Ministério da Ciência e Tecnologia - MCT

Financiadora de Estudos e Projetos - FINEP

Programa de Apoio ao Desenvolvimento Científico e Tecnológico - PADCT

ESTUDO DA COMPETITIVIDADE DA INDÚSTRIA BRASILEIRA

THE ACCESS OF DEVELOPING COUNTRIES TO NEW TECHNOLOGIES: THE NEED FOR NEW APPROACHES TO MANAGEMENT AND POLICY FOR TECHNOLOGY IMPORTS IN BRAZILIAN INDUSTRY

Nota Técnica Temática do Bloco
"Condicionantes Internacionais da Competitividade"

Campinas, 1993

Documento elaborado pelos consultores Martin Bell e José Cassiolato (Science Policy Research Unit/University of Sussex).

A Comissão de Coordenação - formada por Luciano G. Coutinho (IE/UNICAMP), João Carlos Ferraz (IEI/UFRJ), Abílio dos Santos (FDC) e Pedro da Motta Veiga (FUNCEX) - considera que o conteúdo deste documento está coerente com o Estudo da Competitividade da Indústria Brasileira (ECIB), incorpora contribuições obtidas nos workshops e servirá como subsídio para as Notas Técnicas Finais de síntese do Estudo.

IE/UNICAMP - IEI/UFRJ - FDC - FUNCEX

CONSÓRCIO

Comissão de Coordenação

INSTITUTO DE ECONOMIA/UNICAMP
INSTITUTO DE ECONOMIA INDUSTRIAL/UFRJ
FUNDAÇÃO DOM CABRAL
FUNDAÇÃO CENTRO DE ESTUDOS DO COMÉRCIO EXTERIOR

Instituições Associadas

SCIENCE POLICY RESEARCH UNIT - SPRU/SUSSEX UNIVERSITY
INSTITUTO DE ESTUDOS PARA O DESENVOLVIMENTO INDUSTRIAL - IEDI
NÚCLEO DE POLÍTICA E ADMINISTRAÇÃO EM CIÊNCIA E TECNOLOGIA - NACIT/UFBA
DEPARTAMENTO DE POLÍTICA CIENTÍFICA E TECNOLÓGICA - IG/UNICAMP
INSTITUTO EQUATORIAL DE CULTURA CONTEMPORÂNEA

Instituições Subcontratadas

INSTITUTO BRASILEIRO DE OPINIÃO PÚBLICA E ESTATÍSTICA - IBOPE
ERNST & YOUNG, SOTEC
COOPERS & LYBRAND BIEDERMANN, BORDASCH

Instituição Gestora

FUNDAÇÃO ECONOMIA DE CAMPINAS - FECAMP

EQUIPE DE COORDENAÇÃO TÉCNICA

Coordenação Geral:	Luciano G. Coutinho (UNICAMP-IE)
	João Carlos Ferraz (UFRJ-IEI)
Coordenação Internacional:	José Eduardo Cassiolato (SPRU)
Coordenação Executiva:	Ana Lucia Gonçalves da Silva (UNICAMP-IE)
	Maria Carolina Capistrano (UFRJ-IEI)
Coord. Análise dos Fatores Sistêmicos:	Mario Luiz Possas (UNICAMP-IE)
Apoio Coord. Anál. Fatores Sistêmicos:	Mariano F. Laplane (UNICAMP-IE)
	João E. M. P. Furtado (UNESP; UNICAMP-IE)
Coordenação Análise da Indústria:	Lia Haguenauer (UFRJ-IEI)
	David Kupfer (UFRJ-IEI)
Apoio Coord. Análise da Indústria:	Anibal Wanderley (UFRJ-IEI)
Coordenação de Eventos:	Gianna Sagázio (FDC)

Contratado por:

Ministério da Ciência e Tecnologia - MCT

Financiadora de Estudos e Projetos - FINEP

Programa de Apoio ao Desenvolvimento Científico e Tecnológico - PADCT

COMISSÃO DE SUPERVISÃO

O Estudo foi supervisionado por uma Comissão formada por:

João Camilo Penna - Presidente
Lourival Carmo Mônaco (FINEP) - Vice-Presidente
Afonso Carlos Corrêa Fleury (USP)
Aílton Barcelos Fernandes (MICT)
Aldo Sani (RIOCELL)
Antonio dos Santos Maciel Neto (MICT)
Eduardo Gondim de Vasconcellos (USP)
Frederico Reis de Araújo (MCT)
Guilherme Emrich (BIOBRÁS)
Júlio Fusaro Mourão (BNDES)
Lauro Fiúza Júnior (CIC)
Mauro Marcondes Rodrigues (BNDES)
Nelson Back (UFSC)
Oskar Klingl (MCT)
Paulo Bastos Tigre (UFRJ)
Paulo Diedrichsen Villares (VILLARES)
Paulo de Tarso Paixão (DIEESE)
Renato Kasinsky (COFAP)

José Paulo Silveira (MCT) Wilson Suzigan (UNICAMP)

CONTENTS

SUMMARY EXECUTIVE

1. TECHNOLOGICAL DEVELOPMENT AND IMPORTS IN BRAZILIAN INDUSTRY

Since the mid 1970s Brazilian payments for imported technology have fallen steadily to very low levels. If, for instance, imports of technology are measured by payment for technology contracts registered at INPI, the reduction was from US$ 321 million in 1980 to US$ 174 million in 1987. The ratio of payments for technology transfer contracts as a percentage of GDP, which increased during the last phase of import substitution to more than 0.35 per cent in 1972, consistently decreased during the following period to 0.24 per cent in 1980 and to 0.07 per cent in 1987. Imports of capital goods also declined during the 1980s.

This collapse in payments for imported technology has come to reflect an almost total disconnection of Brazilian industry 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 during the 1970s and 1980s as that economy strengthened its international competitiveness in existing lines of production, and opened up successive new areas of competitiveness. During that period, payments for imported technology (licensing and consultancy payments) massively increased 13-fold in absolute terms between 1972-76 and 1982-86.

This highlights one of the major technology-related challenges now faced: the need to reverse the recent trend of technology imports and re-connect industry to international sources of technology. But there is a second challenge. This is not about the 'quantity' of technology acquired from abroad; it is about how 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 imported technology in the past. Those approaches must be radically altered. There are two broad sets of reasons for this.

1) 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.

2) 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, direction 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 dominant approaches to acquiring imported technology in Brazil, in the past, with a few notable exceptions, have been characterised by two basic features.

1) Technology imports were typically disconnected from significant innovative activity in the technology importing firms: they were usually not preceded by, accompanied by, or followed by substantial complementary research, development or engineering efforts.

2) 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.

Some of the new understanding about technology, international 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. Older perspectives must be replaced by new understanding if more effective approaches are to be developed for acquiring imported technology:

a) to create and sustain industrial competitiveness, technical change must be a continuous, not intermittent, process; and imported technology must ve incorporated into that continous technological dynamism;

b) 'adopters' and 'users' of technology play active and creative roles in generating these trajectories of competitive technological dynamism, and they depend on a variety of interactions with other firms doing so;

c) industrial firms play important roles as creators, not just employers, of the human resources required to generate and manage technical change;

d) technology imports and local innovative capabilities are complements, not alternatives, in the process of technical change;

e) 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;

f) infrastructural technology institutes can only complement, not substitute for, the innovative activities of industrial firms.

2. THE INTERNATIONAL CONTEXT IN THE 1990s

The assessment of the main features of the international context for technology acquisition in the 1990s must emphasise the significance of new challenges that stem from the combination of:

(i) new patterns of technical change (the so-called 'new techno-economic paradigm'); and

(ii) new factors that may influence the accessibility of foreign technology and the terms of its acquisition.

Several key features of new patterns of technical change have become increasingly important during the 1980s.

a) Technical change has been intensified in ways that result in the whole structure of technology underlying the competitiveness of most industries now changing much faster than in the 1960s and 1970s.

b) The rising IT-intensity of technical change both contributes to much faster rates of technical change and alters the organisational basis for generating that change.

c) In particular, IT-intensive forms of technical change, especially those involving networks and systemic change, usually have to be highly localised and specific to the particular characteristics of firms and the markets they face. Consequently various forms of interaction between users and producers of IT devices and systems are becoming increasingly important as the basis for effective generation of technical change.

d) The growing importance of change in the organisation and management of production ('lean' production, flexible especialisation, etc.) reinforces the overall intensity of technical change - acting as an increasingly significant complement to, but not substitute for, more 'hardware-centred' technical change.

e) These intensified and diversified patterns of technical change have greatly increased the overall knowledge-intensity of industrial production, with a correspondingly massive increase in the importance of investment in knowledge assets and human capital as sources of competitiveness.

These changes in the nature of technical change reinforce the significance of issues already emphasised. If imported technology is to contribute effectively to competitiveness in both natioinal and international markets, it must be incorporated into localisec processes of significant technoological dynamism; the 'users' of imported technology, interacting with other firms, need to play active and creative roles in generating that dynamism; and firms themselves need to be significant investors increating the human resources they require in order to play those roles.

The general accessibility of foreign technology, and the terms for its acquisition may not have changed in systematic ways over the last decade. However, views on this issue are contradictory, and evidence is lacking. On the one hand it has been argued that factors such as the rising costs of innovation in the advanced industrial countries, changes in intellectual property systems, and increased technological complexity combined with greter 'tacitness' in many areas of technology have reduced the accessibility and transferability of technology, while the terms for access have become more onerous.

It is not clear, however, whether there are indeed such new problems. One can argue just as convincingly (with similar inadequate evidence) that many areas of technology are becoming increasingly accessible and transferable, while the conditions for access may be less onerous than in the past.

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.

a) 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.

b) 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).

c) 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.

d) 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 modicum 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 and it has been 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.

a) 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."

b) 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."

c) 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.

d) 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. 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.

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.

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. 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; and (iv) the institutional arrangements they use in approaching the acquisition of technology.

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 - probably in that order!

3. MANAGEMENT AND POLICY IMPLICATIONS FOR BRAZIL

At the firm level, action should be taken not only during the acquisition of technologyh but also, **before the acquisition of technology** - when management should be concerned with creating, enhancing and 'assembling' the technological and organisational capabilities needed to define in adequate detail the technology required, to locate its possible sources, to gain access to it, to minimise its financial and other costs, and to acquire and absorb the 'depth' and 'breadth' of knowledge and expertise sought - and **after the acquisition of technology**, when management should focus on the dynamic assimilation of what had been acquired - not just on using the technology, but on further improving and developing it.

There are four broad areas for management attention during each time period. Management should concentrate on creating intra-firm organisational structures, creating inter-firm organisational structures, investment in knowledge and expertise and investment in implementing technical change.

