process of technological change, its role in the competitiveness of industry, and its interaction with technology imports, that has become more widely accessible since the 1970s, suggests that these aspects of

Brazilian experience were neither inevitable nor similar to the experience of a few other industrialising economies that have exploited imported technology much more effectively. Also, the 1990s are not the 1970s and the international context for technology acquisition by Brazilian firms is now radically different. New approaches to management and policy will be needed if Brazilian industry is to exploit the full contribution to competitiveness that can be made by imported technology.

1. INTRODUCTION

The recent Brazilian industrial and technology policy seems to be anchored in the idea that, as part of the so-called globalisation process, technology has also become 'global' and that like a commodity, technology could be acquired internationally under market conditions. In such view, policies geared to attract foreign investment and pressures on local firms to achieve better quality and improve productivity would suffice in order for the Brazilian industry to increase competitiveness. Recent research, however, has extensively clarified the 'globalisation of technology' thesis.

Techno-globalism is a term that is being widely used for the hypothesis that generation, transmission and diffusion of technologies are becoming increasingly global in scope. Implicitly, techno-globalists assume that technologies are commodities and propose that, in a borderless world, international technologies are accessible by firms and could be transferred internationally under a market mediation via the price mechanism.

The extensive literature on the economics of technical change, innovation and diffusion of technologies published in the last 20 years[1] may help to clarify and qualify techno-globalism. Archibugi and Michie (1995), for instance, proposed three distinct categories under which technological globalisation should be analysed. The first category, 'global technological collaboration', refers to the idea that there is international collaboration between firms, sharing know-how with competitors from different countries. The second category, 'global generation of technology', is that big firms, multinational corporations are increasing the international integration of their R&D and technological activities. The third should be the 'global exploitation of technology', meaning that an increasing proportion of technological innovations are exploited in international markets.

Empirical evidence for the first category - global technological collaboration - shows that there has been a significant increase in cross-border collaboration by both non-profit institutions (such as universities) and the business sector (Frame and Narin, 1988; Hagedoorn and Schakenraad, 1992; Lastres, 1993). However, joint R&D by the business sector is confined to a very few, although crucial, fields: information technology, biotechnology and advanced materials. Also, and most important, joint R&D by firms is a phenomenom that tends to occur either inside the 'home country' of firms (approximately 50 per cent of recorded technological agreements are made by firms exclusively of US, Japan and Western Europe) or between firms of the Triad (Hagedoorn and Schakenraad, 1992; Lastres 1993).

As for the second category - global generation of technology - empirical evidence (Patel 1995) based on patenting activities shows that US and Japanese firms are still very 'national' in their strategies of technology generation: only 3,1% and 1,2%, respectively, of their R&D results originated outside their borders. European firms, however, are more prone to use foreign R&D, although a substantial part of this is done in other European countries. In short, global generation of technology is largely an intra-European phenomenom.

Finally, the third category refers to the exploitation of technology by firms in international markets. This is certainly not a new phenomenom, but has increased its importance in recent times. The point to be made here is that if a larger share of firms' output directed to foreign markets the global exploitation of technology is the consequence rather than a cause of the increase in international trade (Archibugi and Michie 1995).

Summing up, the case for 'global generation of technology' is very weak, 'global technological collaboration of technology' refers to few 'hi-tech areas' and is concentrated on 'Triad countries' and 'global exploitation of technology' is the only strong case for 'techno-globalism'. Technologies are increasingly been exploited in foreign markets both embodied in products and disembodied, for example, via transfer of licences and know-how. However, as emphasised by Archibugi and Michie (1995), the willingness of firms to exploit their innovations in foreign market does not necessarily mean that they will be successful. As for disembodied technologies, this depends on policies by national governments and firms which can facilitate and foster the import of technology.

Since the mid-1970s Brazilian recorded payments for technology (royalties, technical assistance fees and commissions) have fallen steadily to very low levels, both in absolute terms and as a proportion of GDP (Bell and Cassiolato 1993). When associated with the stagnant levels of domestic R&D, this trend, closely linked to low levels of industrial investment since the early 1980s, also seems to reflect a collapse in the overall demand for new technology, not a shift towards greater domestic sourcing of technology. The trend also indicates that Brazilian industry has become increasingly disconnected from an important source of inputs to enhance its international competitiveness. Something of the significance of that can be glimpsed in the corresponding data for South Korea. where payments for imported technology (licensing and consultancy payments) were rising rapidly as a proportion of GDP during the mid 1980s. That reflects a longer trend through the 1970s and 1980s as Korea strengthened its international competitiveness: during that period, payments for imported technology massively increased - 13-fold in absolute terms between 1972-76 and 1982-86 (KDB 1988, Hobday 1991).

This highlights one of the major technology-related challenges now faced: the need to reverse the recent trend of technology imports. Rapid growth of imported technology must be set in motion, so re-connecting industry to international sources of technology. The driving force at the heart of this growth must be a corresponding resurgence of investment in new plant and equipment incorporating the new vintages of technology required to enhance competitiveness across the whole spectrum of industry. That revival of industrial investment will depend heavily on macro-economic conditions.

But there is a second challenge that is the main focus of this paper. This is not about the 'quantity' of technology acquired from abroad; it is about how that technology is acquired. If increased volumes of imported technology are to play their full potential role in enhancing competitiveness in the 1990s, it will be totally inadequate just to go back to the typical ways of acquiring technology in the past. Those approaches must be radically altered. There are two reasons for this.

First, there is now much greater understanding about the process of technological change, its role in the competitiveness of industry, and its interaction with technology imports. This understanding, a benefit from hindsight that was not then widely available, suggests that the dominant approaches to acquiring foreign technology in Brazil in the period up to the 1970s failed to exploit its full potential. Different approaches will be needed in the 1990s if any increase in the 'quantity' of imported technology is to contribute as effectively as it might to the competitiveness of Brazilian industry.

Beyond that, an obvious but important point is that the 1990s are not the 1970s and the international context for technology acquisition by Brazilian firms is now radically different. The rates, directions and processes of

technological change have fundamentally altered, as have the opportunities and constraints facing firms seeking to acquire technology in the international 'market'. These changes are a further set of reasons for radically changing Brazilian industry's earlier approaches to the acquisition of imported technology.

The most evident implications of these two points are for the dynamic evolution of industrial enterprises. In summary, managing the acquisition of imported technology will have to be linked into much more intensive and strategic investments in the firms' own resources for generating and managing their technological dynamism. These enhanced investments in innovative capabilities will be required not as alternatives to technology imports, but as essential complements that will be needed to gain the greatest possible competitive benefits from what is imported. Indeed, they will be needed even to gain any access at all to some areas of foreign technology.

There are, however, implications for government policy as well. In part, these are about continuing the changes in economic policy that have sought to bring greater competitive pressures to bear on enterprises. Also, they are about other measures designed to overcome the limitations of market mechanisms in stimulating 'optimal' investments in knowledge and related intangible assets - measures that will (i) enhance the technological responses that firms make to greater competitive pressures in the shorter run, and (ii) increase the extent to which they create the technological basis for new areas of competitiveness in the longer run.

The dominant approaches to acquiring imported technology since the 1950s have been characterised, with a few notable exceptions, by two basic features. Technology imports were typically disconnected from significant innovative activity in the technology importing firms: they were usually not preceded, accompanied, or followed by substantial complementary research, development or engineering efforts (Erber 1981; Coutinho and Ferraz 1994). As a consequence, technology imports were only rarely assimilated into continuous processes of rapid technical change. Obviously, they were often followed by some degree of improvement in process efficiency and product performance, as 'learning-by-doing' and minor adaptation occurred, but the intensity of such 'incremental' technical change was often inadequate to sustain competitiveness in technologically dynamic international markets, and it rarely created new bases of competitiveness in progressively higher value-added activities.[2]

Some of the new understanding about technology, innovation, international technology transfer and industrial competitiveness that has become more widely accessible since the 1970s suggests that these aspects of Brazilian experience were neither inevitable nor similar to the experience of a few other industrialising economies that have exploited imported technology much more effectively. These issues are outlined in Section 2. Section 3 then examines features of the international context for technology acquisition in the 1990s. It emphasises the significance of new challenges that stem from the combination of (i) new patterns and processes of technical change (the so-called 'new techno-economic paradigm'), and (ii) new factors that may influence both the accessibility of foreign technology and the terms of its acquisition. Section 4 summarises the new approaches to management and policy that will be needed if Brazilian industry is to exploit the full contribution to competitiveness that can be made by imported technology.

2. NEW UNDERSTANDING ABOUT TECHNOLOGY, COMPETITIVENESS AND INTERNATIONAL TECHNOLOGY TRANSFER

The approaches to technology management and policy in Brazil were, as in other countries, heavily influenced by pervasive and often very simple ideas about how technological innovation and international technology transfer contribute to industrial growth and competitiveness. However, as new understanding has been generated over the last two decades, the 'mental models' that influenced managers and policy-makers in the 1960s and 1970s have become outdated and misleading in many aspects.

One dominant issue is about the central role of business enterprises in generating the technological dynamism of industry. This may seem self-evident in the 1990s, but it was much less obvious in the 1960s and 1970s. At that time, in Brazil, as in most other industrialising countries, considerable emphasis was placed on infrastructure institutions as the prime movers of domestic innovative activity. It was expected that they would be able to generate new technology on behalf of industrial firms that were seen as being too small, too foreign or too incompetent to generate their own.

That simple optimism about the potential role of technological institutions stemmed partly from correspondingly simple views about the nature of technology. Apart from the elements that are embodied in people by education and training, technology was either seen as 'information' that could be transmitted fairly easily between organisations, or it was viewed as being embodied in machinery which could be bought and sold like any other goods. However, we now understand a bit more about the complexity of industrial technology. In particular, much of it is tacit and inherently difficult to transmit; and much of it is highly specific to particular firms and their markets. Those firms themselves must therefore play the prime-mover role in technological development.

