From technology absorption to technology production: industrial strategy and technological capacity in Brazil's development process

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ABSTRACT

This article surveys the evolution of technology policy in Brazil from its inception to the present day, examining the changes that it has undergone along the way. Having sketched in the apropriate background, it goes on to discuss the broad technological impact of rapid liberalization in the 1990s.

Key words: export diversification, import substitution, invention, patents, research and development, technology.

RESUMO

Este artigo apresenta uma visão geral da evolução da política tecnológica no Brasil desde o seu começo até o dia de hoje, examinando as mudanças que ela sofreu pelo caminho. Havendo delineado o pano de fundo apropriado, discute-se o amplo impacto tecnológico decorrente da liberalização dos anos 90.

Palavras-chave: diversificação das exportações, substituição de importações, invenção, patentes, pesquisa e desenvolvimento, tecnologia.

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Over the past 40 years the Brazilian economy has experienced dramatic changes in its structure and in its relationship with the rest of the world. From being a rapidly industrialising, closed economy in the 1950s, by the early 1970s Brazil had entered a period in which structural transformation became subordinated to expansion of exports and improvements in internal efficiency. The deterioration of the international economic environment in the mid 1970s forced a re-evaluation of this strategy. From 1974 onwards, Brazil embarked on a programme of enhanced import substitution, which, by and large, remained in place up until **the mid 1980s**. Most of the 1990s have seen yet another radical change in course as policy makers embraced Neo Liberalism, abandoned import substitution and exposed the Brazilian economy to the forces of globalisation. This series of events, in so far as they concern the process of industrialisation, will have become extremely familiar to most observers of the Brazilian economy. What perhaps will be less familiar is the implications that these shifting industrial strategies had for the pursuit of technological capabilities within Brazil. It is with this crucial, and often over looked issue, that this article is concerned. This article aims to survey the evolution of technology policy in Brazil from its inception to the present day, examining the very substantial changes that it has undergone along the way. Having sketched in the appropriate background, this article then goes on to discuss the broad technological impact of rapid liberalisation in the 1990s.

In analysing the evolution of technology policy within an emerging market context, it is important to be aware of the theoretical debate which has grown up around the implementation of such policies. From the perspective of the 1990s in which the Neo Liberal paradigm is dominant, one might claim that explicit technology policies are at best redundant or at worst positively harmful. The development of technological capabilities should instead be conducted through the interplay of market forces. As Schmitz and Cassiolato (1992, p.2) have summarised this point of view... "*Market imperfections exist but are less serious than government failures. LDCs are more likely to succeed in industries which use mature technologies. Government intervention seeking to foster a local capability in the production of hi-tech tends to be a waste of resources.*"

However, there exist a number of strong, if not compelling, counter arguments, many of which are based on contemporary derivations of Schumpeterian insights. Given the inability of many LDCs to break out of technological dependency, a role for the state may exist in either direct or indirect form to encourage a greater degree of participation of these countries in the creation of new products and processes. Failure to do so condemns LDCs to the production of goods at the end of the product cycle where the potential for rapid market growth, technological spin-offs and other positive externalities is stunted. For Gilpin (1987) "*every state, rightly or wrongly, wants to be as close as possible to the innovative end of*

the 'product cycle' where, it is believed, the highest 'value added' is located." Given the trend for the shortening of the product cycle, many LDCs find a compelling need to be able to produce products and/or processes as close as possible to the state of the art. Schmitz and Cassiolato (1992, p. 3) summarise this position by calling attention to the "*conclusion which can be derived from the Neo Schumpeterian school of thought...Put schematically, it suggests that 'windows of opportunity' exist for LDCs, particularly at the early stage at the development of new technologies. In order to make use of these opportunities, strategic state intervention is required so that synergies are created between the various hi-tech sub-sectors and between producers and users of hi-tech.*"

The theoretical debate above provides the context in which we shall examine the evolution of Brazil's technology policies, their achievements and shortcomings. This will be accomplished in Section 2 by dividing Brazil's industrialisation into a series of sequential stages and examining the implicit and or explicit technology policies that prevailed in each. Given the scale and significance of the policy shifts involved, particular attention is paid to the developments of the past 18 years. This period was one in which technology policy underwent something of a transformation, reflecting the abandonment of import substitution and the advent of trade and market liberalisation. In a necessarily brief attempt to gauge the impacts of this shift, Section 3 presents various indicators of Brazil's recent technological effort and capability. Next, Section 4 considers the impact of recent privatisations on technological capabilities within the industrial sector. Finally, the conclusion attempts to evaluate the country's current and potential capacity to contribute to technological innovation and feasible roles of the state within the context of an increasingly liberalised market economy.

2 The evolution of technology policies

2.1 1950-1964: the era of 'classical' import substitution

During the ISI process of the 1930s and its intensification in the 1950s, the major concern of Brazil's policy makers was to diversify the economy and to make industry an engine of growth.[1] There was very little explicit technology policy and the main goal of the government was to establish new industrial sectors with whatever technology multinationals would introduce or whatever technology domestic public or private firms could obtain

1 For further details see Baer (1995).

abroad. Explicit concern about a technological strategy developed only gradually. Such preoccupation as existed concerned itself with the adaptation of newly imported technologies to suit local conditions.