Policy in this area must obviously be part of a wider policy regime concerned more broadly with technology and other aspects of competitiveness. Within that, it can be emphasised that:

1) Policy prescriptions should recognise that since firms are the main locus of technological accumulation, **a firm's possession of internal R&D capacities cannot be replaced and there is no possible substitutability between internal and external R&D**. Another novel feature of technical change is the promotion of a wide range of technical activities **within industry and commerce itself** involving not only R&D but also scientific and technical services - including design, quality control, product engineering, technical information services, etc. - which reinforce and interact with R&D.

2) Policy prescriptions should also recognise that, if R&D inside the firm or outside the firm cannot substitute for each other, they are necessarily **complementary** activities. Another major determinant of success in technological accumulation lies in the nature and intensity of the interaction with external sources of technical change, particularly with contemporary and furture users of the technology. Policies, then, should concentrate in promoting these linkages and management attitudes should contemplate cooperation with buyers and sellers instead of conflicting or mere commercial relations.

Within that, some broad orientations can be pointed out here.

First, the focus of policy in this area must concentrate on the industrial firm - not to the exclusion of action concerned with a wide range of technological institutions, but in recognition of firms as the necessary driving forced of industrial technological dynamism and as the core agents in acquiring and absorbing foreign technology.

Second, it must be emphasised that key elements of the strategic management of technology acquisition involve **investment** by firms in their own resources as complements to their expenditures on foreign technology. Clearly this requires an adequately stable macro-economic environment within which firms will undertake any significant investment in assets that yield their returns over the relatively long term future.

Third, its is clear that competitive pressure plays an important role in stimulating firms to change the technology they use, and hence to invest in the resources of foreign technology and domestic technological capabilities required to do so. Other things being equal, therefore, policies that enhance those competitive pressures are likely to increase, and increase the effectiveness of, the acquisition of foreign technology.

Fourth, however, much of Brazilian industry appears to have limited technological capabilities to respond to such competitive pressures; and, just as important, it has limited experience of investing in the accumulation of those resources. Moreover, much of that investment involves investment in knowledge and human capital where markets operate very imperfectly. There are therefore strong grounds for government intervention that stimulates investment in such assets.

In particular, one must recognise the limitations of financial institutions in this area. Most of them are accustomed to financing investment in fixed, physical assets which themselves provide significant security for the finance. Some more specialised institutions are also accustomed to financing innovative technical change projects for which the potential returns are reasonably evident, even if somewhat uncertain. However, much more risky and uncertain for such institutions, as for firms themselves, in investment in knowledge and human capital. Yet these are the kinds of assets that have become increasingly important for dynamic competitiveness in increasingly change-intensive and knowledge-intensive industrial production in the 1990s. This appears to be reflected in the shifting patterns of public policy that focus increasingly on stimulating and subsidising investment in knowledge assets in the industrially advanced countries. In an economy where investment in these assets has not become a significant component of industrial behaviour and 'culture, such policy intervention is even more important. In particular, innovative new measures may be needed to link government intervention to the operations of industrial financial institutions.

It is true that there is no possible alternative policy proposal which do not concentrate in strenghtening **internal** (to the firm) R&D capabilities. However, in general terms, as recently shown by the 'OECD industrial support programmes database', it is advisable a shift away from general-purpose, horizontal policies such as general investment aids to more focused support measures, such as aid to R&D which comprise programmes supporting general private R&D efforts and others supporting certain types of technologies, sectors and enterprises.Even in developed countries which, apparently, have relied since the 1980s on 'market forces' to lead their industrial development the above mentioned type of intervention is being implemented. For example, in the US, the R&D tax credit and the National Cooperative Research Act were made permanent and in the UK, the main R&D policy focus of the Department of Trade and Industry is a number of programmes on the encouragement of pre-competitive collaborative research in firms.

Fifth, important elements in the strategic management of technology acquisition involve the development of institutional linkages and networks. This suggests that other types of government intervention may be important - types of intervention that involve governments playing a catalytic role in facilitating collaboration in a wide spectrum of technological activities. Action to stimulate such technological partnerships may be particularly important in linking users and producers of technology, especially in the areas of industrial automation and other types of information technology - areas where governments in many of the industrialised countries play a substantial role. For example, in the Netherlands, one of the key policy actions is the subcontracting and outsourcing programme aimed at mutual cooperation in the field of technology and product development and at improvement projects in the field of just-in-time delivery, logistics and quality management.

Finally, in ways illustrated in the experience of Japan, government policy may have an important role in shaping the structure of markets to create conditions that enhance the competitive pressures on firms in ways that stimulate, rather than constrain, investment in technological capabilities to complement the acquisition of foreign technology.

1. INTRODUCTION: THE CHALLENGE FACED

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 - for the latter see Figure 1.[1] When associated with the stagnant levels of domestic R&D,[2] 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.

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

---

1 As it is well known, technology payments are just a proxy for imported technology. In the Brazilian case they do not include, since 1971 - when INPI was created - any payment between subsidiaries of multinational firms and their parent companies. Given the importance of such firms in Brazil, it could be argued that data on Figure 1 underestimates technology imports. This is certainly true for the 1970s when the last phase of import substitution took place and investments were peaking. However, since the early 1980s investment by these firms have substantially declined and, then, there is no reason to believe that this underestimation persisted. The final result is, probably, a much sharper decline on technology payments over GDP, starting by the mid-1970s, then what is suggested by Figure 1.

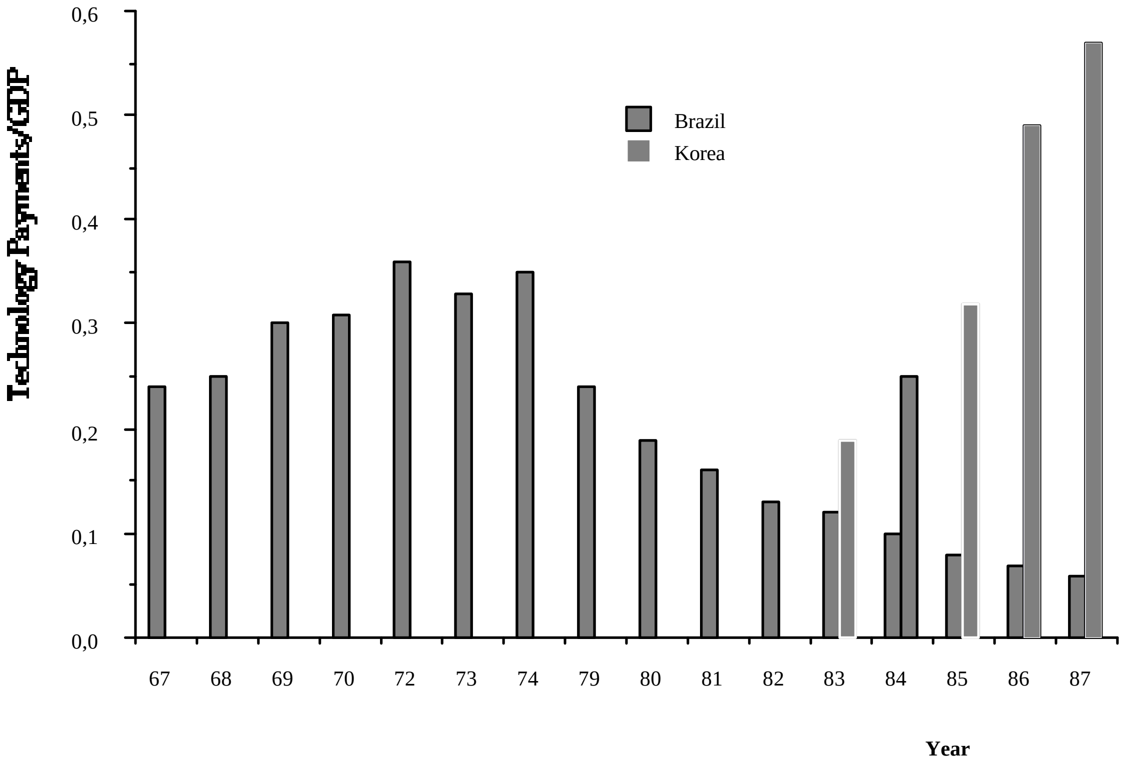
2 This trend is examined in greater detail in Section 2 of the report.

macro-economic reform and the return of stability and confidence. These issues are addressed in other papers in the overall study, and are not examined further here.

FIGURE 1

PAYMENTS FOR TECHNOLOGY TRANSFER CONTRACTS AS A PERCENTAGE OF GDP

BRAZIL - 1967-1987 AND SOUTH KOREA - 1983-1987



Notes:
Amount refers to payments effectively made during each year as registered in the Central Bank.
They include technical assistance fees, royalties and commissions.
Sources: Brazil: own calculation, basic data in Biato et al. (1973) for 1967-1970 data, Fung & Cassiolato (1976) for 1972-1974 data and Cardoso (1988) for 1979-1988 data; South Korea: KDB (1988).

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.

1) 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.

2) 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 management 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. In part 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 competive 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 next section of the report sets out the background for our examination of these needs for change in management and policy in this area. It outlines the dominant approaches to acquiring imported technology since the 1950s, and emphasises that, with a few notable exceptions, those approaches have been characterised by two basic features.

1) Technology imports were typically disconnected from significant innovative activity in the technology importing firms: they were usually not preceded by, accompanied by, or followed by substantial complementary research, development or engineering efforts.

2) 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.[3]

Some of the new understanding about technology, international transfer and industrial competitiveness that has become more widely accessible since the 1970s suggests that these aspects of Brazilian experience were neither inevitable nor

3 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.

similar to the experience of a few other industrialising economies that have exploited imported technology much more effectively. These issues are outlined in Section 3. Section 4 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 5 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. PAST PATTERNS OF TECHNOLOGY IMPORTS AND TECHNOLOGICAL DEVELOPMENT BY BRAZILIAN INDUSTRY

The aim of this section is to outline patterns and trends in Brazilian technology imports during and after the era of import substituting industrialisation. However, it sets this outline in the context of the broader technological behaviour of Brazilian firms. In particular, it suggests that, across most firms, imported technology has been used merely as the basis for achieving one-off steps of increased competitiveness by acquiring the designs and specifications for new products and/or the specifications, equipment and operating know-how for new processes. With a few exceptions, those imports of technology were not being incorporated into a significant process of technological development and change within Brazilian industry itself; nor were they being used to augment the importing firms' own technological capabilities for generating such paths of technological dynamism.

2.1. Technology Imports in the Import Substitution Era

Import substituting industrialisation increased the demand for foreign technology. Table 1, for instance, summarises the findings of research conducted in 1971 among 454 of the 500 largest manufacturing firms in Brazil. It shows that, particularly after 1945, these firms tended to rely increasingly on foreign technology at the time they were set up. Of the national firms which were installed between 1946 and 1955, 54.2 per cent needed foreign technology. This proportion grew to 62.9 per cent for those which started production between 1956 and 1965 and to 68.2 per cent for those created between 1965 and 1970. Foreign-owned firms, obviously, counted on foreign technology, but as Table 1 also shows this reliance grew as industrialisation deepened and more complex production methods were required.