This point is evident from the structure of R&D activity in the industrialised countries, especially the more technologically dynamic ones like Germany and Japan, where enterprises fund very large proportions of total industrial R&D and execute even larger proportions. It is also evident in dramatic transformations of the structure of R&D funding that have occurred over the last two decades in some of the East Asian NICs. In South Korea, for instance, government accounted for nearly 70 per cent of total R&D expenditure in 1975. By 1985, despite huge increases in the absolute level of government expenditure, that share had fallen to about 20 per cent, with non governmental sources (mainly industrial enterprises) accounting for 80 per cent.

In principle, the central importance of industrial enterprises as the driving force in technological development has already been well recognised in Brazil - for instance, in several of the policy statements of the early 1970s - and the issue therefore needs only brief emphasis here.

The same can be said about another issue: the criteria by which one would assess the macro-economic impact of industrial technology imports. In the 1960s and 1970s, the dominant perspectives centred in growth and structural change. In Brazil, as in most developing countries, technology imports were seen as serving the central economic objective of accelerating industrial growth. More specifically, as in many of the other larger and more industrially advanced developing countries, technology imports were seen as contributing primarily to structural change in the industrial sector - to the relatively rapid growth of 'heavy' industries (e.g. iron and steel and basic chemicals) and the 'capital goods' industries producing machinery and transport equipment.

By the 1990s, however, that perspective has changed. The experience of many economies, especially in Latin America, Eastern Europe and the former USSR, has indicated the high costs that may be associated with long periods of emphasis on growth and structural change as the dominant objectives of industrial development. Much greater attention is now given to issues about international competitiveness and the efficiency of resource use in industrial growth. Questions about management and policy concerned with acquiring imported technology are increasingly addressed in that context: the key issues are about developing approaches that will more effectively link imported technology to rising industrial efficiency and competitiveness.

This section starts from that point and concentrates on six key issues where available new understanding must replace outdated perspectives in developing more effective approaches for acquiring imported technology: (i) to create and sustain industrial competitiveness, technical change must be a continuous, not intermittent, process; and imported technology must be incorporated into that continuous technological dynamism; (ii) 'adopters' and 'users' of technology play active and creative, not passive, roles in generating these trajectories of competitive technological dynamism; (iii) the resource base needed to play those change-generating technological roles includes interacting structures of firms, not just individual firms acting in technological isolation, and a very wide range of engineering and other capabilities, not just R&D capabilities; (iv) industrial firms play important roles as creators and diffusers, not just employers, of the human resource components of those wide-ranging technological capabilities; (v) technology imports and local innovative capabilities are complements, not alternatives, in the process of technical change; (vi) market mechanisms and government intervention are also complements, not alternatives, in providing the necessary framework of inducements for investment in technology accumulation in industrialising economies.

2.1 Technical Change: A Continuous, Not Intermittent, Process

In the 1960s and 1970s, technical change was seen essentially as an intermittent phenomenon. Such views were encouraged by two sets of 'models' of how technology is incorporated into economic activity. One centred on the role of technology and investment in the process of economic growth, and the other on the process of innovation.

2.1.1. Technology, Investment and Economic Growth

Common analyses of economic growth not only emphasised the importance of investment in physical capital as the vehicle for incorporating technology in production. They also tended to view such capital-embodied technical change as involving infrequent and relatively large 'lumps' of investment - in effect, distinct new plant and factories.[3] At the same time, these views about intermittent injections of large lumps of capital-embodied technology were often set (sometimes only implicitly) within the framework of 'putty-clay' models of technical progress: the technical characteristics 'embodied' in particular vintages of capital were assumed to be fixed by the time of investment projects, and no further technical progress would occur in the subsequent lifetimes of those facilities.

All this was consistent with the practical experience of economists and financiers working in development banks and ministries of industry or planning in developing countries: their somewhat attenuated contact with the realities of industrial technology tended to centre on relatively large investment projects for setting up new plants and factories. Also, the project feasibility studies which they examined in their banks and ministries almost invariably had at their core

a set of technical (and hence economic) characteristics which remained fixed through the projected 10-20 year lifetimes of the projects.

2.1.2. The Process of Technological Innovation

Emerging from a different tradition, common models of innovation led in very similar directions. They focused on individual product and process innovations - intermittently occurring phenomena that emerged from a sequence of research and development activities. In the 1960s and early 1970s, therefore, most of the empirical analysis that sought to clarify the main features of the innovation process focused on individual innovations - distinct new products and processes that were examined in isolation from both preceding and subsequent paths of technical changes (e.g. Sherwin and Isensen 1967, Myers and Marquis 1969, Langrish et al. 1972, and SPRU 1972). These perspectives also incorporated a feature that was very similar to the economists' putty-clay distinction: the separation between (i) the various stages leading up to innovation (the first commercial application of the new technology), during which the evolving technology was creatively shaped; and (ii) the subsequent stage of diffusion, during which it was presumed to remain fixed as a succession of users simply 'adopted' and 'used' it as it diffused through the economy.

Thus, within both these perspectives, technical change was seen as stemming from intermittent 'injections' of technology into the economy. In addition, both perspectives involved sharp boundaries between (i) technologically creative phases of activity in advance of the injections, and (ii) technologically static, 'post-injection' phases during which the technology was diffused and used, but not changed. Industry in developing countries was usually seen as acting on the technologically static sides of those boundaries. It was involved in the 'adoption' of **given** technologies as they diffused internationally after earlier innovation in the advanced industrial economies; and, after the investment projects required to implement the adoption of technology, firms in developing countries were seen as undertaking the technologically static use or operation of **given** facilities and systems.

International technology transfer was seen, therefore, as a relatively simple affair. It was just a channel used intermittently to provide/acquire some or all of the product specifications, process designs, capital goods, operating know-how, and so forth that were needed to adopt particular technologies. Usually seen as 'inputs' for investment projects, these forms of technology were needed for the immediate task of setting up new production capacity at least cost, and any problems for policy or management were concerned with short-term issues about these project-linked inputs and their costs. Virtually absent from debate were any longer term questions about whether and how international transfer might be linked into local processes of technical change and innovation. Indeed for some analysts, those local innovative activities were simply presumed to be absent, irrelevant, or unnecessarily costly relative to the alternative of importing the technology involved.[4]

Evidence about the grossly distorting simplifications involved in these perspectives already existed by the 1960s, but it attracted little attention. For example, Hollander (1965) had already shown that the economic gains from continuing technical change through the operating lifetimes of particular vintages of capital might be just as significant as the gains from investment in new plants incorporating complete new vintages of technology. Enos (1962) had also provided striking evidence to illustrate a point made by Rosenberg (1972 and 1976): the economic gains from major innovations (in this case a succession of novel petroleum refining processes) may be matched by the gains from continuing

improvement to each of those innovations during their subsequent diffusion and use.

Since then, a wealth of evidence has been accumulated to indicate the importance of seeing technical change as a continuous, not intermittent, process. This has been associated with fundamental changes in the basic frameworks used in theoretical and empirical analysis of innovation and technical change, and, during the 1980s, attention came to focus much less on individual innovations, and much more on **paths** of technological learning, **trajectories** of innovation, and **cumulative sequences** of technical change (e.g. Dosi 1988 and Imai and Baba 1989).

These altered perspectives on the dynamics of technical change have been associated with radical shifts in perspectives about the underlying processes. While neo-classical perceptions identified technology as being freely available for choice by all firms, more empirically informed perspectives in the neo-Schumpeterian tradition have emphasised quite different perspectives: a large proportion of the stock of technical knowledge is tacit and highly specific to particular firms and markets, and its accumulation depends heavily on highly localised learning processes (Atkinson and Stiglitz 1969, Nelson and Winter 1982).

One consequence of this clarification of the continuous and localised nature of the innovation process is that one can no longer view the management of technology imports as simply a matter of securing one-off 'injections' of technology at least cost. It must focus on the more complex task of ensuring that imported technology is incorporated into, and contributes to, a continuing process of technological dynamism.

In addition, it no longer make much sense to draw neat distinctions between technologically creative 'producers' of technology on the one hand and technologically passive 'adopters' and 'users' on the other; and it makes even less sense to presume that firms in industrialising countries necessarily fall into the latter category.

2.2 The Active and Creative Roles of Technology 'Users'

With technical change now more clearly identified as a continuous process, it has become quite evident that the diffusion of innovations does not involve the adoption and use of technologically fixed products and processes. Instead, in technologically dynamic situations, it typically involves two stages of technical change in each successive application of the diffusing technology.

First, the basic features of the technology to be used in investment in new production facilities may be improved or adapted for application in the specific situation involved. This typically entails a complex process of engineering development, design and re-configuration of the specifications of the production systems involved - a technologically creative process which is totally obscured by simple terms like "technology adoption" or "technology choice".

Second, after initial investment in new production capacity that incorporates the diffusing technology, technical change may continue through the subsequent lifetimes of the production facilities in each adopting firm. With an intensity which varies between situations, this post-adoption phase of technical change incorporates a stream of incremental developments and modifications which further improve the performance of the technology above the levels initially achieved and/or mould it to continuing change in competitive input and product markets. The analysis of "learning curves" in industrial production has commonly shown the significance of the economic gains from this continuing improvement in apparently "given" technologies. However, this 'learning' perspective has typically obscured

the underlying processes by suggesting that the improvement arises as a more or less automatic product of experience through 'learning by doing'. In practice, that experience effect has very little significance, and the so-called "learning curves" are generated by continuing paths of creative technical change that are obviously associated with growing experience, but not simply as an automatic result of it (Bell and Scott-Kemmis 1990).

As integral components of the so-called diffusion process, these two types of technical change are widespread and pervasive. They are a feature of technologically dynamic industry in both developed and developing countries - although, within both groups, some countries appear to pursue these paths of change more intensively than others.[5] These paths of continuous change are also common across widely different industries - for example the semiconductor industry and the brick industry, the machinery industry and the chemical industry, the textile industry and the steel industry. They also appear to be common across differences within industries - for example, in the production of high-performance coated steels in large integrated plants and the production of standard construction reinforcing bar in small-scale 'mini-mills', or in the production of semiconductors at the IT 'frontier' as well as in the assembly of circuit boards at various distances behind it.[6]

Perspectives on technical change that neglect these technologically dynamic dimensions of the diffusion process see only a small part of the way technology and technical change affect the competitiveness of firms and industries. They also obscure the significantly creative roles played by the so-called adopters and users of technology. These roles are important in the first of the two stages of technical change noted above: investment in new production facilities. This stage frequently draws on a range of suppliers for capital goods, engineering services, project management services and so forth; but technologically dynamic firms rarely play a purely passive role in these technological aspects of investment in the production facilities they will subsequently use. They may generate a significant part of the technology themselves, perhaps also incorporating it in the designs of capital goods to be used; and they may interact with their suppliers in various ways in developing designs and specifications for the products and processes involved. These technologically creative roles are even more important in the second of the two stages noted above: incorporating technical change into existing production systems. Although this also will often draw on inputs from external suppliers, the technology-using firm itself must play a significant role - both independently and in interaction with external suppliers.

Playing these roles obviously requires more than the accumulation of skills and know-how for operating new processes at their expected performance standards, or for producing products to existing specifications. Firms must accumulate the deeper forms of knowledge, skill and experience required to generate continuing paths of incremental change, which both improve on the original performance standards of the technology in use, and modify its inputs, outputs and processes in response to changing input and product markets. They must also strengthen their capabilities for seeking out and acquiring technology from other firms and economies. And they must then build on these capabilities to introduce more substantial technical changes: for example incorporating significant improvements into processes already used or into process technology acquired from elsewhere for new projects, modifying the existing types of product, producing substitutes for those already produced, diversifying into the production of input materials or equipment, or creating improved process or materials technologies for use by supplier industries. This phase may then blur into one in which firms produce the kinds of technical change which have usually been thought of as significant "innovations".

So, even if we accept the rather narrow view that the competitiveness of Brazilian firms will depend on their efficiency as adopters and users of technology generated by innovation elsewhere (not on their ability to generate significant technological innovations themselves), we now know that this has very different implications from those we might have drawn in the 1970s. In particular, firms will need to accumulate significant change-generating technological capabilities of their own in order to play those roles.

2.3 The Resource Base for Technical Change: Interacting, not Individual, Firms and 'Engineering' more than 'R&D'

By the 1990s, the importance of the technologically creative roles of technology 'adopters' and 'users' has become much clearer. But so also has the fact that technical change is generated by interactions between firms as much as by individual firms themselves. Some of these interactions involve suppliers and customers in the input-output chain - user-producer technological relationships (Lundvall 1988 and 1992, OECD 1990). Many others, however, involve a wide range of technology collaboration arrangements between competing as well as complementary firms (Chesnais 1988, Cainarca et al. 1992, Kleinknecht and Reijnen 1992, Lastres 1993, and Hagedoorn and Schakenraad 1992). Thus, an important part of the resource base for industrial technical change is not just the technological capabilities of individual firms; it is the complex structure of change-generating interactions between the technological capabilities of firms.

But what are those technological capabilities? In the 1960s and 1970s such a question would rarely have been asked. At that time, the nature of the resources required to generate technical change seemed obvious: they were R&D resources. The various activities defined as research and experimental development were clearly identified in the accepted linear models as the 'sources' of innovations; the advanced industrial countries had developed a well structured system for collecting statistics on R&D to provide basic indicators of their 'inputs' to innovative activity; and international organisations (e.g. UNESCO), together with bi-lateral technical assistance agencies, were busy advising developing countries that their technological capabilities (or "scientific and technological potential") could be defined adequately enough as their R&D capabilities.

All that now seems remarkably unhelpful since it focuses on only a small part of the activities and resources involved in generating technical change. Clearly major innovations **do** draw fairly directly on new knowledge generated by various kinds of research, and they frequently **do** require the design , construction and testing of prototype products and pilot process plants. But these R&D activities are only the tip of the iceberg - only one part of a much wider set of activities that contribute directly to technical change.

We must also include in the total iceberg the wide range of design and production engineering activities through which the results of R&D must pass before they result in the commercial, productive use of technology. We must also recognise that, without any direct inputs from R&D, those design and engineering activities are frequently sufficient in their own right as sources of technical change in production - especially as generators of the continuous paths of technical change that we now recognise as integral features of the process of technology diffusion. Then we must take note of a point that has received greater attention as we have learned more about the process of continuous change ("kaizen") in Japanese industrial production: workers whose primary task is the ongoing operation and maintenance of existing production systems may also make significant contributions to the process of technical change.

Unfortunately, although we now recognise more clearly the significance of these various change-generating activities and resources, we can provide very limited information about them. We have spent years collecting information about R&D. But, apart from the fragments of information in a few illustrative case studies, we can say little about the scale of the various design and engineering resources which, with or without direct inputs from R&D, are required to generate technical change in particular sectors and economic contexts. Indeed, we would be hard pressed even to describe in concrete terms what those resources would consist of in specific situations. Similarly, while we can present a little information about the change-generating role of workers whose primary task is operation and maintenance, we have only limited understanding about the significance of that role, about how it is played, or about how it interacts with the change-generating activities of other components of the 'iceberg'.

In short, if industrial firms are to interact effectively in generating competitive rates and directions of technical change, they must invest in acquiring and accumulating a range of change-generating resources that is much wider than, and may not even include, R&D resources. Their management of the acquisition of imported technology will need to take that into account, as will approaches to government policy. Among other things, this will require much greater emphasis on the firm as a creator, and not just an employer, of technological capabilities embodied in human capital.

2.4 INDUSTRIAL FIRMS AS CREATORS OF HUMAN CAPITAL

Some perspectives on the role of human capital in economic growth have given primary emphasis to formal education and training in institutions operating outside the structure of industrial firms. And, sometimes with only passing reference to 'on-the-job-training', firms themselves have been seen essentially as users, not creators, of the human capital they require to generate and manage technical change. Such perspectives understate the central importance of firms as human capital creators. This has been especially significant in countries like Japan and Germany which have been particularly effective in exploiting the dynamic gains of technological accumulation.

Other perspectives have emphasised 'learning by doing' as an important mechanism for creating these types of knowledge and human capital; and recognition of the significance of tacit knowledge has highlighted the importance of 'doing' as a means of learning. However, two caveats should be noted about the role of learning by doing.

First, doing one kind of activity is seldom an adequate basis for acquiring the capabilities needed for others. This obvious, but often neglected point, has become increasingly important as the knowledge base for routine production activities has become increasingly differentiated from the kinds of knowledge, skill and experience that are required to generate and manage technical change (with the latter organised in increasingly specialised R & D Laboratories, Design Offices, Project Management Teams, Production Engineering Departments, etc.). As the gap between these two kinds of technological competence has widened, the doing of routine production has contributed less of the kind of learning that can contribute to the capabilities for generating and managing technical change. Instead, types of 'doing' that are specifically change-related have become an increasingly important basis for change-related learning (Bell et al. 1982; Bell 1984).

Second, while various forms of 'doing' are central to technological accumulation, learning should not be seen simply as a doing-based process that yields additional

knowledge essentially as a by-product of activities undertaken with other objectives. It may need to be undertaken as a costly, explicit activity in its own right: various forms of technological training and deliberately managed experience accumulation. Such intra-firm efforts, undertaken as complements to education and training outside industry, have been especially significant in Japanese and German firms.

In these ways, the contribution made by firms to an economy's overall pool of technological capabilities are little different from the contributions of other institutions more explicitly concerned with education and training. However, the two types of institution are not just substitutable alternatives: particular kinds of skill and knowledge can be acquired only in firms and through their investments in learning - by doing or by training. This has fairly obvious implications for the way firms manage their international technology transfer projects. However, it also has two important implications for policy.

First, because of the diffusion of skill and knowledge between firms, they are usually unlikely to be able to appropriate the full returns to their investment in learning, and there is therefore likely to be significant under-investment from a social, and possibly also private, perspective. Second, these 'externalities' should not be seen simply as unfortunate problems ('failures' that hinder the effectiveness of market mechanisms). Instead, they can be seen as powerful channels for the accumulation and diffusion of change-generating knowledge and skills in industry, and mechanism might be found to enhance their significance, by inducing firms to invest in creating these kinds of human capital deliberately in excess of their private needs.

2.5 Complementarity I: Technology Imports and Domestic Technological Capabilities

It has been very common to see technology imports and domestic technological capabilities as **alternative** sources of technical change in industrialising economies. This was a common view within the influential 'dependency' perspectives of the 1960s and 1970s. Technology imports were considered as substitutes for domestic technology and squeezed out ('marginalised') nascent domestic technological capabilities. The volume of imported technology should therefore be controlled as one mechanism for stimulating the development of those capabilities.

Exactly the same basic view remains common within a totally different ideological and policy perspective. Domestic technological capabilities and technology imports are again seen as alternative sources of inputs for technical change. The former, however, are usually presumed to be high-cost and low-efficiency sources; and any measures to protect them and stimulate their development **instead of** drawing on imported technology therefore imposes a burden on technology 'users'.

Those views give little attention to what we have learned about the experience of the advanced industrialised countries where imported technology has played a central role in industrial growth. It was obviously important when those economies were catching up from behind the technological frontier - as in the case of Germany in the nineteenth century and Japan in the twentieth. However, it remains important for those that are operating close to the frontier: a very large proportion of total international trade in technology (either as disembodied knowledge or as technology embodied in capital goods and engineering services) takes place between the advanced industrial countries themselves, rather than between them and the

industrialising countries of the developing world. At the same time, a significant proportion of the 'innovations' developed by firms in industrialised countries involve large elements of imitation of technology already developed in other countries (De Melto et al. 1980, Smith and Vidvei 1992, and Deiaco 1992), and a large amount of R and D in the developed countries is also 'imitative': that is, it is performed to monitor, assimilate and modify the technological developments of competitor firms that are often located in other countries (Levin et al. 1987; Cohen and Levinthal, 1989).