TABLE 1
BRAZIL - ORIGIN OF TECHNOLOGY USED WHEN INDUSTRIAL FIRMS WERE INSTALLED (454 LARGEST FIRMS)

PERIOD OF INSTALLATION	NATIONAL FIRMS		FOREIGN FIRMS	
	Local Techn.	Foreign Techn.	Local Techn.	Foreign Techn.
Before 1930	53.1	46.9	16.2	83.8
1931-1945	63.7	36.3	21.2	78.8
1946-1955	45.8	54.2	13.3	86.7
1956-1965	37.1	62.9	10.4	89.6
1965-1970	31.8	68.2	_	100.0
Total	51.4	48.6	14.5	85.5

Source: Biato & Guimarães (1971).

TABLE 2
BRAZIL - TECHNOLOGY CONTRACTS BY THE INDUSTRIAL SECTOR 1962-1969

SECTOR	N°	%	SECTOR	N°	%
Metallurgy	308	18.50	Non-metallic Minerals	76	4.56
Mechanical	202	12.13	Pharmaceuticals	130	7.80
Chemicals	204	12.27	Textiles	108	6.48
Electric and Communic.	193	11.60	Paper and pulp	22	1.32
Car Industry	178	10.69	Wood	7	0.42
Plastics	35	2.10	Rubber	19	1.14
Leather goods	3	0.18	Furniture	7	0.42
Personal Appliances	25	1.50	Clothing & Shoes	18	1.08
Food Industry	32	1.92	Beverages	20	1.20

Tobacco	3	0.18	Editorial	6	0.36
Others	69	4.15			

Note: Total (1665) refer to the sum of the five categories (technical assistance, patents, trademarks, engineering services and projects) of the 1224 contracts of the transformation industry.
Source: Biato et al. (1973).

A detailed account of technology imports can only be made for the period since 1962 when Law 4131 (of 27/09/1962) was implemented. This attempted to regulate the entry of foreign capital into Brazil and introduced for the first time regulations regarding payment for transferred technology[4].

From 1962 to 1969, 1,224 contracts for technical assistance, patents and trade marks licences, engineering services and projects of manufacturing industries were registered at the Central Bank. Table 2 shows the sectoral distribution of contracts. The sectors responsible for the bulk of import substitution, such as metallurgy (18.50 per cent), chemicals (12.27 per cent), mechanical (12.13 per cent), electric materials and communications (11.60 per cent) and the car industry (10.69 per cent) were those which accounted for most of technology imports as represented by the contracts registered[5].

For the firms which registered contracts in INPI, there was no correlation between transfer of technology and internal efforts to develop innovative capabilities. The only available survey of the period points to a very inadequate situation. Of the above mentioned 454 largest firms, only 290 (64 per cent) reported any internal effort to develop technology following the acquisition of foreign technology. Even with these firms, the internal undertaking was very limited: no single firm informed of R&D leading to a new product or process. The bulk of technological activities was directed towards introducing small, less complex, modifications to existing products or processes (66.7 per cent). Prototype experiments came a distant second (16.9 per cent) and major adaptations and changes to existing products or processes in third place (16.4 per cent) (Biato & Guimarães, 1971).

---

4 The law stated that any contract which included payment for technologies acquired abroad should be registered at the Central Bank.

5 It is important to point out that registered contracts represent only a fraction of all imported technology since they refer only to technologies which were paid for. For instance, it may be that when a subsidiary of a MNC was installed technology would be introduced without external payment.

Low levels of internal R&D activities were accompanied by very weak linkages with government-owned industrial research institutes and universities, as documented by this and other studies which analyse the technological behaviour of firms in the early 1970s (Biato et al., 1973; Figueiredo, 1972; Erber et al., 1974). The general impression was that:

> "industrial entrepreneurs were 'satisfied' with a low level of local technological activities and a strong reliance on imported technology and such 'satisfaction' can be understood in the light of the pattern of development followed in Brazil since the mid-fifties - which reduced the importance of some of the reasons for a policy of more technological self-reliance" (Erber, 1980:422).

2.2. Technology Imports in the 1980s

Imports of technology 'embodied in capital goods fell at the beginning of the 1980s. They then steadily increased over the next decade to the point where they exceeded the level of the early 1980s (Table 3). This rising trend accompanied the overall reduction in domestic capital goods consumption (and production) over the decade: despite the temporary increase in both in the mid-1980s, by 1991/92 consumption and production of capital goods were only at about 60 per cent of their 1980/81 levels. The combination of these two trends resulted in the share of imports in total capital goods consumption doubling between 1980/81 and 1991/92 from around 8 per cent to 16 per cent.

In contrast, imports of 'disembodied' technology (referred to hereafter simply as 'technology') appear to have declined during the 1980s. If, for instance, these imports of technology are measured by payment for technology contracts registered at INPI, the reduction was from US$ 321 million in 1980 to US$ 174 million in 1987 (Table 4). This decline in absolute levels was also evident in relative terms - as earlier indicated in Figure 1, which shows payment for technology transfer contracts as a percentage of GDP for the 1966-1987 period. This ratio, which increased during the last phase of import substitution to more than 0.35 per cent in the mid-1970s, consistently decreased during the 1980s to 0.07 per cent in 1987.

TABLE 3
BRAZIL - CAPITAL GOODS - INTERNAL PRODUCTION, EXPORTS, IMPORTS AND CONSUMPTION
1975-1992

(1992 US$ Billion)

YEAR	INTERNAL PRODUCTION	EXPORTS	IMPORTS	CONSUMPTION (IP-X+M)
1975	15.71	0.33	1.65	17.03
1980	24.89	1.76	2.75	25.88
1981	22.19	1.81	3.20	23.58
1982	18.19	1.30	2.06	18.95
1983	14.90	1.24	1.25	14.91
1984	15.63	1.54	1.06	15.15
1985	18.40	1.74	1.17	17.83
1986	21.04	1.55	1.51	21.00
1987	21.59	1.77	2.02	21.84
1988	20.96	2.34	2.55	21.17
1989	20.10	2.44	1.99	19.65
1990	18.34	2.18	2.60	18.76
1991	15.19	2.08	2.47	15.58
1992	13.72	2.19	2.31	13.84

Source: ABIMAQ/SINDIMAQ.

TABLE 4
BRAZIL - TECHNOLOGY IMPORTS
1979-1988

(US$ Million)

YEAR	PATENTS & TRADEMARKS	LICENSED TECHNOLOGY	OTHERS	TOTAL (2+3)	TECHNICAL SERVICES	TOTAL
1979	9	6	11	17	287	313
1980	12	11	14	25	284	321
1981	12	18	12	30	234	276
1982	5	17	10	27	208	240
1983	12	10	14	24	182	218
1984	9	8	8	16	177	202
1985	5	21	41	62	108	175
1986	2	20	43	63	119	184
1987	3	39	26	65	106	174
1988	3	12	27	39	93	135

Total	72	206	162	368	1798	2238
(%)	3.2	9.2	7.2	16.4	80.4	100

Source: INPI.

It is instructive to compare this trend of falling 'dependence' on technology imports with the experience of South Korea. During the same period, as that country increased it international competitiveness in existing industries while also creating bases of competitiveness in **new** industries, its payments for foreign technology **increased** in absolute terms from US$ 150 million in 1983 to US$ 637 million in 1987 (KDB, 1988), and then to US$1.18 billion in 1991 (OECD, 1992). Also, as a proportion of GDP, those payments increased from 0.19 per cent in 1983 and 0.57 per cent in 1987 (Figure 1). In other words, rising industrial competitiveness was accompanied by an increase - not a reduction - in imported technology.

Even more striking, however, was the fact that this rapid growth in technology imports was linked to yet faster growth in domestic innovative activity - as reflected only imperfectly in data on domestic R&D expenditure. While payments for imported technology in 1982-86 were 13 times larger than in 1972-76, total domestic R&D expenditure was 33 times larger, and private R&D expenditure was nearly 70 times larger. Thus, as South Korea increased its competitiveness across a wide range of industry, the country's rapidly rising payments for imported technology constituted a **falling** proportion of total innovative effort. In short, South Korea (like Taiwan and Singapore)[6] was vigorously exploiting the international stock of technology within a much broader spectrum of even more intensive domestic efforts to strengthen the technological basis of its international competitiveness.

The contrast with Brazil is striking. Not only were technology imports steadily falling, they were not accompanied by any significant increase in R&D expenditure by local firms. A

6 See the companion paper for this project: Mike Hobday, The Development of Technological Innovation Capability in Developing Countries: Strategies of East Asian NICs for Catching up in Electronics, 1993.

detailed evaluation of technology expenditure by private firms using income tax forms (technology expenditure is subject to tax rebates) estimated that in 1976, the Brazilian manufacturing sector as a whole devoted only 0.1 per cent of sales to R&D (M. Cassiolato, 1981). Another survey carried out in the mid-1980s (FTI, 1986) concluded that in 1982 the technology expenditure of the Brazilian manufacturing sector represented only 0.15 per cent of operational revenues. This can be compared with equivalent figures of 1.5 per cent for the US (ten times larger) and 2.5 per cent for Japan (Ferraz, 1989).

Another assessment was a study carried out at CNPq which, based on a survey of 1,118 firms, suggested that in 1983, private firms' R&D expenditures accounted for only about ten per cent of the country's total R&D expenditure (Paulinyi, 1984). But that may overstate the relative importance of private sector R&D. The 1985 Brazilian industrial census introduced, for the first time, questions related to the technology behaviour of firms. Preliminary results show that, in 1985, only 1,288 firms (two per cent of firms included in the census) reported to have made R&D expenditure (Table 5). Also, according to the census, these firms spent US$ 311 million in R&D in 1985. Government-owned enterprises were responsible for 54.7 per cent of expenditure (US $ 170 million) and private firms for the remaining 46.3 per cent (US $ 141 million). The share of industrial R&D of total R&D was 17 per cent, with state enterprises accounting for 9.3 per cent and private firms for only 7.7 per cent.

These figures have not been very much disputed since the number of firms which are engaged in any type of formal R&D is very small. Table 6 shows the absolute and relative number of R&D active firms from the largest 3,869 firms in 1985. Of these, only 366 (9.5 per cent) are regarded as performing R&D in a systematic way. Not surprisingly, they are heavily concentrated in the most dynamic sectors of metal-mechanics, electronics and the chemical-petrochemicals complex. But even inside these sectors, apart from electronics, where 34.9 per cent of the largest firms performed R&D, the relative number of active R&D

firms was very small: 9.7 per cent of the metal mechanics firms and 16.6 per cent of the chemicals and petrochemicals firms.