This highlights two issues. First, there is often no clear-cut distinction between the kinds of activities and resources required for 'innovation' and so-called 'imitation'. Second, the argument that importing foreign technology and creating it locally are alternative (substitutable) means for generating technical change does not reflect the experience of these countries, where technology imports and local technological accumulation have in fact been complementary. This has taken several forms.

Imported technology can contribute directly to technical change without there being any significant involvement of local technological capabilities. More often, only some elements of the necessary total combination of technology are imported and are combined with elements generated locally. The experience of European countries in the development of the North Sea oil industry in the 1970s illustrates both these patterns. In the early years of the 'infant industry', projects drew directly and almost totally on American technology, but this was followed by a rapid transition to more indirect patterns in which imported and locally developed elements were combined (Bell and Oldham, 1988).

Even when technical change depends heavily and directly on technology imports, these may be complemented by intensive efforts to accumulate locally the technological capabilities needed subsequently for improving what was acquired initially, for generating elements of technology to be combined with imported elements in later projects, or for building a more independent position in the long term development of the technology. This, for example, was the pattern followed by the US Du Pont corporation when it entered the rayon industry in the 1920s on the basis of imported technology (Hollander 1965). It was also very evident in the early industrialisation experience of Japan. Tanaka (1976) has shown this in the case of the development of the chemical industry between the 1870s and 1920s; and, in the development of the shipbuilding industry in the early part of this century, the licensing of designs and the acquisition of foreign expertise was complemented by large investments in skill and know-how for developing and improving what was initially acquired from overseas, not just for using it (Fukasaku 1986). Similarly, technology acquisition from foreign firms was necessary in the early development of the automobile, electrical and railway rolling stock industries, but localised reverse engineering was also a major channel for accumulating product design and development capabilities once local firms had mastered production and component technologies (Nakaoka 1987; Odagiri and Goto 1992; Lastres 1994) of expenditure on imported technology by Japanese firms was more than matched by their complementary expenditure on engineering and R & D to ensure the dynamic assimilation of what had been imported (Ozawa 1974 and 1985, Tanaka 1992).

The process of importing technology may also be preceded, not just followed, by local investment in related technological capabilities. This can provide the knowledge base needed by an informed buyer of foreign technology, but it also creates a basis for the dynamic assimilation of what is subsequently imported. The experience of Japan again provides examples: for instance, in the 1950s, entry into

synthetic fibre production with licensed technology was preceded by substantial investment in R & D and related engineering activities (Ozawa 1980).

Imported technology also contributes to local accumulation itself, and not just to technical change. This is fairly obvious when technology imports are acquired through educational and informal channels - as with the training of design engineers or research scientists in foreign universities and research centres. It is often less visible in commercial technology transactions between firms - for instance, when the licensing of process specifications is accompanied by access to underlying design data, training in design routines, and opportunities to acquire experience in design projects. Such international learning arrangements blur into various forms of international technological collaboration between firms. The primary objectives of such linkages and networks are usually less concerned about relocating existing knowledge and expertise from one firm to another and more about pooling intangible assets to develop new elements of technology. Nevertheless, these arrangements may then be important mechanisms for transferring internationally the resulting new technology.

The challenge for managers seeking to link imported technology into the technological dynamism of their firms is to exploit these kinds of complementarity, especially the last. As noted earlier, a few Brazilian firms have already demonstrated innovative ways of doing so. The challenge for government policy is to stimulate a very much larger number of firms to follow similar approaches.

2.6 COMPLEMENTARITY II: MARKETS AND GOVERNMENTS

Much of the analysis of innovation and international technology transfer in the 1960s and 1970s lacked any reference to the market contexts in which those activities took place. That is no longer the case, and issues about the nature of markets are now often central to analyses of industrial innovation, international transfer and the accumulation of technological capabilities.

Emphasis on that issue is not just a reflection of a-priori presumptions. It is sustained by important empirical evidence. For example, the importance of competitive pressures and rivalry as an incentive for technological accumulation emerges from studies of the origins of competitiveness (for example, Porter 1990), and from statistical studies of the technological activities of the world's large firms (Patel and Pavitt, 1992). Conversely an almost complete lack of competitive pressures was one reason why production units in centrally planned economies had no incentive to develop or adopt more efficient techniques.

Nevertheless, it is also evident that government intervention in competitive markets, together with government shaping of their structure and functioning, have been important in stimulating paths of technological development that are commonly accepted as having been efficient. Such intervention has taken several forms.

2.6.1 TRADE PROTECTION

During the industrialisation of currently developed countries, governments typically took measures to protect their infant industries from the competition of established

producers in more industrialised countries. The objective was to enable firms to learn and master the technologies involved, and the extent and duration of protection varied widely. In some cases, it was provided only for relatively short periods - as in the case of the Japanese synthetic fibre industry in the 1950s (Ozawa, 1980). In others it persisted for long periods - sometimes with questionable justification in terms of local learning. But at other times the persistence of protection seems to have been an apparent necessity for developing effective mastery of the technology involved (e.g. in the case of the Japanese automobile industry). More recently, trade policy has been used in this flexible way during the rapid industrialisation of South Korea: protection has been provided for limited periods to permit the accumulation of a level of technological and other capabilities required for competitive survival, and industries have then been exposed to the pressures of international competition (Pack and Westphal 1986). However, such patterns of trade protection were usually accompanied by other measures to stimulate the accumulation of significant technological capabilities.

2.6.2. EDUCATION, TRAINING, AND RESEARCH

Nearly all governments in market economies have a similar core of policies that are designed explicitly to influence the rate and direction of technical change, and that are justified because they correct market failure. In particular, several areas of government policy have focused on the creation of new knowledge through research, and on the diffusion of existing knowledge through education and training since there are significant externalities in both these activities, in the sense that the full benefits are not necessarily appropriable by the firms investing in them.

With respect to research, all the industrialised countries have developed institutions outside firms for generating new industrial knowledge and information. Some of these have been private commercial institutions (contract research organisations, industry-funded co-operative R&D centres, and so forth), but many have been public or quasi public institutions (universities, government research laboratories, subsidised co-operative R &D centres, etc.). In a trivial sense, these institutions are complements to industrial firms: their outputs of knowledge are inputs to firms. More significant, however, is the complementarity of innovative activity in the two sets of institutions. Reflecting the points made earlier about firms as the primary driving force in innovation, it is very rare for infrastructure institutions to act as substitutes for the innovative activities of firms themselves (Foray 1993, Foray and Mowery 1989). Much more commonly, they generate only some elements of the overall knowledge sets that firms need to generate technical change. Several studies have found that the firms that make most use of the R & D activities of these kinds of institution are not seeking to compensate for the absence of their own technological capabilities. Instead, they are firms that have significant in-house R & D of their own, and they are seeking specific knowledge inputs to complement those in-house innovative activities (Mowery 1983, Arora and Gambardella 1990, Bell and Oldham 1988, Kleinknecht and Reijnen 1992).

The contribution of government has been particularly large in the area of investment in education and training. This has not been limited to the provision of infrastructure facilities (schools, universities, training centres etc.), but has involved measures to stimulate the training and learning efforts of firms themselves. At least in the case of Japan, such measures seem to have been especially important in assisting the technological accumulation process through more significant discontinuities.

The costs and risks of technical change and technological learning vary with the 'distance' of the jumps being attempted from existing bodies of technological competence. Drawing on the industrialisation experience of Japan, Nakaoka (1987) points out that government policies assisted firms making relatively large 'jumps' during early learning phases by providing finance to cover risk, funds for training in the appropriate skills, and a market for the products developed during the learning processes. Ozawa (1980) illustrates similar forms of intervention in the case of the entry of Japanese firms into the synthetic fibre industry in the early post-war years: the government created conditions which not only reduced market risks but also stimulated firms to intensify investment in their technological capabilities alongside their investment in new production capacity. However, a significant dimension of that government role is better described as 'shaping' the market in the first place rather than just intervening in its operations.

2.6.3. Shaping the Market

A frequent and important feature of government policy as late-industrialising Japan entered successive new industries was the regulation of entry. This usually involved some combination of limiting the number of firms, phasing the sequence of their entry, and designating criteria for selecting entrants that included significant issues concerned with their technological capabilities and management of technology acquisition. These entry regulating measures were often combined with (i) temporary limits on the extent of domestic and/or foreign competition, but also (ii) the predictable termination of those limits.

The primary explicit objective of such measures was usually to ensure that firms set up production plants at the most efficient scale and then operated them at full capacity.

However, an additional important consequence was that substantial incentives were provided for investment in the technological capabilities required to generate and manage technical change. Nakaoka (1987), for example, describes one example of this approach: the development of the railway rolling stock industry between 1900 and 1920. Apart from playing a major role in accumulating and then diffusing relevant engineering design and development expertise, the National Railways designated only two private engineering firms as manufacturers of locomotives and two others for wagons and carriages. What was significant about this was not that it limited competition, but that it shifted the timing of intense inter-firm competition: firms not only competed **after** entering production, they competed intensely **before** **that** in order to be able to enter. Moreover, the selection of limited numbers of entrants ensured that the firms were large enough to accumulate substantial technological capabilities, and hence to incorporate a significant technology-centred dimension in their competition. As Nakaoka describes it:

... designated manufacturers were always plural. Competition was an essential factor in the process. Though manufacturing opportunities were restricted to designated firms, the opportunity to become a designated firm was open to all local firms. Many ambitious firms competed with each other to become a designated firm and, after being designated, competed to manufacture a better locomotive than others. (p.17)

Ozawa (1980) describes a similar example some thirty years later when Japan entered successive segments of the synthetic fibre industry in the 1950s and early 1960s. In this case, entry was usually staggered - with only one firm initially permitted to enter segment that was protected from international competition, but with subsequent entry by others and/or the elimination of protection from international competitors being quite predictable at that stage. Ozawa

indicates that this had striking implications for the way Japanese firms approached the acquisition of foreign technology:

Clearly there have been many benefits from the strategy, with the staggered-entry formula particularly enhancing the Japanese firms' ability to absorb sophisticated foreign technologies. To be qualified as an early entrant, a firm had to demonstrate its technological and financial capabilities to assimilate the latest technologies. Therefore the industrial groups competed in searching for new promising technologies, conducting preparatory research, finding an appropriate foreign licenser, and securing the necessary investment funds.