TABLE 5
BRAZIL - R&D EXPENDITURES BY INDUSTRIAL SECTOR
1985

SECTOR	NE (1)	EARNINGS (2)	%	R&D (2)	%	R&D AVERAGE (3)	R&D INTENSITY (4)
Metallic minerals	32	3528	5.5	39.5	12.7	1.23	1.12
Non-ferrous metallurgy	23	768	1.2	39.3	12.6	1.71	5.12
Electronic equipment	92	1813	2.8	45.6	14.7	0.5	2.52
Auto industry	36	8181	12.7	45.0	14.5	1.25	0.55
Chemicals	23	3715	5.8	34.8	11.2	1.51	0.94
Oil refining & petrochem.	39	21310	33.0	38.2	12.3	0.98	0.18
Subtotal	245	39315	61.0	242.4	78.0	0.99	0.62
Others	1043	25208	39.0	68.5	22.0	0.07	0.27
Total	1288	64523	100	310.9	100	0.24	0.48

Notes: (1) Number of firms reporting spending on R&D.
(2) Amount in US$ Million.
(3) Average R&D expenditure by firm.
(4) R&D expenditures as a percentage of earnings.
Source: FIBGE, 1985 census, preliminary results, special tabulation.

TABLE 6
NUMBER OF R&D ACTIVE FIRMS IN BRAZIL AMONG THE 3 869 LARGEST MANUFACTURING FIRMS
1985

INDUSTRIAL SECTOR	N° OF R&D ACTIVE	TOTAL	% OF ACTIVE FIRMS
Metal-Mechanics	111	1 145	9.7
Electronics	90	258	34.9
Chemicals/Petrochemicals	102	635	16.1
Non-Metallic Minerals/Paper and Pulp	21	362	5.8
Others (Mostly Traditional Sectors)	42	1 469	2.9
Total	366	3 869	9.5

Source: Dahlman & Frischtak (1990).

External technical relations did not substitute for the low level of firms' own R&D. A study of CDE (the Council of Industrial Development of the Ministry of Industry and Trade), as described by Braga and Willmore (1990), may help to clarify this issue. Table 7 gives alternative sources of technology for a survey of the 4,324 largest industrial units. It shows that, for all types of technology considered - product design, tool design, product engineering, process engineering and layout - the main source of technology used was reported to be in-house development. This is so even if it is recalled that only a small portion of the sample acknowledged having any internal formal R&D activity. Brazilian R&D institutes made a very insignificant technological contribution (apart from project engineering where 13.1 per cent of firms relied on this source). Also, as a reflection of the above figures on payment for foreign technology, imported technology seems negligible.

TABLE 7

BRAZIL - ALTERNATIVE SOURCES OF TECHNOLOGY OF 4 324 LARGEST MANUFACTURING FIRMS SOURCE OF TECHNOLOGY

TYPE OF TECHNOLOGY	IN-HOUSE	BRAZILIAN SUPPLIERS	BRAZILIAN R&D INSTITUTES	IMPORTED
Product design	81.3	22.5	2.8	9.1
Tool design	65.4	32.1	5.6	7.2
Product engineering	86.4	9.8	4.3	5.2
Project engineering	75.2	17.5	13.1	5.9
Layout	82.3	11.4	9.6	4.0

Note: Multiple sourcing explains why total adds up to more than 100 per cent.
Source: Braga & Willmore (1990).

As for Brazilian suppliers, their contribution was not very significant. The only types of technology for which suppliers contributed are the design of tools (32.1 per cent of firms acknowledged that suppliers provided them) and of products (22.5 of firms received their product designs from suppliers). On the other end, only 9.8 per cent of the 4,324 largest manufacturing firms acknowledged that suppliers were an important source of technology for product engineering and only 17.5 per cent recognised that they contributed to project engineering. Also, customers were not considered as an important source of technical change. In the end, the use of external sources of technology seems at least precarious. This was confirmed by two studies made by FINEP (Carvalho et al., 1985; Façanha, 1988) which, through a survey conducted with all the firms which received financial support for their technology programs, concluded that independently of the sector, the use of external sources of technology was very limited.

In short, the steady reduction in technology imports during the 1980s was not an isolated phenomenon that was at odds with other aspects of the technological behaviour of Brazilian firms. Instead it was merely one facet of that broader pattern of behaviour: firms were acquiring limited technology from foreign sources, from other Brazilian firms, from domestic institutions and from their own innovative activities.

2.3. The Role of Government

As Brazil lacked a coherent industrial technology strategy during the import substitution phase, policy towards technology imports was essentially 'defensive' and 'negative'. It concentrated on legal regulation - attempting to regulate conditions associated with contracts for technology transfer. INPI was created in 1971 at the Ministry of Industry and Trade with the aim of registering and evaluating these contracts. Its role was mainly concerned with controlling the financial payments for technology (part of the so-called 'costs' of technology) and legal aspects (for example, examining the restrictive clauses in licensing agreements).

Apart from very general conditions imposed on licensees (such as the need for them to invest in R&D or to engage in joint work with industrial R&D institutes) which were generally never fulfilled, there seems to have been little or no direct support for training, learning or R&D in association with the acquisition of imported designs, specifications, equipment and operating know-how. The ADTEN programme of FINEP (which was under the Ministry of Planning) apparently did include a sub-item to finance technology licensing, but this appears to have been of minor significance - probably reflecting the generally 'passive' nature of the broader technological behaviour of firms. Also the RHAE Programme provided support for overseas training of personnel from firms, but this does not seem to have been directly linked to broader technology acquisition projects and programmes of firms and was not very substantial (and limited to the few selected 'high tech' areas). Apart from these limited programmes, no other aspects of explicit policy, except for those affecting segments of the informatics industry, were ever directed systematically towards strengthening the role of local technological development either as a substitute for, or a complement to, the country's imports of industrial technology.

Other aspects of government support for industrial R&D did not help very much. Most of the government's support to R&D in the late 1960s consisted of building up an R&D infrastructure. Continuation of this approach achieved considerable success during the 1970s: as shown in Table 8, the share of R&D as a proportion of GDP was estimated to be 0.24 per cent in 1970 and it more than doubled to 0.58 in 1980 (approximately US$ 958 million)[7]. However, crisis conditions during the 1980s resulted in a collapse of government expenditure on the R&D infrastructure, and long term finance for R&D deteriorated. As a consequence, overall R&D expenditure as a proportion of GDP

7 In 1980 according to the Central Bank of Brazil, GDP was US$ 165.26 billion (Central Bank of Brazil, 1989 annual report.

stagnated throughout the 1980s. Table 8, for instance, provides two alternative hypotheses for the behaviour of this indicator throughout the 1982-1987 period[8]. Both alternatives converge around the stagnating trend throughout the period. If the pattern of the 1970s is compared with the corresponding patterns of the 1980s, the change in pace is notable.

TABLE 8

BRAZIL - TOTAL R&D EXPENDITURES OVER GDP

1970-1987

YEAR	R&D/GDP (1)	YEAR	R&D/GDP (2)	R&D/GDP (3)
1970	0.24	1982	0.80	0.66
1971	0.24	1984	0.62	0.51
1975	0.51	1985	0.74	0.63
1980	0.58	1986	0.80	0.66
1981	0.58 (4)	1987	0.90	0.66

Notes:
(1) Cassiolato (1981). Based on CNPq's statistics.
(2) MCT (1988). CNPq's statistics. Include expenditures by federal and regional governments and an estimate of expenditures by private sector of 20 per cent of total expenditures, based on a survey made in 1983.
(3) Dahlman & Frischtak (1990).
(4) After a change of methodology CNPq revised the 1981 figure to 0.7 per cent of GDP. A most debatable inclusion in S&T expenditures, after those methodological alterations, are current expenses of several federal agencies not dealing directly with science and technology.

Regardless of which estimate one considers, Brazil fares very badly in international comparisons for the 1980s. Table 9 presents estimates of gross expenditure on research and development (GERD) as a proportion of GDP in 1985 for some OECD and developing economies. It is notable that estimates for all countries are substantially higher than Brazil's even if we choose the most optimistic estimate of CNPq. For the OECD economies, they range from 2.20 per cent (U.K.) to 3.20 per cent

8 The first consists of official CNPq (the Brazilian National S&T Council) statistics which include actual expenditure by federal agencies and estimates of expenditure by regional agencies, state governments and the private sector. they tend to overestimate the total expenditure since they include, after 1981, the current expenses of several federal agencies which could hardly be considered S&T commitments. The other alternative also relies on CNPq's statistics but in a more precise way (Dahlman & Frischtak, 1990).

(West Germany) and for the other developing countries they range from 0.90 (India) to 1.78 per cent (South Korea), all substantially above CNPq's hypothesis regarding the Brazilian GERD (0.74 per cent of GDP).

But perhaps more significant than the aggregate level of R&D expenditure is the fact that the government has been responsible for most R&D expenditure, and a very large part of that expenditure has been used to execute R&D in government institutions. This pattern is very different from that in other countries. For example, Table 9 summarises the share of the private sector and government in total R&D expenditure in 1985 for some selected OECD and developing countries. In the most advanced OECD economies, the private sector was responsible for at least 40 per cent of total expenditure and in some countries, such as West Germany and Japan the private sector contributed more than 60 per cent. As far as some of the largest developing countries are concerned, the private sector was responsible for 68 per cent of total R&D expenditure in South Korea in 1983/84, 54.3 per cent in Taiwan in 1982/83 and 23 per cent in India in 1982/83. In contrast, the Brazilian private sector was responsible for only 7.7 per cent of total expenditure in 1985 when the only comprehensive evaluation of private sector R&D expenditures was compiled by the industrial census (Vaitsos, 1990).

TABLE 9

TOTAL R&D AS A PERCENTAGE OF GDP/GNP AND SHARE OF PRIVATE SECTOR AND GOVERNMENT R&D EXPENDITURES ON TOTAL R&D EXPENDITURES OF SELECTED COUNTRIES

1985

COUNTRIES	R&D/GNP	PRIVATE (%)	GOVERN. (%)	OTHERS (%)
U.S.	2.94	48.4	49.8	1.8
Japan	2.11	74.0	19.1	6.9
United Kingdom	2.20	44.6	43.4	10.5
France	2.97	41.4	53.0	5.6
West Germany	3.20	60.9	37.6	1.5
Brazil	0.74	7.7	92.3	_
India (82/83)	0.90	23.0	NA	NA
South Korea (83/84)	1.78	68.0	NA	NA
Taiwan (82/83)	1.20	54.3	NA	NA

Sources: R&D/GDP - UNESCO (1987).
Other data - OECD (1987) for OECD countries, CNPq (1986) for Brazil, CSIR (1986) for India, Rushing & Brown (1986) for South Korea and Taiwan.

Alongside this pattern of limited investment in R&D, and in contrast to Japan for example (see Section 3.6), little effort was made to regulate the entry by firms into particular areas of technology in order to ensure that the structure of particular industries was aligned with objectives about incorporating technology imports into longer term trajectories of technological dynamism. Indeed, the approach seems to have been simply (i) to maximise the number of entrants in order to achieve 'competition', rather than (ii) to regulate the structure in order to create the basis for technologically active forms of competition. So, policy on industrial entry has fragmented industries between large numbers of firms which, apart from being permanently protected from international competition, have been too small to develop any significant technological dynamism of their own. Also, although the huge Brazilian market endowed firms with substantial bargaining power vis-a-vis foreign technology suppliers (over what they will supply and how they will contribute to local technological capabilities), the policy of permitting (and usually encouraging) fragmented entry into new industries simply frittered away that advantage.

2.4. The Overall Pattern

To summarise then, across the majority of technology importing Brazilian firms and over four decades from the 1950s to the 1980s, the acquisition of foreign technology was not part of a broader process of technologically dynamic industrial development. Instead, industrial firms - usually technologically insulated from others and from the wide range of technological institutions - acquired foreign technology to achieve one-off steps in changing their products and processes.

One implication of this pattern has been the limited intensity of technical change in industry. As is well known from numerous studies of 'technological learning' during the 1970s, there was often some degree of adaptation of technology and significant mastery of its basic operation (for example, Katz, 1984 and 1987, and Teitel, 1981 and 1984). There might also be some elements of 'learning-based' further improvement and development of the imported technology - although some detailed studies suggest that even that type of active improvement and dynamic assimilation of acquired technology might often be very limited - for example, the technologically 'passive' adoption of digital process control technology by firms in the petrochemical industry during the 1980s (Carvalho, 1992). More generally, it seems clear that the assimilation of imported technology seldom amounted to a trajectory of persisting improvement and development that matched, let alone surpassed, the rates needed to sustain international competitiveness. These 'ex-post' patterns of limited dynamism in assimilating what had been imported were typically associated with only limited 'ex-ante' efforts to create the technological capabilities required for effectively exploiting international sources of technology in the first place. And, as firms' ex-post phases of limited assimilation of imported technology became the ex-ante phases of their subsequent technology imports, the trajectories persisted over long periods.

It is not surprising, therefore, that it is now widely agreed that poor technological performance is at the core of most of Brazilian industry's weak competitive position. Firms' limited capacities to innovate have been identified as central elements in most recent diagnoses - either from external sources (Dahlman & Frischtak, 1990) or from extensive internal studies of industry and technology (Coutinho & Suzigan, 1991).

It would obviously be misleading to suggest that the general pattern outlined above has been totally uniform across all firms and all times. It is quite clear that some firms have drawn intensively on foreign technology to enhance their own technological capabilities, and they have linked that to the development of trajectories of rapid technical change and rising competitiveness - for instance USIMINAS (Dahlman & Fonseca, 1987). Others have taken aggressive and strategic approaches to their management of major projects for the acquisition of foreign technology. They have invested ex-ante in their own engineering and research capabilities, and then used those as the basis for searching out, acquiring and absorbing much greater 'depths' of technology and expertise than just the basic elements needed to implement a one-off step - for instance, PETROQUISA during the investment project for the COPESUL ethylene complex (Sercovich, 1980). Others have taken even more aggressive and strategic approaches. Seeking to link foreign technology directly into their own intensive product development and design activities, they have set out not merely to acquire and accumulate technology **from** foreign sources, but to do so **in** the immediate context of technological development at the international frontier - for instance, Metal Leve's establishment of an R&D centre in Michigan to support its technological competitiveness in the automobile component industry. Unfortunately, such exceptions to the general pattern are just that - fairly rare exceptions. Nevertheless, they illustrate possibilities and potentials that might be much more widely exploited.

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

The approaches to management and policy outlined in the previous section 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 respects.

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 infrastructural 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.

As indicated in the previous section, 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. As reflected in the focus of the Brazilian study to which this paper is a contribution, 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 of the report 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.

a) 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.

b) 'Adopters' and 'Users' of technology play active and creative, not passive, roles in generating these trajectories of competitive technological dynamism.

c) The resource base needed to play those change-generating technological roles includes (i) interacting structures of firms, not just individual firms acting in technological isolation, and (ii) a very wide range of engineering and other capabilities, not just R&D capabilities.

d) Industrial firms play important roles as creators and diffusers, not just employers, of the human resource components of those wide-ranging technological capabilities.

e) Technology imports and local innovative capabilities are complements, not alternatives, in the process of technical change.

f) 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.

3.1. 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.

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.[9] 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

9 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".

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.

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 & Isensen, 1967; Myers & 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.[10]

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

10 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.

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 & 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 & Stiglitz, 1969; Nelson & 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.

3.2. 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 & 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.[11] 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.[12]

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.[13] 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:

---

11 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.

12 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.

13 Debate about whether continuous paths of 'incremental' innovation are more or less important than more 'radical' innovative steps are about as useful as debates about angels on pin-heads. Both components of the technical change process are a necessary basis for achieving and sustaining competitiveness.

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.

3.3. 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, 1990a). 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 & Reijnen, 1992; Hagedoorn & Schakenraad, 1992)[14]. 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

14 For a full elaboration on this point see Helena Lastres' companion paper for the Estudo da Competitividade da Indústria Brasileira.

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 bilateral 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.

3.4. 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.

1) 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.

2) 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.

3.5. 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 & Vidvei, 1992; 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 & 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.

1) 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 & Oldham, 1988).

2) 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 & Goto, 1992). Similarly, in the post-war period, the high levels 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).

3) 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).

4) 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.

3.6. 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 & 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.

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 & Westphal, 1986). However, such patterns of trade protection were usually accompanied by other measures to stimulate the accumulation of significant technological capabilities.

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 infrastructural institutions to act as substitutes for the innovative activities of firms themselves (Foray, 1993; Foray & 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 & Gambardella, 1990; Bell & Oldham, 1988; Kleinknecht & 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 infrastructural 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.

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,[15] 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.

15 In principle, this role was very similar to that played by PETROQUISA during the COPESUL project when it not only organised the acquisition of its own process engineering expertise, but also mobilised similar accumulation by selected engineering and equipment firms.

> "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 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.

4. 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 4.1, 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 **after** they have got it. The second, examined in Section 4.2, 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 **before** 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.

The Integration of International Trade and Technology Policies

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.

Changing International Structures of Production and Competition

Brazilian industry is 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:

a) intensive efforts to achieve continuing increases in productivity and all aspects of process efficiency in existing lines of production;

b) intensive efforts to raise product quality and move 'upwards to higher value-added products in the existing industries;

c) 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.

4.1. 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.

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.

1) 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.

2) 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.

3) 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 differentiations. 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 also 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 **whole structure of technology** 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.

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 & 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,[16] 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

16 As he 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.

contribute to the development of innovations that improve the efficiency of the technologies in the specific local context of their use (von Hippel, 1988)[17]. 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

17 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).

permit more intensive analysis of changes in the 'organisational technology' of firms.

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.

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 electronics/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 (1983, 1985, 1986 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.[18]

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

18 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).

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.[19] 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.

---

19 For a related critique of such perspectives, see Walsh (1988).

The Knowledge-Intensity of Industrial Production

The rising change-intensity of industrial production is being accompanied by its rapidly growing knowledge-intensity. Indeed, a fundamental transformation seems to be taking place in the relative significance of investment in knowledge and investment in fixed capital. In an ever widening range of sectors in the developed countries, leading firms' annual expenditures on R&D are now often larger than their investments in fixed capital (for Japan, see Kodama, 1991). This requires a fundamental change in the perspectives of those who are accustomed to see fixed capital investment as the engine of economic growth. For a widening range of industries, we need to turn that upside-down and recognise that, at the international technological frontier, investment in new knowledge assets is coming to exceed investment in physical assets as a major source of competitiveness. The implications for industrialising countries like Brazil are not wholly clear: it is unlikely that, over the next decade, many firms will face the need to sustain their competitiveness by investing more in R&D than in fixed capital, but it is almost certain that many will have to invest many times more than they have in the past.

One must also bear in mind the point made earlier about R&D resources being only part of the total set of capabilities needed to generate technical change in industry. Although systematic data are lacking, it is almost certain that the importance of a wide spectrum of engineering skills is also increasing in response to various aspects of the rising change-intensity of production - a trend that may be reinforced by increasingly localised innovative activity drawing on larger elements of knowledge that are less standardised and more tacit. Finally, one must also note an aspect of the experience of western companies that have sought to learn from Japanese industry and generate more intensive processes of "continuous improvement" ("kaizen"). As noted earlier, those paths of change draw heavily on the skills and knowledge of direct production workers. But it has become evident that those workers cannot play a significant change-generating role on the basis of the same stock of skills and knowledge they used for more routine operational tasks, and substantial investment in training is required to mobilise those latent resources.

Across a wide spectrum of capabilities, therefore, many firms in the advanced industrial countries have greatly increased their training and related expenditure to raise the levels of skill and knowledge they have available for generating and managing change, and they have often developed novel institutional mechanisms for doing so.[20] A Particularly striking example is the case of Motorola which, seeking to raise quality and production flexibility while intensifying technical change, raised training and education expenditure from $7 million to $60 million per year and developed its own corporate university (Wiggenhorn, 1990).

Government policy in the advanced industrial countries has matched these shifts towards increased investment in knowledge and skill at the firm level. For example, the European Community is pursuing a strategy of promoting R&D co-operation, complemented with policies to stimulate competition (Moore & Harris, 1992). At the national level, there has been real growth in government R&D budgets in most OECD countries over recent years, and in many of them this has been coupled with other measures to stimulate firms' investment in R&D and other intangible assets. The OECD data base on public support to industry (OECD, 1992) has identified 159 such programmes among its member countries. Information about the 'Net Cost to Government' was available for 144 of these, and the total amounted to about US$ 6.1 billion in the most recent year, with direct grants accounting for 50 per cent and tax incentives for 40 per cent. The OECD analysis suggests that these trends are part of a shift in the general structure of government policies for industrial support. The most striking aspect of this is a

---

20 Eurich and Boyer (1985), for example, provide a review of this increased role for "Corporate Classrooms", and Fortune (3 June 1991) reviews "How Intellectual Capital Is Becoming Corporate America's Most Valuable Asset".

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.

4.2. Access to International Technology: New Patterns and Conditions

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:

a) 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.

b) 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).

c) 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 & Soete, 1990).

d) 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 modicum 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, 1992:152-153); 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:

a) 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)

b) 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)

c) 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.

d) 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.

1) 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?

2) 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)[21] suggests that, while the former has been much discussed, the latter has frequently been the focus for practical action.

3) 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).

4) 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

21 The companion paper by Mike Hobday (The Development of Technological Innovation Capability in Developing Countries: Strategies of East Asian NICs for Catching up in Electronics) discusses these arrangements for Original Equipment Manufacture (OEM) and Original Design and Manufacture (ODM).

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:

a) the characteristics of the technologies involved;
b) the characteristics of the supplier firms and their industries;
c) the technological capabilities of would-be technology importers, together with other elements of the bargaining power they can draw on;
d) 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.

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:

1) 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 & Park, 1988), but it is illustrated by Brazilian experience as well - for example in the PETROQUISA/COPESUL case noted earlier (Sercovich, 1980).