The preparatory research often consisted of 'backward engineering' and 'patent-literature-based reproduction'. These approaches enabled Japanese firms, first, to know the real merits and demerits of a new foreign technology; second to prepare themselves technologically to absorb only the desired components of foreign technology (...thereby enhancing their bargaining power in negotiating with the supplier); and third, often to come up with significant technological improvements in the course of 'reproduction'.

...the staggered-entry formula also served to strengthen the bargaining position of Japanese firms in negotiating with foreign technology suppliers, because only one (or at most a selected few) was permitted to enter a new industry at a time. (p.146)

Blind adherence to views that governments should not intervene in markets would neglect these aspects of Japanese experience in which governments shaped the structure and functioning of markets in ways that enhanced effectiveness in acquiring and dynamically assimilating foreign technology.

Similarly, blind adherence to views about the importance of protectionist trade policy as a means of enhancing technological 'learning' would ignore the related aspects of Japanese experience in which competitive pressures (in particular forms) played a major role in stimulating aggressive approaches to the acquisition of foreign technology. It might also lose sight of two other aspects of that experience: (i) active investment in acquiring knowledge and expertise (not just 'doing') was the main basis for technological learning; and (ii) to the extent that 'doing' was important for that learning, it was particular kinds of doing - those concerned with designing, developing and improving the imported technology, not just using it.

In developing approaches to policy in Brazil in the 1990s, it seems essential not to fall into either of these camps of blind adherents to outdated preconceptions. Much more useful, but also much more challenging, will be to find new ways to exploit the complementarities between markets and governments - ways that are designed for Brazil, but also ways that are designed for competitiveness in the international context of the 1990s and beyond.

3. THE INTERNATIONAL CONTEXT FOR TECHNOLOGY ACQUISITION BY BRAZILIAN INDUSTRY

This part of the paper examines two aspects of the international context for technology acquisition by Brazilian firms. The first, examined in Section 3.1, is about the patterns and processes of technical change that have become central to competitive industrial performance during the 1980s. These have major implications for what Brazilian firms will have to do with imported technology <u>after</u> they have got it. The second, examined in Section 3.2, is about

new conditions that may be faced by Brazilian firms as they seek to acquire technology through international channels. The main implications of these are about what firms will have to do <u>before</u> they get imported technologies - approaches to strategy, management and organisation that may be needed to acquire technology efficiently in the first place, or even to acquire it all.

First, however, it is important to note two other features of the international context: the increasing integration of trade and technology policies at the international level; and key changes in the international structure of production and trade.

Technology and trade policy issues have become increasingly integrated, during the 1980s; and, as technology-intensive industries have become more central in the managed trade environment of bilateral negotiations and disputes, developing countries are suffering the dual difficulties of (i) greater difficulty in exporting their own goods, and (ii) the slow diffusion of new technologies.

Also, under significant changes in the economic and political balance of power among developed countries in the late 1980s, a new series of international rules and agreements have been negotiated. Examples include not only new bilateral and regional initiatives (such as the various US-Japanese agreements and the EEC) but also attempts to change multilateral agreements (such as the 'Uruguay Round' of GATT). While developing countries are participating more actively in these new multilateral agreements than they did in the major post-war arrangements, such agreements are being negotiated under two very distinct principles. On the one hand, the North-North bilateral and regional agreements have been increasingly influenced by a concept of 'fair trade', whereby access to markets depends on its effects on the economic structure of the recipient countries/regions. At the same time, various forms of protection are provided for high-technology industries; and, as noted by one analyst:

...free trade in high-technology products is a largely meaningless option - the real policy choice is not between free-trade and protection but between appropriate combinations of liberalization and government intervention that improve national economic welfare in the short run and sustain a more open international trading system in the long run. (Tyson 1992).

In contrast, in North/South relations the old concept of 'free trade' has been pushed further and focused on areas related to new technology (such as intellectual property rights and services). Thus protectionism and market liberalisation are treated unevenly in North-South relations. The North accepts the principle of protecting both mature industries and novel technologies, while (i) seeking various forms of market access in the South and (ii) disputing the validity of Southern ('fair', it might be argued) structures of protection and other measures to enhance technological development. The South must respond to changing international structures of production, trade and technology-based competition within that kind of imbalance in ideology (and power) - an issue that may become increasingly important for Brazil in particular.

Brazilian industry is now competing in a changing international **structure** of production and trade - an issue that is well known, but merits constant re-emphasis in any discussion of technology and industrial competitiveness. The point is especially important in the context of structural changes in Brazilian industry itself. These have involved shifts towards two areas of current comparative advantage: partly, towards labour-intensive industries, and more substantially towards industries that are natural resource-intensive and energy-intensive. While these shifts open up short term opportunities, they also open up considerable vulnerability in the medium-to-long term.

Rapidly growing production in other countries with lower wage rates and rising skill levels is likely to erode the competitiveness of labour-intensive products like shoes. In particular, an enormous potential threat is emerging for these kinds of industry as very low labour costs in China are being combined with high levels of technical skill and international marketing expertise that have been accumulated by firms in Hong Kong, Taiwan and Korea. At the same time, many other countries are increasing investment in the energy-intensive and natural resource-intensive industries, most of which are already suffering from excess capacity. In the basic chemical industry, for instance, huge increases in capacity are expected in the Asian Pacific rim - especially in China. International competition in these industries will be particularly intense for many years.

In these contexts, three broad types of response are likely to be critical for sustaining competitiveness: intensive efforts to achieve continuing increases in productivity and all aspects of process efficiency in existing lines of production; intensive efforts to raise product quality and move 'upwards to higher value-added products in the existing industries; and, intensive efforts to develop new areas of competitiveness in related products and industries - moving 'downstream' to higher value products and 'upstream' to areas of specialised strength in machinery and equipment, instrumentation, information systems and software, engineering services, etc.

In short, within the changing international structure of industrial production, the recently strengthened short term competitiveness of large segments of Brazilian industry almost certainly cannot be sustained over the medium-to-longer term by depending on the 'spurious' advantage of low wages and devaluation or on natural resource endowments. It will depend increasingly on resources of knowledge, expertise and institutional structures for generating and managing technical change - 'created' bases of comparative advantage.

3.1 Changing Patterns and Processes of Industrial Technical Change

The preceding sections have emphasised that, if firms are to achieve efficiency and competitiveness, they will have to incorporate technology imports into trajectories of continuous technological dynamism. More specifically, however, sustaining international competitiveness will require those trajectories to generate rates of productivity increase and product performance improvement that at least match international rates. However, this requirement poses much greater demands than in the past. In the international context of the 1990s, the required rates of technical change appear to be greater; the necessary directions of change are different and more complex; the underlying processes of change will have to be driven by much greater investment in firms' own resources of knowledge and skill; and the organisational basis for change will have to involve more intensive patterns of interaction and collaboration between firms and related organisations.

3.1.1 The Intensification of Technical Change

During the import substitution period of the 1960s and early 1970s, most of the technologies acquired by industrialising countries like Brazil were relatively 'mature'. This was particularly true of technologies in sectors such as iron, steel and other metal products, machinery, pulp and paper, and chemicals (especially bulk chemicals). This had several implications.

First, although competitive performance depended heavily on both types of incremental technical change discussed in the previous section (improvements incorporated in new facilities at the time of investment, and further improvements in the post-investment period), the intensity of those kinds of change was **relatively** low, as was the frequency of more substantial technological discontinuities.

Second, a large proportion of the specifications for products and processes could be embodied in relatively standardised capital goods, and could be transferred via 'turn-key' projects - with only limited needs for innovation and design for application in specific circumstances. There were correspondingly limited needs for local involvement in the engineering and design activities involved in creating new production systems.

Finally, most of the capabilities to use and operate the given product and process technologies could be relatively easily acquired via training in basic routines and a modest amount of experience in 'doing' those routines.

There were therefore very limited **requirements** for accumulating significant capabilities for generating and managing technical change, and those requirements were even more limited in industries with persisting protection against competing imports (and/or subsidies for exports) that shielded them from the effects of the continuing improvements in these mature technologies that were being generated in the international economy. In that context, investment in change-generating capabilities was more of an 'optional extra' that might be added to routine operating capabilities by a few firms for idiosyncratic reasons. Not surprisingly, however, the majority of firms took advantage of the combination of technological maturity and protection/ subsidy, and invested little in developing their own resources for developing, improving, creating and designing the product and process technologies they used. The implications for competitiveness subsequently became evident.

That international technological environment for Brazilian industry has changed fundamentally during the 1980s. The whole spectrum of industries that were technologically mature in the 1960s and 1970s has been rejuvenated by radical changes in technology or (more often) by an intensification of more incremental forms of change - or by a combination of both. At the same time, of course, a wide range of new industries that were in their infancy in the 1960s and 1970s have emerged on the basis of rapid technological development to play a substantial role in international production and trade. As a result:

> ...in most areas of manufacturing, engineers are confronted with new criteria for dominant designs and must adapt to new technological and industrial paradigms, some of which are compatible with earlier approaches to design and product management, while others require a complete break with previous procedures and ways of thinking. (Chesnais 1990:15-16)

At the centre of this technological transformation lie a relatively small number of well-known areas of rapid technological development: micro-electronics and information technologies; radical improvements in old materials and the development of new ones; and accelerating developments in cell and molecular biology. Important as these are, they should not obscure the much wider diversity of intensified technical change across all industries, all activities within them, and most of the technologies they use.