2) 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.

3) 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.

4) 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, Dahlman and Westphal (1991) note that Korean firms increased their own R&D in order to be able to negotiate better for foreign technology - as in the case of VCR technology:

> "Korean firms were having trouble licensing video cassette recorder (VCR) technology from Japan.

> Therefore some firms undertook their own R&D effort in conjunctyion with a government laboratory to develop their own VCR technology around the patents held by the Japanese. Faced with this credible threat, the Japanese firms agreed to license the technology to Korean firms".

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., 1992:293-294).

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.

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:

1) 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.

2) 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.

3) Firms (or groups of firms) may set up technology acquiring-cum-developing organisations in 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.

4) 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.

5) 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 - probably in that order!

5. CONCLUSIONS: NEW APPROACHES TO MANAGEMENT AND POLICY

Two basic orientations underlie our 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. 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). We focus only on the second of these strategies.[22]

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. We focus only on the second of those strategies.

22 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. We presume that, 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.

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:

1) 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.

2) 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, two points should be noted about the conclusions that can be drawn in these areas in a paper like this.

1) Societies obviously differ. They have different economic structures and social characteristics, posing requirements for different approaches to policy and management. In addition, they have different political systems and underlying structures of power that fundamentally influence the patterns of what is feasible by way of policy, and even management. Thus, while much can be learned from international trends and the experience of other countries, this is limited to understanding of broad approaches and principles. The development of practical details must be rooted in local specificities and processes.

2) Issues concerned with the acquisition of imported technology cannot be treated as isolated areas of "Technology Transfer Policy" or "technology Acquisition Management". Precisely because of the importance of incorporating technology imports into localised trajectories of technological dynamism, policy and management in this area must be parts of wider areas of action concerned with technology, industrial efficiency and the longer run evolution of firms and industries. At the same time, they must reflect the specificities of particular firms, industries and markets.

We can therefore highlight here only a few key directions for management and policy in this area, leaving the details to be elaborated in the light of insights from other components of the overall study of industrial competitiveness.

5.1. Approaches to Management

Table 10 outlines a simple framework covering the key areas that may be involved in managing strategically the acquisition of foreign technology. The table first distinguishes between three time periods:

Before the Acquisition of Technology. Management in this period is concerned with creating, enhancing and 'assembling' the technological and organisational capabilities needed to define in adequate detail the technology required, to locate its possible sources, to gain access to it, to minimise its financial and other costs, and to acquire and absorb the 'depth' and 'breadth' of knowledge and expertise sought.

During the Acquisition of Technology, management is concerned with effectively using the organisational and technological resources and bargaining power created and assembled in the previous period. In part this would focus on relatively short-term objectives such as negotiating over price and other terms, and implementing the immediate technical changes based on the imported technology. In part also, management in this period should frequently focus on using the previously accumulated resources to achieve strategic, longer-term objectives: using the access to foreign sources of technology to implement explicit training and learning activities designed to enhance the firm's capabilities for changing and developing the technology in future.

After the Acquisition of Technology. Management in this period focuses on the dynamic assimilation of what had been acquired - not just on using the technology, but on further improving and developing it. However, as noted earlier, within continuing trajectories of technological dynamism, the period after one technology acquisition project is likely to blend into the period before another. Managing the dynamic assimilation of what was acquired in one period therefore blends into managing the further strengthening of technological and organisational capabilities that will be needed for future technology acquisition.

TABLE 10
A FRAMEWORK FOR STRATEGIC MANAGEMENT OF THE ACQUISITION OF FOREIGN TECHNOLOGY

	TIME PERIODS FOR MANAGEMENT ACTION		
AREAS OF MANAGEMENT ACTION	BEFORE Technology Acquisition	DURING Technology Acquisition	AFTER Technology Acquisition
CREATING INTRA-FIRM ORGANISATIONAL STRUCTURES			
CREATING INTER-FIRM (AND INSTITUTION) ORGANISATIONAL STRUCTURES			
INVESTMENT IN KNOWLEDGE AND EXPERTISE			
INVESTMENT IN IMPLEMENTING TECHNICAL CHANGE			

Table 10 also distinguishes between four broad areas for management attention during each time period:

Creating Intra-Firm Organisational Structures. This involves developing the project teams that will play the core roles during all three phases of technology acquisition. It is likely to require the 'assembly' of multi-functional and multi-disciplinary teams and, as noted below, it may require substantial strengthening of the existing knowledge and skill resources of those teams.

Creating Inter-Firm Organisational Structures. In many cases, the transfer of technology may be simply between two individual firms. However, the effectiveness of acquisition may depend on technology importing firms linking themselves into wider networks of organisations that will collaborate in at least some phases of technology acquisition projects. As noted earlier, these networks may consist not only of domestic firms (complementary or pre-competitive), they may also consist of firms in other countries - either in other industrialising countries, or in the advanced industrial countries. They may also involve some form of collaboration with domestic (or perhaps foreign) technological institutions.

Investment in Knowledge and Expertise. This will often be the most important area for management attention. Bearing in mind that the value of the technology one gets out of an international transfer project seems to depend heavily on what one brings into it, an important part of this investment in knowledge and skill may take place in advance of projects. This can involve a range of activities: for example, training, research and development that may focus more on the acquisition of existing knowledge than on creating new knowledge, reverse engineering, acquisition of information about sources of technology and their strategic positions of those foreign firms, and the organised acquisition of relevant experience. Important components of these kinds of activity may take place during projects - explicit components that focus on developing the knowledge bases needed for subsequent change and improvement, not just for introducing, marginally adapting and using the 'given' elements of transferred technology. Subsequently, further investment in accumulating knowledge by R&D or by other forms of learning and training will often be a necessary basis for generating paths of continuing technical change.

Investment in Implementing Technical Change. This is obviously a central focus for management during the technology acquisition project itself, and we have emphasised that it must continue as a central focus for management after the project. However, it may also be an important area for action before the project. For example, the credibility and 'weight' of the bargaining power created by prior R&D may have to be enhanced further by continuing through to the implementation of at least small scale or prototype production - an activity that may itself be an important source of technological learning needed for effective acquisition and assimilation of the foreign technology.

Our brief review of the past patterns of importing technology transfer in Brazil (Section 2) suggested that a few firms had approached the management of technology acquisition in ways that incorporated several of these strategic elements. However, the dominant approaches seem to have incorporated few of them, and many cases appear to have incorporated none - concentrating only on the immediate short-term tasks. In effect, the 'typical' past approaches to management have concentrated on little more than one column of Table 10 ("During Technology Acquisition") and one row ("Investment in technical Change") - i.e. on not much more than one of the twelve possible 'cells' of management action.

The competitiveness of Brazilian industry in the 1990s will depend on many factors (many of them having little connection with technology), but among those must be included widespread and radical change in these past approaches to managing the acquisition of imported technology.

5.2. Approaches to Policy

As emphasised earlier, policy in this area must obviously be part of a wider policy regime concerned more broadly with technology and other aspects of competitiveness. Within that, however, the importance of a few broad orientations can be emphasised here.

First, the focus of policy in this area must concentrate on the industrial firm - not to the exclusion of action concerned with a wide range of technological institutions, but in recognition of firms as the necessary driving force of industrial technological dynamism and as the core agents in acquiring and absorbing foreign technology.

Second, we have emphasised that key elements of the strategic management of technology acquisition involve **investment** by firms in their own resources as complements to their expenditures on foreign technology. Clearly this requires an adequately stable macro-economic environment within which firms will undertake any significant investment in assets that yield their returns over the relatively long term future.

Third, its is clear that competitive pressure plays an important role in stimulating firms to change the technology they use, and hence to invest in the resources of foreign technology and domestic technological capabilities required to do so. Other things being equal, therefore, policies that enhance those competitive pressures are likely to increase, and increase the effectiveness of, the acquisition of foreign technology.

Fourth, however, much of Brazilian industry appears to have limited technological capabilities to respond to such competitive pressures; and, just as important, it has limited experience of investing in the accumulation of those resources. Moreover, much of that investment involves investment in knowledge and human capital where markets operate very imperfectly. There are therefore strong grounds for government intervention that stimulates investment in such assets.

In particular, one must recognise the limitations of financial institutions in this area. Most of them are accustomed to financing investment in fixed, physical assets which themselves provide significant security for the finance. Some more specialised institutions are also accustomed to financing innovative technical change projects for which the potential returns are reasonably evident, even if somewhat uncertain. However, much more risky and uncertain for such institutions, as for firms themselves, in investment in knowledge and human capital. Yet these are the kinds of assets that have become increasingly important for dynamic competitiveness in increasingly change-intensive and knowledge-intensive industrial production in the 1990s. This appears to be reflected in the shifting patterns of public policy that focus increasingly on stimulating and subsidising investment in knowledge assets in the industrially advanced countries. In an economy where investment in these assets has not become a significant component of industrial behaviour and 'culture, such policy intervention is even more important. In particular, innovative new measures may be needed to link government intervention to the operations of industrial financial institutions.

Fifth, as indicated in Table 10 above, important elements in the strategic management of technology acquisition involve the development of institutional linkages and networks. This suggests that other types of government intervention may be important - types of intervention that involve governments playing a catalytic role in facilitating collaboration in a wide spectrum of technological activities. Action to stimulate such technological partnerships may be particularly important in linking users and producers of technology, especially in the areas of industrial automation and other types of information technology - areas where governments in many of the industrialised countries play a substantial role.

Finally, in ways illustrated in the experience of Japan, government policy may have an important role in shaping the structure of markets to create conditions that enhance the competitive pressures on firms in ways that stimulate, rather than constrain, investment in technological capabilities as a complement to imported technology. In particular, output in several important industries appears to be fragmented between firms that are too small to build up the scale of technological capabilities needed to generate the dynamism required for sustained competitiveness. This problem seems important in a wider range of industries than just those where 'privatisation' is likely. However, the existing plans to restructure the ownership of enterprises may provide especially opportune occasions also to overcome these other deficiencies in industrial structure that have been inherited from the past.

BIBLIOGRAPHY

ALLEN, D. (1988) New Telecommunications Services: Network Externalities and Critical Mass. *Telecommunications Policy*, sept., p. 257-271.

ANTONELLI, C. (1986) The International Diffusion of New Information Technologies. *Research Policy*, 3:139-147.

ANTONELLI, C. (1991) *The Diffusion of Advanced Telecommunications in Developing Countries*. Paris, Development Centre, OECD.

ANTONELLI, C. (1992) *Technology Transfer Revisited*. Report written for the FAST Programme Research Project: Global Perspectives 2010 - Tasks for Science and Technology. Turin.

ATKINSON, A.B. & STIGLITZ, J.E. (1969) A New View of Technological Change. *Economic Journal*, v. LXXIX, sept.

ARORA, A. & GAMBARDELLA, A. (1990) Complementarity and External Linkages: The Strategies of the Large Firms in Biotechnology. *Journal of Industrial Economics*, v. XXXVIII, p. 361-379.

BELL, M. (1984) Learning and the Accumulation of Technological Capacity in Developing Countries. In: FRANSMAN, M. & KING, K. (eds) *Technological Capability in the Third World*. London, Macmillan.

BELL, R.M. & OLDHAM, C.H.G. (1988) *Oil Companies and the Implementation of Technical Change in Offshore Operations: Experience in Development Drilling and the Design and Operation of Production Facilities in the North Sea*. Report n. 2, Study of Technology Transfer to China's Offshore Oil Industry. Brighton, Science Policy Research Unit, University of Sussex.

BELL, R.M. & PAVITT, K. (1992) *National Capacities for Technological Accumulation*. Paper presented at the World Bank Conference on Development Economics. Washington.

BELL, R.M. & PAVITT, K. (1993) Technological Accumulation and Industrial Growth: Contrasts between Developed and developing Countries. *Industrial and Corporate Change* (forthcoming).

BELL, R.M. & SCOTT-KEMMIS, D. (1990) *The Mythology of Learning-by-Doing in World War II Airframe and Ship Production*. Science Policy Research Unit, University of Sussex.

BELL, R.M.; SCOTT-KEMMIS, D. & SATYARAKWIT, W. (1982) Limited Learning in Infant Industries. In: STEWART, F. & JAMES, J. (eds) *The Economics of New Technologies in Developing Countries*. London, Frances Pinter.

BESSANT, J. & HAYWOOD, B. (1986) The Introduction of Flexible Manufacturing Systems as an Example of Computer Integrated Manufacturing. *Operations Management Review*, spring.

BIATO, F.; GUIMARÃES, E. & FIGUEIREDO, M. (1973) A Transferência de Tecnologia no Brasil. *IPEA/IPLAN (Estudos para o Planejamento*, 4).

BIATO, F. & GUIMARÃES, E. (1971) *Algunos Aspectos de la Produccion y Transferencia de Tecnologia en el Brasil*. Washington, Organisation of the American States - OAS.

BRAGA, H. & WILLMORE, L. (1990) As Importações e o Esforço Tecnológico: uma Análise de seus Determinantes em Empresas Brasileiras. *Revista Brasileira de Economia*, 44(2):131-155.

BUSINESS WEEK (1992) How Japan is Keeping the Tigers in a Cage, may 11, p. 24-26.

CAINARCA, G.C.; COLOMBO, M.G. & MARIOTTI, S. (1992) Agreements Between Firms and the Technological Life Cycle Model: Evidence from Information Technologies. *Research Policy*, 21:45-62.

CARDOSO, A. (1988) *A Implantação de Leis e Regulamentos sobre Transferência de Tecnologia: a Experiência do Brasil*. Rio de Janeiro, mimeo.

CARVALHO, F.; ORTEGA, J. & FAÇANHA, L. (1985) *O Apoio ao Desenvolvimento Científico e Tecnológico: Atuação da FINEP*. Rio de Janeiro, FINEP.

CARVALHO, R.Q. (1992) Why the Market Reserve is not Enough: The Diffusion of Industrial Automation Technology in Brazilian Process Industries. In: SCHMITZ, H. & CASSIOLATO, J. *HI-Tech for Industrial Development: Lessons from the Brazilian Experience in Electronics and Automation*. Routledge.

CASSIOLATO, J. (1980) *Notas sobre Tecnologia na Indústria de Equipamentos para a Produção de Açúcar e Álcool*. Paper presented at the V Annual Meeting of ANPEC. Nova Friburgo.

CASSIOLATO, J.; HEWITT, T. & SCHMITZ, H. (1992) Learning in Industry and Government. In: SCHMITZ, H. & CASSIOLATO, J. *Hi-Tech for Industrial Development: Lessons from the Brazilian Experience in Electronics and Automation*.

Routledge, London and New York.

CASSIOLATO, M. (1981) *Gastos com Tecnologia no Setor Industrial*, Rio de Janeiro, Institute of Industrial Economics, Federal University of Rio de Janeiro, mimeo.

CHESNAIS, F. (1988) Technical Co-operation Agreements Between Firms. *STI Review*, 4. Paris, OECD.

CHESNAIS, F. (1990) *Present International Patterns of Foreign Direct Investment: Underlying Causes and Some Policy Implications for Brazil*. Paper prepared for the seminar "The International Standing of Brazil in the 1990s". Campinas, Centre for the Study of International Economic Relations, University of Campinas.

COHEN, W. & LEVINTHAL, D. (1989) Innovation and Learning: the Two Faces of R&D. *Economic Journal,* 99:569-596.

CNPq (1988) *Estatísticas de Ciência e Tecnologia no Brasil: Panorama Comentado*. Brasília, Conselho Nacional de Desenvolvimento Cientifico e Tecnológico.

COUTINHO, L. & SUZIGAN, W. (1991) *Desenvolvimento Tecnológico da Indústria e a Constituição de um Sistema Nacional de Inovação no Brasil*. Campinas, Instituto de Economia, Universidade Estadual de Campinas.

CSIR (1986) *Status Report on Science and Technology in India.* New Delhi, Council on Scientific and Industrial Research - CSIR.

DAHLMAN, C. & FONSECA, F. (1987) From Technological Dependence to Technological Development: The Case of the USIMINAS Steel Plant in Brazil. In: KATZ, J. (ed) *Technology Generation in Latin American Manufacturing Industries*. London, Macmillan Press.

DAHLMAN, C. & FRISCHTAK, C. (1990) *National Systems Supporting Technical Advance in Industry: the Brazilian Experience*. The World Bank (Industry Series Paper, 32).

DAHLMAND, C. & NELSON, R. (1991) *Social Absorption Capability, National Innovation Systems and Economic Development*. Paper prepared for the Korea Development Institute's Twentieth Anniversary Symposium, jul. 1-2.

DAVID, P. (1990) The Dynamo and the Computer: an Historical Perspective on the Modern Productivity Paradox. *AEA Papers and Proceedings*, 80(2):355-361.

DAVID, P. (1992) *Computer and the Dynamo; the Unclear Productivity Paradox in a Not Too Distant Mirror*. Paper presented at the OECD Seminar on Science, Technology and Economic Growth. Paris.

DEIACO, E. (1992) New Views on Innovative Activity and technological performance: The Swedish Innovation Survey. *STI Review*, (11), dec. Paris, Organisation for Economic Co-operation and Development.

DE MELTO, D.; McMULLEN, K. & WILLS, R. (1980) *Innovation and Technological Change in Five Canadian Industries*. Ottawa, Economic Council of Canada (Discussion Paper, 176).

DORE, R. (1989) Latecomers Problems. *The European Journal of Development Research*, 1(1).

DOSI, G. (1988) The Nature of the Innovative Process. In: DOSI, G. et al. (eds) *Technical Change and Economic Theory*. London, Pinter Publishers.

DOSI, G. & FREEMAN, C. (1992) *The Diversity of Development Patterns: On the Process of Catching up, Forging Ahead and Falling Behind.* Paper presented at the International Economics Association meeting. Verona.

DOSI, G.; PAVITT, K. & SOETE, L. (1990) *The Economics of Technical Change and International Trade.* Hemel Hempstead, Harvester Wheatsheaf.

ENOS, J. (1962) Invention and Innovation in the Petroleum Refining Industry. In: NATIONAL BUREAU OF ECONOMIC RESEARCH. *The Rate and Direction of Inventive Activity.* Princeton University Press.

ENOS, J. & WOO-HEE, P. (1988) *The Adoption and Diffusion of Imported Technology: The Case of Korea*. London, Croom Helm.

ERBER, F. et al. (1974) *Reflexões Sobre a Demanda pelos Serviços dos Institutos de Pesquisa*. Rio de Janeiro, FINEP (Série de Pesquisas, 1).

ERNST, D. & O'CONNOR, D. (1992) *Competing in the Electronics Industry: The Experience of Newly Industrialising Economies*. Paris, OECD Development Centre.

FAÇANHA, L. (1988) *Financiamentos Públicos para Projetos de Pesquisa e Desenvolvimento: uma Experiência de Avaliação da FINEP*. Rio de Janeiro, FINEP, mimeo.

FERRAZ, J. (1989) A Heterogeneidade Tecnológica da Indústria Brasileira: Perspectivas e Implicações para Política. *Revista Brasileira de Economia*, 43(3):373-392.

FIGUEIREDO, N. (1972) *A Transferência de Tecnologia no Desenvolvimento Industrial do Brasil*. Rio de Janeiro, IPEA (Série Monográfica, 7).

FORAY, D. (1993) General Introduction. In: FORAY, D. & FREEMAN, C. (eds) *Technology and the Wealth of Nations: the Dynamics of Constructed Advantage*. London, Pinter Publishers.

FORAY, D. & MOWERY, D. (1989) L'Integration de la Recherche Industrielle: Nouvelles Perspectives D'Analyse. *Revue Economique*, (3).

FORTUNE (1991) *Brainpower: How Intellectual Capital Is Becoming Corporate America's Most Valuable Asset*. June 3L.

FREEMAN, C. (1990) *Networks of Innovators: a Synthesis of Research Issues*. Paper presented at the International Interdisciplinary Workshop on Network of Innovators. Montreal, University of Quebec.

FREEMAN, C. (1993) The Economics of Technical Change. *Cambridge Journal of Economics* (forthcoming).

FTI (1986) Desempenho Industrial e Tecnológico: Proposição de Sistema de Informações Estatísticas. Rio de Janeiro, FTI.

FUKASAKU, Y. (1986) Technology Imports and R&D at Mitsubishi Nagasaki Shipyard in the Pre-War Period. *Bonner Zeitschrift fur Japanologie,* 8:77-90.

GLETE, J. (1984) *High Technology and Industries Networks - Some Notes on the Cooperation Between Swedish High Technology Firms and their Customers*. Paper presented at the International Research Seminar on Industrial Marketing. Stockholm, Stockholm School of Economics.

HAGEDOORN, J. (1989) *The Dynamic Analysis of Innovation and Diffusion - a Study in Process Control*. London, Pinter Publishers.

HAGEDOORN, J. & KALFF, P. (1985) *Sectoral and Technological Development: Information Technology and Process Control Equipment.* Interim Report. Amsterdam, STB.

HAGEDOORN, J. & SCHAKENRAAD, J. (1992) Leading Companies and Networks of Strategic Alliances in Information Technologies. *Research Policy,* 21:163-190.

HOBDAY, M. (1991) *The Needs and Possibilities for Cooperation Between Selected Advanced Developing Countries and the Community in the Field of Science and Technology - Country Report on the Republic of Korea*. Strategic Analysis of

Science and Technology. Brussels, Commission of the European Communities.

HOFFMAN, K. (1988) *Technological Advance and Organizational Innovation in the Engineering Industry; a New Perspective on the Problems and Possibilities for Developing Countries*. Report submitted to the World Bank. Brighton, Sussex Research Associates.