Part of this diversity involves process-centred change with its implications for rising productivity - increasing efficiency in the use of capital, labour, energy and materials. But other parts are reflected in intensified product-centred change which, apart from reinforcing process efficiency, has (i) shortened the time gaps between major technological discontinuities, (ii) reduced life-times and lead-times for less radically novel products, and (iii) widened the diversity of

smaller product differentiation. At the same time, combinations of process-centred and product-centred change have been directed more intensively at reducing environmental costs per unit of industrial output - an objective that is being achieved increasingly by forms of technical change that <u>also</u> reduce other unit costs.

As it emerges from the crises and macro-economic instability of the 1980s, Brazilian industry therefore faces a world in which the technological basis for competitiveness is totally different from that of the 1960s and 1970s. The point is not simply that there now exist a large number of 'new technologies' that were not available before. The more fundamental point is that the **<u>whole structure of technology</u>** underlying the competitiveness of industry is now changing much faster than in the 1960s and 1970s. For such a large industrial economy that did not match the relatively modest international rates of technical change in the 1960s and 1970s, competing in this new technological environment of the 1990s constitutes a most formidable challenge.

3.1.2. THE IT-INTENSITY OF TECHNICAL CHANGE

Within the overall complex of intensified technical change, the importance and pervasive impact of electronics and information technologies are well recognised and need no further emphasis here (see Freeman 1993 for a recent review). However, three characteristics of IT-centred technical change require a little elaboration.

First, to an extent that is perhaps greater than in other areas of technical change, the incorporation of electronics and IT elements into products, processes and organisational systems seems to require direct user-involvement in technology development and design. Compared with some other areas of technology, the application of many areas of electronics/information technology requires much less standardised systems that are highly specific to the characteristics of individual firms, their products and processes, and their markets. These system specifications are not easily transferred in the form of 'ready-made' capital goods and blueprints and their efficient introduction therefore requires much more localised technical change. Moreover, that localisation must often go beyond the routine 'adaptation' of systems. It has to be deeply rooted in development and design of the hardware, and especially the software, in the immediate context of use. Also, since that frequently involves relatively complex engineering and design, the importance of tacit knowledge is often particularly great (David 1992). In particular, however, what is frequently involved is the integration of electronics/IT elements and systems within existing products, processes and organisational procedures, and large proportions of the tacit and other knowledge needed for localised development and design must therefore be drawn from the 'user' of those elements and systems. Thus, the technology users frequently need to play a particularly significant and direct role in the process of technology development and design. Then, of course, subsequent dynamic assimilation of the technology after its initial implementation requires, as with most other areas of technology, a yet greater direct involvement of the user in generating and managing technical change.

Second, most applications of electronics/information technologies involve systems and networks. This raises important issues about 'network externalities' (Katz and Shapiro 1983, Allen 1988), with progressive diffusion yielding falling transactions costs (Williamson 1988) and benefits to all users, not just the marginal adopters. At one level, this has important implications for change within individual firms. As Kaplinsky (1988) has emphasised, the gains from using automation and information technologies rise disproportionately fast with increasing degrees of system integration. This does not mean that merely trivial gains can

be captured from implementing only parts of the "electronic jigsaw", but it does suggest that there are likely to be high returns to rapid intra-firm diffusion of the technology. Correspondingly, adopters and users of the technology are likely to gain high returns to investment not simply in 'the technology' itself, but in the bodies of knowledge and expertise that are needed to interact with users in developing and extending their IT systems.

The network characteristics of IT systems also have important implications at the overall inter-firm level. Significant benefits accrue to individual firms (as 'externalities' from the actions of other firms) as the overall density of IT adopters and users increases within the total population of geographically related and market-linked firms. In particular, the efficiency of using IT systems increases with increasing local availability of (i) information about the technology from other users, (ii) a trained and experienced workforce, (iii) technical assistance and maintenance services, (iv) suppliers of equipment and software,[7] and (v) complementary innovations - both supplier-developed and user-generated, and both technical and organisational.

Within such evolving structures and processes of collective learning, the diffusion of electronics/information technology is frequently accelerated by the presence of advanced user-firms that not only act as 'demonstrators' for others, but also contribute to the development of innovations that improve the efficiency of the technologies in the specific local context of their use (von Hippel 1988)[8]. Given these patterns, it is not surprising that public policy in many of the advanced industrial countries has played a significant role in accelerating the diffusion of information technologies - in particular by stimulating the emergence of efficient technology users and the development of user-producer linkages. With respect to advanced automation technology in Sweden, for example, public policy and public institutions were crucial in setting up several 'demonstration plants' partly financed by the National Board for Industrial and Technical Development and the Board for Industrial Development.

Third, information technology is not just an area of changing technology, it is frequently also a powerful instrument for generating innovation and technical change. This is most obvious in the case of computer aided design systems which not only permit more rapid and frequent changes in product and process design, but also allow much more intensive and extensive exploration of design options. However, the same change-stimulating role of IT is evident in other ways that 'feed into' product and process design. In the various types of development and research, IT systems evidently play an enormously important role in accelerating the generation of new knowledge, in acquiring existing knowledge, and in developing new configurations of technology for incorporation into specific designs. Perhaps less evident is the change-stimulating role of IT when applied in production and management processes themselves. For example, the information that can be generated by various types of advanced process control technology, combined with the power of advanced computing, allows the acceleration of incremental process improvements. Similarly, the knowledge generated by IT applications for organisation and administration permit more intensive analysis of changes in the 'organisational technology' of firms.

3.1.3. THE INCREASING SIGNIFICANCE OF ORGANISATIONAL CHANGE

Although it has always been important, the significance of change in the organisational (or social) dimension of industrial technology has become much more evident during the 1980s. Given the flood of publications on this issue - Japanese management methods, 'Lean' production, 'Flexible

Specialisation', and so forth there is no need here for any general review (See Humphrey 1993 for a recent review that also includes several studies of Brazilian experience). Only one point require emphasis.

Organisational change is frequently an important integral component of many other types of technical change that may appear to be centred primarily on 'hardware'. This seems to be particularly so in changes involving IT and automation systems. For example, one survey about the diffusion of flexible manufacturing systems (Hoffman 1988) provides evidence to show that most of the gains in competitiveness arise from the preparation for, rather than the implementation of, such systems. Bessant and Haywood (1986) suggest that the extent of the benefits from the organisational dimension of change is around 75 per cent of the total derived from flexible manufacturing.

This does not mean, however, that organisational change can simply be substituted for investment in more 'hardware-centred' technical change. In the short run that is sometimes possible, especially when there is a large backlog of organisational inefficiency to overcome. Indeed, there are some cases where firms have found that substantial organisational change implemented in preparation for the introduction of IT systems has made the latter redundant. However, given the intensity of the overall multi-dimensional process of technical change in most industries, competitiveness cannot be sustained for long on the basis only of changes in the organisational dimension of production technology.

3.1.4. User-Producer Interactions and Innovation

We have earlier stressed the importance of the technology 'user' as a creative contributor to the process of technical change; and the importance of change-centred interactions between technology users and producers has already been emphasised with particular reference to information technology. But the significance of these interactions in raising the rate and effectiveness of technical change in industry is much more comprehensive. The work of Lundvall (1985 and 1992) on interactions between innovation users and producers in a range of industries emphasises that their geographical proximity constitutes a competitive advantage. On the other hand, the absence of effective user-producer interactions can lead to significant inefficiencies (Glete 1984). The key to effectiveness is not just the proximity of both agents but the 'quality' of their interaction, which in turn seems to depend heavily on the technological capabilities of the technology user as much as those of the producer. Lundvall (1989-16-17) pointed out, for example, that when producers dominate users (or when users have a limited technical competence) there has been a tendency towards 'hyper automation' - that is, users are faced with designs that do not meet their needs, and with overly complex and costly capital goods. In such cases, instead of attaining productivity gains, automation leads to diseconomies.[9]

It is important to note that the significance of these types of interaction appears to increase with (i) the complexity of the information about technology that has to be sent between the firms, (ii) the degree of non-standardisation of production, and (iii) the degree of technological discontinuity involved in the innovation. In other words, it appears to be much more significant in the technological environment of the 1980s that it was in the

context of more stable technologies and standardised production in the 1970s.

The dynamic significance of these user-producer interactions reinforces a point already made about conventional perspectives on the international division of technological labour - with innovation and technological creativity concentrated in the advanced industrial countries and technologically passive adopting and using concentrated in the developing world.[10] Our earlier argument was that such perspectives were misleading in a world where international competitiveness on the part of adopters and users of technology in the developing world requires them to contribute creatively to developing and changing the technologies they use. To that we must now add the argument that, in the environment of the 1990s, the dynamic importance of user-producer interactions calls for the increased presence of technologically creative producers (not just users) in industrialising countries, particularly because the importance of those interactions seems to be greater the earlier they occur in the life-cycles of the technologies concerned.

In other words, the developments of the 1980s have changed the forum for debating a key global issue: whether to reinforce or to reduce the technological dualism of the global economy in which (i) rich regions reap the dynamic gains of innovation within interacting networks of technologically creative firms and institutions, and (ii) industrial firms in the developing world 'specialise' in the technologically passive adoption and use of technology that has mostly been created within structures and systems in which they play no part. In the 1960s and early 1970s that issue was on the agenda of ideological and political debate. In the 1990s, especially in relatively advanced industrialising economies like Brazil, that same question must be on the agenda of economic debate about efficiency and competitiveness.

most striking aspect of this is a shift away from subsidies for general capital costs and investment aid, and towards more focused support for R&D, training and related knowledge-centred activities (Cassiolato 1994).

3.2 Access to International Technology: New Patterns and Conditions

3.2.1. New Patterns or Old Continuities?

Despite their obvious importance, key features of the international transfer of technology have attracted only limited systematic analysis over the last decade or so. This, however, has not precluded numerous comments about the emergence of new trends and patterns. Many of these suggest that industrialising countries face increasing problems in their efforts to acquire technology from the more advanced industrial economies. In particular, the following issues have been noted.

With innovation coming to depend on rising levels of R&D expenditure, higher payments may be required for licensing and other forms of access to the technologies involved.

Changes in intellectual property rights systems in the industrialised countries, together with pressures for more stringent enforcement of those regimes in industrialising countries, are reinforcing such trends - as well as bringing into the scope of those systems areas of technology previously excluded (e.g. in software and biotechnology).

The characteristics of some new technologies are making them inherently more difficult to transfer. It has been suggested, for example, that many areas of information technology involve particularly high levels of tacit and firm-

specific knowledge that are less easily transferred than more equipment-embodied technologies (Dosi, Pavitt and Soete 1990).

The growing importance multi-firm collaborative arrangements for developing new technologies across a wide spectrum of industries, combined with the rising importance of basic research in some areas, may hinder the access of developing countries to the knowledge involved.

Several studies have provided a reasonable of support for such views. For example, drawing on interviews, the UNCTAD Secretariat has suggested that royalty rates on patents and know-how may be rising (UNCTAD 1992:152-3); and Vickery (1990) has observed a relatively slow growth of technology licensing as compared with other technology transfer activities, such as imports of capital goods. However, one can also find equally convincing arguments that point in opposite directions.

With increasing R&D investment levels, often associated with shorter product life cycles, there are pressures to increase, not reduce, access to the technologies involved: "...innovators must reap profits faster, sometimes by licensing their technology rather than by exporting it or establishing affiliates abroad." (Soete 1985)

More specific studies of the international diffusion of advanced technologies like telecommunications systems have suggested that intense competition among technology leaders in international markets has pushed monopolistic profits from innovations lower and lower, and that "the 'appropriability' of innovations has greatly declined in recent years." (Antonelli 1991)

Advanced information and communication technologies may enhance, not constrain, international access to technology; and this may be further increased, not reduced, by the growing use of collaborative networks for technology development - networks into which firms in industrialising countries may be incorporated. For example, Hindustan Aeronautics in India and a leading UK aerospace company have recently entered into a collaborative engineering design programme that will operate through a sophisticated network of computers and satellite links.

Advanced information technologies may well involve greater elements of tacit knowledge and greater degrees of user-specificity, while yielding their greatest gains as total system integration is achieved. But, at least in some situations, this does not seem to have been a great obstacle to their international diffusion, combined with (i) their localised adaptation to meet user-specific requirements, (ii) their efficient application to yield significant benefits from cumulative partial steps towards integration, and (iii) their further development and improvement by users after initial implementation. These characteristics can be identified in some situations - for example, in the case of the port management system in Singapore (Wan et al. 1992), just as their virtual absence can be identified in others situations - for example, in the case of digital process control systems in the petrochemical industry in Brazil (Carvalho 1992). Perhaps the key issues are less about any inherent general characteristics of 'new technologies', and more about differences between the situations for which they are acquired and into which they are introduced.

In short, it is not clear that any broad generalisations can usefully be drawn in these areas at this stage. In any case, there are more focused arguments that may be more significant for some Brazilian industries. These are about the problems of limited access to technology that arise as firms and industries in the NICs begin to approach particular segments of the international technological frontier. For example, it has been noted that some of the more technologically advanced firms in South East Asian have encountered increasing problems in acquiring technologies

through international channels: firms in the advanced countries "are refusing to license the relevant technology since they do not want to encourage direct competition in products which they are still producing themselves", (O'Brien 1985:214). More recently, as Korea has become a major competitor, it has been suggested that Japanese firms have become increasingly reluctant to sell or license technology in key areas of components, software, capital goods and machinery (Business Week 1992). Moreover, there is a common view in Korea that Japanese firms have formed a consensus (implicitly at least) not to supply strategic technology inputs to Korea. Indeed, some observers within Korea believe that, during the latter half of the 1980s, they were experiencing the 'tail end' of technology transfer from Japan, and they claim that in some cases, the large Japanese conglomerates have begun not only to restrict their own transfer of strategic technologies to Korean competitors, but also to pressurise their technology suppliers to do the same.

Again, however, this set of issues is not wholly clear, and there is considerable evidence that points towards different conclusions. At a general level, it is obvious enough that, as firms in the NICs begin to approach the international technology frontier, they will face changing conditions in seeking to acquire technology through international channels. However, the significance of those changing conditions is not so obvious.

The 'price' of relatively young technology may be higher than that of older technology, but presumably the returns to acquiring and using the newer technology are also higher. Is one getting more 'value for money' or less?

Other conditions for acquiring and using technology may well be more restrictive for younger than for older technologies. For example, restrictions on exporting may be tighter for technologies that firms in the advanced countries are still actively using in their own products. However, is that an insurmountable obstacle or a challenge to find new ways of acquiring relatively young technologies and exporting products based on them? The experience of the East Asian NICs (for example in developing OEM and ODM arrangements with large firms in the advanced countries)[12] suggests that, while the former has been much discussed, the latter has frequently been the focus for practical action.

It is quite evident that some large Japanese firms have recently restricted what had previously been relatively open access to technology by firms from Korea and Taiwan. However, while again generating a considerable volume of Korean comment, this has also stimulated Korean firms to find other sources for the technology they need. For example, the Daewoo corporation has slashed its reliance on Japanese technology (from 85 per cent of total procurement in the mid-1980s to 15 per cent) by increasing its reliance on western companies (Business Week 1992).

It is also quite evident that opportunities for such switching of sources for relatively advanced technology may narrow with the contracting diversity of potential suppliers that usually follows the early stages of product/technology life cycles. However, there are very few segments of industry that are so monopolised as to preclude the exploration of alternative sources - although these tend to attract most attention. Also, the process of concentration in advanced technology industries may actually increase, rather than reduce, effective opportunities for access to technology - at least during the phase of concentration itself. For example, Korean firms obtained key elements for their entry into semi-conductor production from relatively small US firms that, being 'squeezed' by competition from the larger firms, were under particularly strong pressure to generate revenue from their existing technological assets.

What this seems to suggest is two general points. First, if there are obstacles and barriers to technology

acquisition as NIC firms approach the international frontier, they do not all seem to be insurmountable or impermeable. After all, despite all the talk about growing constraints on Korea's access to technology since the mid-1980s, the actual payments made for technology have continued to rise dramatically - nearly doubling between 1987 and 1991. Second, and more generally, it seems highly likely that as the age of the technology falls the openness of international channels for acquiring it probably narrows; and the terms and conditions for acquisition will almost certainly also change, perhaps becoming more onerous, reflecting the greater commercial value of the technology to the user and the greater opportunity costs for the supplier. However, the precise outcome in any situation will depend primarily on the interaction between four sets of conditions: (i) the characteristics of the technologies involved; (ii) the characteristics of the supplier firms and their industries; (iii) the technological capabilities of would-be technology importers, together with other elements of the bargaining power they can draw on; (iv) the institutional arrangements they use in approaching the acquisition of technology.

In the absence of any systematic evidence about the relative importance of these, one can choose to give more and less emphasis to any of them. For example, one might focus on the first two, perhaps seeing those 'external' conditions as invariant constraints, barriers and obstacles. Here, however, we focus on the second two - 'internal' conditions over which Brazilian firms and government policy can exercise some influence.

3.2.2. The Technological Capabilities and Bargaining Power of Technology Importers

The recent experience of the East Asian NICs confirms the validity of a much older general principle: access to technology through international channels depends heavily on the strength of the importers' existing technological capabilities. This relationship seems to operate in a variety of ways.

First, the 'depth' of knowledge and expertise that can be acquired and absorbed from particular transfer projects depends on the strength of related knowledge and skill that are taken **into** those projects. This is illustrated in the experience of several 'heavy' industry projects in Korea (e.g. Enos and Park 1988), but it is illustrated by Brazilian experience as well - for example in the PETROQUISA/ COPESUL case (Sercovich 1980).

Second, the strength of existing mastery of production technologies, particularly the ability to increase efficiency and quality, can open access to increasingly advanced product technology (and sometimes also elements of new process technology) via OEM, sub-contracting and similar arrangements.

Third, the strength of existing engineering and design capabilities may permit effective exploitation of only 'partial' access to technology - for example, via reverse engineering from existing products and equipment, or engineering around existing patent specifications.

Finally, the importer's technology-related bargaining power can have a significant influence on the willingness of potential suppliers to enter into transfer agreements in the first place. As illustrated by Korean experience in the electronics industry, this link may be quite 'visible' and 'explicit' (for example, in the form of cross licensing

agreements), or it may reflect more 'implicit' strategic considerations. For example, some Korean firms increased their own R&D in order to be able to negotiate better for foreign technology. This is precisely the case of video cassette recorder (VCR) technology where, having trouble licensing technology from Japan, they undertook their own R&D effort in conjunction with a government laboratory to develop their own VCR technology just for the Japanese firms, faced with this credible threat, to agree to license the technology to Korean firms (Bell and Cassiolato 1993).

A similar relationship between domestic technological capability and access to foreign technology seems to have been involved in the Brazilian electronics industry as the willingness of foreign companies to transfer technology increased with the growing experience and R&D capability of Brazilian firms (Cassiolato et al. 1992: 293-94).

Other dimensions of bargaining power cut across such technology-related issues - for example, the scale and expected growth of markets. But, as noted earlier in connection with Japanese experience, the effective bargaining power arising from an apparently 'given' market can be highly variable: it can be harnessed as a powerful means to stimulate a combination of wider access to international technology and stronger domestic investment in technological learning. Alternatively, it can be fragmented and frittered away.