HOLLANDER, S. (1965) *The Sources of Increased Efficiency: A study of Dupont Rayon Plants.* Cambridge, MIT Press.

HUMPHREY, J. (ed) (1993) Quality and Productivity in Industry: New Strategies in Developing Countries. *IDS Bulletin*, 24(2), apr.

IMAL, K-I. & BABA, Y. (1989) *Systemic Innovation and Cross-Border Networks*. Paper presented at the International Seminar on Science, Technology and Economic Growth. Paris, OECD.

KAPLINSKY, R. (1988) *Industrial Restructuring in LDCs: The Role of Information Technology*. Paper prepared for Conference of Technology Policy in the Americas. Stanford, Stanford University.

KAPLINSKY, R. (1989) Technological Revolution and The International Division of Labour in Manufacturing: a Place for the Third World. *The European Journal of Development Research*, 1(1).

KATZ, J. (1984) Domestic Technological Innovation and Dynamic Comparative Advantage. *Journal of Development Economics,* (16):13-37.

KATZ, J. (ed) (1987) *Technology Generation in Latin American Manufacturing Industries*. London, Macmillan Press.

KATZ, N. & SHAPIRO, C. (1988) *Network Externalities, Competition and Compatibility*. Princeton, Woodrow Wilson School, Princeton University (Discussion Paper, 54).

KDB (1988) *Industry in Korea - 1988.* Seoul, The Korea Development Bank.

KLEINKNECHT, A. & REIJNEN, J. (1992) Why do Firms Cooperate on R&D? An Empirical Study. *Research Policy*, 21(4).

LANGRISH, J. *et al*. (1972) *Wealth From Knowledge.* London, Macmillan.

LEVIN, R.; KLEVORICK, A.; NELSON, R. & WINTER, S. (1987) Appropriating the Returns From Industrial Research and

Development. *Brookings Papers on Economic Activity*, (3):783-820.

LUNDVALL, B.A. (1983) Technology, Competitiveness and Small Countries. *Smaskrift*, (37). Aalborg, Aalborg University Press.

LUNDVALL, B.A. (1985) Product Innovation and User-Producer Interaction. *Industrial Development Research Series*, (31). Aalborg, Aalborg University Press.

LUNDVALL, B.A. (1986) *Technological Revolutions and The International Division of Labour*. Paper presented at the Workshop on Innovation and Regional Development. Venice, University of Architecture.

LUNDVALL, B.A. (1988) Innovation as an Interactive Process: From User-Producer Interaction to the National System of Innovation. In: DOSI, G.; FREEMAN, C.; NELSON, R.; SILVERBERG, G. & SOETE, L. (eds.) *Technical Change and Economic Theory*. London, Pinter.

LUNDVALL, B.A. (1989) *Innovation, the Organised Market and the Productivity Slow-Down*. Paper presented at the International Seminar on Science, Technology and Economic Growth. Paris, OECD.

LUNDVALL, B.A. (1992) *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning.* London, Pinter Publishers.

MOORE, G. & HARRIS, M. (1992) Linking Trade and Technology Policies: Themes and Issues. In: HARRIS, M. & MOORE, G. (eds) *Linking Trade and Technology Policies: an International Comparison of the Policies of Industrialized Nations*. Washington, National Academy Press.

MOWERY, D.C. (1983) The Relationship Between Intrafirm and Contractual Forms of Industrial Research in American Manufacturing, 1900-1940. *Explorations in Economic History*, (20):351-374.

MYERS, S. & MARQUIS, D. (1969) *Successful Industrial Innovations.* Washington, National Science Foundation.

NAKAOKA, T. (1987) On Technological Leaps of Japan as a Developing Country. *Osaka City University Economic Review*, (22):1-25.

NELSON, R. (1979) Innovation and Economic Development: Theoretical Retrospect and Prospect. *Research Program in Science and Technology Working Paper*, (31). Buenos Aires, Programa BID/CEPAL/PNUD.

NELSON, R. & WINTER, S. (1982) *An Evolutionary Theory of Economic Change*. Cambridge, Mass, Harvard University Press.

O'BRIEN, R. (1985) Technology and Industrial Development: The Irish Electronics Industry in an International Context. In: FITZPATRICK, J. & KELLY, J. (eds) *Perspectives on Irish Industry*. Dublin, Irish Management Institute.

ODAGIRI, H. & GOTO, A. (1992) Technology and Industrial Development in Japan. Japan, Tskuba University, mimeo.

OZAWA, T. (1974) *Japan's Technological Challenge to the West, 1950-1974: Motivation and Accomplishment*. Cambridge, Mass., MIT Press.

OZAWA, T. (1980) Government Control Over Technology Acquisition and Firms' Entry into New Sectors: The Experience of Japan's Synthetic-Fibre Industry. *Cambridge Journal of Economics*, (4):133-146.

OZAWA, T. (1985) Macroeconomic Factors Affecting Japan's Technology Inflows and Outflows: The Postwar Experience. In: ROSENBERG, N. & FRISCHTAK, C. (eds) *International Technology Transfer.* New York, Praeger.

OECD (1987) *Bulletin des Indicateurs*, (10).

OECD (1990a) Technological Innovation: Some Definitions and Building Blocks. *Draft Background Report*, Chapter 2, Technology/Economy Programme. Paris, OECD.

OECD (1990b) New Technology, Latecomer Industrialisation and Development Today. *Draft Background Report*, Chapter 11, Technology/Economy Programme. Paris, OECD.

OECD (1992a) *Subsidies and Structural Adjustment*. Report to the OECD Council at Ministerial Level. Paris, OECD.

OECD (1992b) *Industrial Policy in OECD Countries - Annual Review -1992.* Paris, OECD.

PACK, H. & WESTPHAL, L.E. (1986) Industrial Strategy and Technological Change: Theory Versus Reality. *Journal of Development Economics*, (22):87-128.

PATEL, P. & PAVITT, K. (1992) The Innovative Performance of the World's Largest Firms: Some New Evidence. *The Economics of Innovation and New Technology*, (2):91-102.

PAVITT, K, ROBSON, M. & TOWNSEND, J. (1989) Technological Accumulation, Diversification and Organisation in UK Companies, 1945-1983. *Management Science*, 35(1):81-99.

PAULINYI, E. (1984) Empresa Nacional: Panorama do Setor Industrial em 1983. *Revista Brasileira de Tecnologia*, 15(3).

PORTER, M. (1990) *The Competitive Advantage of Nations*. London, Macmillan.

RAY, G. (1984) *The Diffusion of Mature Technologies.* Cambridge, Cambridge University Press.

ROSENBERG, N. (1972) Factors Affecting the Diffusion of Technology. *Explorations in Economic History*. Fall.

ROSENBERG, N. (1976) *Perspectives on Technology*. Cambridge, Cambridge University Press.

ROTHWELL, R. *et al*. (1974) SAPPHO updated - Project SAPPHO, Phase 2. *Research Policy*, 3(3).

RUSHING, F. & BROWN, C. (eds) (1986) *National Efforts for Developing High Technolgy Industries: International Comparisons*. Boulder and London, Westview Press.

SALTER, W. (1966) *Productive and Technical Change*. Cambridge, Cambridge University Press.

SERCOVITCH, F. (1980) *State-owned Enterprises and Dynamic Comparative Advantages in the World Petrochemical Industry: the Case of Commodity Olefins in Brazil*. Cambridge, Mass, Harvard Institute for International Development, Harvard University.

SHERWIN, S. & ISENSEN, R. (1967) Project Hindsight. *Science*, (23), jun.

SMITH, K. & VIDVEI, T. (1992) Innovation Activity and Innovation Outputs in Norwegian Industry. *STI Review*, (11), dec. Paris, Organisation for Economic Co-operation and Development.

SOETE, L. (1985) International Diffusion of Technology, Industrial Development and Technological leapfrogging. *World Development*, 13(3).

SOLMITZ, H. (1984) Industrialisation Strategies in Less Developed Countries: Some Lessons of Historical Experience. *Journal of Development Studies*, oct., p. 1-21.

SPRU (1972) *Success and Failure in Industrial Innovaiton*. Centre for the Study of Industrial Innovation. Brighton, Science Policy Research Unit, University of Sussex.

TANAKA, M. (1978) *Industrialization on the Basis of Imported Technology: A Case Study of the Japanese Heavy Chemical Industry 1870-1930*. Master of Philosophy Thesis. University of Sussex.

TANAKA, M. (1992) *Technology Transfer in the Petrochemical Industry*. The MIT Japan Program, MITJP 92-06. Cambridge, MA, Massachusetts Institute of Technology.

TEECE, D. (1986) Profiting from Technological Innovation. *Research Policy*, 15(6).

TEECE, D. (1988) Technological Change and the Nature of the Firm. In: DOSI, G. *et al*. (eds) *Technical Change and Economic Theory*. London, Pinter Publishers.

TEITEL, S. (1981) Towards an Understanding of Technical Change in Semi-Industrialized Countries. *Research Policy*, (10):127-147.

TEITEL, S. (1984) Technology Creation in Semi-Industrialized Economies. *Journal of Development Economics*, (16):39-61.

TYSON, L. (1992) Managing Trade Conflict in High-Technology Industries. In: HARRIS, M. & MOORE, G. (eds) *Linking Trade and Technology Policies; an International Comparison of the Policies of Industrialized Nations*. Washington, National Academy Press.

UNCTAD (1992) *UNCTAD VIII - Analytical Report by the UNCTAD Secretariat to the Conference*. Geneva, UNCTAD.

VAITSOS, C. (1989) Radical Technological Changes and the New Order in the World Economy. *The European Journal of Development Research*, 1(1).

VAITSOS, C. (1990) *The Needs and Possibilities for Cooperation between Selected Advanced Developing Countries and the Community in the Field of Science and Technology -Country Report on Brazil*. Strategic Analysis of Science and Technology. Brussels, Commission of the European Communities.

VICKERY, G. (1990) A Survey of International Technology Licensing. *STI Review*, (4). Paris, OECD.

VON HIPPEL, E. (1976) The Dominant Role of the Users in the Scientific Instruments Innovation Process. *Research Policy*, 5(3).

VON HIPPEL, E. (1988) *The Sources of Innovation*. Oxford, Oxford University Press.

WALSH, V. (1988) Technology and the Competitiveness of Small Countries: a Review. In: FREEMAN, C. & LUNDVALL, B.A. (eds) *Small Countries Facing the Technological Revolution*. London, Pinter Publishers.

WHISTON, T. (1992) *Managerial and Organisational Integration*. Springer-Verlag.

WIGGENHORN, W. (1990) Motorola U: When Training Becomes an Education. *Harvard Business Review*, jul.-aug., p. 71-83.

WILLIAMSON, O. (1988) Technology and Transaction Cost Economics: a Reply. *Journal of Economic Behaviour and Organisation*, 10:355-363.