3.2.3. The Institutional Basis for Acquiring Foreign Technology

The influence of the combination of technological capability and other elements of bargaining power will vary with the institutional basis used for technology acquisition. This variation may be a matter of intra-firm arrangements -

for example, the scale, skill composition and lifetime of teams assembled to prepare for, and implement, technology acquisition projects. However, this variation may also be a matter of inter-institutional arrangements.

Public or quasi-public institutions may act as intermediary importers/licensees in particular areas of technology, providing 'localised' knowledge, hardware, training and other services for domestic firms. The Industrial Technology Research Institute in Taiwan seems to have played this type of intermediary role to support (or initiate) relatively small firms in the electronics industry.

Groups of firms may collaborate (perhaps with the involvement of a technological institution) to create a stronger organisational and technological basis for searching out, negotiating over, acquiring and absorbing technology in a particular field. This may involve complementary firms - for example, technology users, engineering firms and equipment producers. Alternatively, it might involve potential competitors that pool their resources and bargaining power in the same manner that firms in some of the developed countries have collaborated in 'pre-competitive' R&D.

Firms (or groups of firms) may set up technology acquiring-cum-developing organisations <u>in</u> the advanced industrial countries in order to get closer to the international technological frontier and provide a basis for acquiring and absorbing elements of technical knowledge that are tacit, embodied in people, transferred through informal channels and networks, or intimately linked with market-related knowledge. Japanese firms have used such strategies for many years, and Korean firms used them to acquire technology for semi-conductor production. Also, as noted earlier, a few Brazilian companies in the automobile components industry have followed similar strategies.

Singly or collectively, technology importers may follow a slightly different approach in cases where the technology

sought is deeply embedded in particular firms in the advanced industrial countries. They may acquire one or more of those firms - a strategy widely followed by technology-seeking firms in the developed countries, and again also used by the Korean electronics industry.

When the technology needed is close to the international frontier, it is also likely to be in the grey area between (i) being 'available', and (ii) needing to be developed. Singly or collectively (and perhaps in association with one or more technological institutions) firms may therefore join collaborative technology-developing networks and alliances involving firms in other countries. These might consist of firms in other developing countries in some situations, or may include mainly firms in the advanced industrial countries in others.

To summarise then, firms and industries in particular countries can approach the acquisition of foreign technology with (i) widely varying technological capabilities, (ii) wide differences in other elements of bargaining power, and (iii) widely differing organisational bases. Strategies for technology acquisition that rest on weak technological capabilities, weak bargaining power, and weak institutional bases may well result quite often in the licensing of product designs and/or the acquisition of equipment, know-how and other inputs for production. But, they are also likely to result in some combination of (i) limited or zero access to the technology in the first place, (ii) the acquisition of limited 'depths' of knowledge and expertise through such channels of access as are opened up, (iii) the payment of relatively high costs for what is acquired, and (iv) limited dynamism in the subsequent assimilation of what was acquired.

At the other end of the spectrum of strategies, firms and industries that are approaching the international technology frontier will usually need considerable technological, bargaining and institutional strengths in order to acquire foreign technology effectively, or at all. On that account alone, the costs of technology transfer may well rise as the frontier is approached, but those rising costs are not 'payments' for technology (which may well rise also). They are investments in domestic resources for acquiring and assimilating technology; and, until one is at the cutting edge of the frontier, those costs are likely to remain substantially less than the costs of original development of the technology. However, that distinction frequently ceases to have much meaning as one approaches the frontier: technology acquisition and technology development become blurred into various combinations of engineering, development and research.

4. CONCLUSIONS

Two basic orientations underlie the conclusions. The first is about how the international competitiveness of existing Brazilian industries can be achieved or sustained in the short-to-medium term. In a technologically dynamic world that is possible in only two broad ways. One involves progressively reducing real wage levels in industry and/or 'finding' progressively cheaper natural resource inputs for industry under a strong belief in a 'technologically globalised' world. The other requires industrial firms to generate paths of technological dynamism that progressively raise production efficiency and product performance (and/or reduce the cost-performance ratio of the natural resources used by industry). The focus here is only on the second of these strategies.[13]

Second, however, even if that strategy is vigorously pursued, there are limits to which it can sustain competitiveness in the medium to longer term across the whole industrial structure while maintaining real income levels. On the one hand, many other countries are rapidly

expanding their natural resource-based industries, with adverse effects on trends in international prices. On the other hand, many are eroding Brazil's existing competitiveness in labour-intensive industries by combining lower wage rates with (access to) technical skills and international marketing expertise. In that context there are again two strategies for maintaining the competitiveness of industry: (i) managing exchange rates so that Brazilian prices in international markets remain competitive, but at the cost of reducing real domestic incomes; or (ii) shifting the structure of industry towards higher value-added products and more technology-intensive industries. Again, the focus here is only on the second of those strategies.

These two strategic orientations have one basic feature at their core: they will require industry to generate trajectories of significant domestic technological dynamism. While the precise meaning of "significant" will vary between firms and industries, one point is clear enough. In most firms and industries the intensity of firms' investment in technological accumulation and technical change that will be required to create and sustain competitiveness will have to be very much greater than in the past - not only greater than in the immediate past of the 'lost decade', but also greater than in the two previous decades which, in terms of these aspects of industrial technological development, were also largely 'lost'.

The central issue we have highlighted is that technology imports will have to play a major role in achieving that new intensity of technological dynamism. This, however, is not just a matter of increasing the 'quantity' of imported technology. Important as that is, there are more important 'qualitative' issues about **how** technology is imported in order to incorporate it into the trajectories of technological dynamism pursued by firms. That involves two sets of issues.

First, imported technology will have to be used not just as the basis for one-off steps which raise competitiveness to new **levels**, or which permit merely **entry into** new product markets. In a technologically dynamic world, fixed levels of competitiveness are rapidly eroded, and the basis for entering markets will rapidly become inadequate for remaining in them, let alone for expanding within them or diversifying beyond them. International technology transfer projects can therefore contribute only to very **temporary** competitive positions on trajectories of continuing technological change and development. Moreover, although further technology imports can obviously contribute to that subsequent trajectory, they can do so only partially - and often only very partially. Initial imports must therefore be complemented by substantial and continuing efforts by the importing firms themselves to generate those subsequent trajectories of technical change.

Second, international technology transfer will often also have to be used to contribute more 'indirectly' to those trajectories - that is, not only by providing inputs to technical change itself, but by providing inputs to the accumulation of domestic technological capabilities for generating change. This implies that technology transfer arrangements will often have to be managed with two objectives in view, not just one. They must be managed (i) in ways that add to domestic knowledge, expertise and other resources for generating technical change, as well as (ii) in ways that contribute as efficiently as possible to the more immediate and direct implementation of technical change.

These issues have implications not only for management at the firm level, but also for government policy. However, precisely because of the importance of incorporating technology imports into overall trajectories of technological dynamism, neither management nor policy concerned with technology acquisition can be treated as distinct areas of isolated action. They must be parts of wider fields of concern about technology and industrial competitiveness in a world where "techno-globalism" is nothing more than "global exploitation of technology" by big international firms and where the accumulation of technological capabilities is a much more complex issue than what the "neo-liberal" agenda would like us to believe.

NOTES

[1] For a recent survey see Freeman (1994)

[2] It is worth pointing out the existence of important exceptions to this general pattern. Also, that there have been some sectors - such as paper and pulp, shoes, steel and petrochemicals - which attained very high exports during the 1980s. However, it is worth recalling that exports in these sectors tend to be restricted to commodities and that exporting firms lack technological capabilities to produce higher value-added goods and are finding difficulties to penetrate more sophisticated market segments at international level.

[3] Following Salter (1966) and others, such 'lumps' of capital-embodied technology were described as 'vintages and, as Salter described it, such a vintage consisted of "a new outfit of capital equipment".

[4] Alternatively, as outlined later in this section, when the development of local innovative activity was seen as desirable, international technology transfer was seen as having little or nothing to do with it - except perhaps as a constraint on the emergence of those activities.

[5] For example, the intensity of continuopus change seems to be much greater in Japanese than US or UK industry, and much greater in Korean than Brazilian or Indian industry.

[6] There are, of course, differences between industries and technologies in the **rates** of continuous, incremental change that are attainable over short term periods. There are also differences in the length of the periods of incremental improvement that occur between more radical innovative steps - for example, successive novel vintages of semiconductor technology have followed each other much more rapidly in the last two decades than successive radical steps in brick-making technology. Nevertheless, across those kinds of difference, the inter-vintage phases of continous, incremental change are key components of the technological competitiveness of firms and industries.

[7] As has been stated above, the integration of customers in the development of new products improves the development work (von Hippel, 1976). This is especially so in the software field, in which product development is so complicated that it has to be performed for a specific customer.

[8] Even when one refers to relatively indivisible technologies, such as basic oxygen steelmaking, continuous casting of steel, float glass and barrel kilns in brickmaking, it is shown that their diffusion process is both constrained and dependent upon improvements generated by both producers and users of the technology (Ray 1984:87).
[9] For example, in the case of waste-water technology and office automation in Denmark, the lack of local user competence had a negative effect upon the systems developed (Lundvall 1989).
[10] For a related critique of such perspectives, see Walsh (1988).
[11] Fortune (3 June 1991) reviews "How Intellectual Capital Is Becoming Corporate America's Most Valuable Asset".
[12] Hobday (1993) discusses these arrangements for Original Equipment Manufacture (OEM) and Original Design and Manufacture (ODM).
[13] There is, of course, a third strategy: to accelerate the destruction of all uncompetitive industries and firms, hoping that the 'resources released' (e.g. people unemployed) will somehow be absorbed in other economic activities. Given the structure of the Brazilian economy, there is limited scope for relying much more on this type of British or Chilean type of strategy for industrial competitiveness.

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