Despite the generally limited scope of official efforts to develop domestic technological capabilities, this period did, however, witness **some** important institutional developments. The state government of São Paulo, in 1960, founded Fapesp (Foundation Research Support) an organisation whose activities have focused on scientific research at university research institutes.[2] In addition, the 1950s saw the beginning of attempts within Brazil to launch a nuclear power programme; an ambitious project guided in no small part by strategic considerations. **In addition, 1951 saw the creation of the research and postgraduate training councils, CNPq and CAPES, which were later to play a vital role in the expansion of the scientific and technological base.** Among economists in Brazil during this period much concern centred around the creation of what would now be termed 'appropriate' technologies, i.e. technologies capable of better reflecting the relative factor endowments (especially with regard to labour absorption).[3] In fact, some of the technology imported by multinationals was already 'second hand' [4] i.e. already relatively more labour intensive than the already 'state of the art technology' and yet, even this technology was creating insufficient employment levels to absorb the burgeoning urban population. The growing participation of foreign capital in the Brazilian industrial sector did little to raise R+D efforts within Brazil. In a pattern that would become very familiar in years to come, the vast majority of newly installed foreign owned enterprise subsidiaries drew on research and development activities conducted outside of Brazil.[5] Given the limited technology policy incentives on offer in this period, the emergence of this pattern is hardly surprising.

2.2 1964-1973: the impact of export diversification and the impact of a military/ technocratic régime

By the early 1960s it was becoming increasingly apparent that the exclusive import substitution strategy was running into a dead end. Not only could the import coefficient be squeezed further, but it actually began to rise again as the newly created industrial capacity required a growing quantity of imported inputs. As the export commodity structure had

2 Schwartzman (1979, p. 288).

3 See, for instance, Faria (1986); Morley and Smith (1973).

4 Corrêa do Lago *et alii* (1979).

5 Motoyama (ed.) 1994.

hardly changed during the classical ISI period (by the early 1960s Brazil's exports were still largely composed of traditional primary products), there was a danger that weakening markets for the traditional export products would cause a decline in foreign exchange earnings, which in turn, would cause the country to contain its imports of essential industrial inputs. It was thus recognised that there was an urgent need to diversify exports, and most of these would be non-traditional industrial products. In the second half of the 1960s the government began to create various incentives for non-traditional exports. Many domestic and multinational firms made use of these incentives. However, they found that to effectively compete in the international market they had to incorporate the latest technology.

In addition, in the second half of the 1960s, the government mobilised resources to finance activities in science and technology. Schwartzman (1979, p. 299) states that this "was the first time in the history of Brazil that there was an organised attempt to place science and technology at the service of economic development through the mobilisation of a substantial volume of resources" Thus, in 1964 the BNDE created FUNTEC (Programme for Technological Development), which in its first ten years of existence spent US$ 100m on research and post graduate training in engineering, exact sciences and other fields. In 1967 an important institutional development occurred with the foundation of FINEP (Financing Agency for Studies and Projects). This body later became heavily involved in the granting of subsidised credit to enterprises engaging in R+D projects.

Looking at the period as a whole, some sources have commented on the fact that much of these expenditures were made in universities and technological institutes whose research efforts were not well connected to the needs of industry.[6] It is interesting to note, however, that in the 1960s some of the major state enterprises founded their own research institutes, for instance Petrobrás (the state petroleum company) established the *Centro de Pesquisa e Desenvolvimento* (**CENPES**) which would be exclusively dedicated to R+D activities; similarly, at the end of the 1960s Cepel, a research institute for the state owned electricity sector was created, with the purpose of increasing the sector's technological autonomy. Finally, in the early 1970s, Telebrás, the state owned telecommunications conglomerate, founded CPqD whose objective was to diminish the sector's dependence on foreign technology.[7]

In another important development the Brazilian state in 1970 established the INPI

6 See, for instance Schwartzman *et alii* (1995, p.18-19).

7 Erber & Amaral (1995).

(*Instituto Nacional de Propriedade Industrial*) or National Institute of Industrial Intellectual Property. The institute was founded in order to regulate the process of technology transfer between foreign and Brazilian industrial enterprises. The objective of the regulation was to broaden the effects of technology transfer through enhancing domestic learning and encouraging the 'spread effects' of each licensing agreement. At the same time, INPI required that all new technology transfer agreements which were signed concerned technologies not yet available within Brazil. The institute was particularly concerned to ensure that new technology transfer agreements did not have the effect of displacing existing domestic innovative effort.[8]

2.3 Import substitution deepening: 1974-1980

Brazil's response to the crisis resulting from the OPEC oil shock of 1973 was to engage in 'debt led growth',[9] one of whose principle components was to embark on a massive programme of import substitution in the intermediate and capital goods industries. The other key element of the strategy was to launch a vast programme of infrastructural investment which included such projects as the Itaipú (the World's largest hydro-electric dam) and a nuclear energy complex at Angra dos Reis. **As part of this programme, the government established the Núcleos de Articulação com a Indústria (NAIs) in an attempt to shape the growth of the burgeoning and technologically complex capital goods sector (Amann, 1996). Attempts were also made to increase the extent of capabilities in basic scientific research with the launch of the Planos Básicos de Desenvolvimento Científico e Tecnológico (PBDCTs) and the Sistema Nacional de Desenvolvimento Cientifico e Tecnológico, founded in 1975. The 1970s also saw the launch of a special fund aimed at stimulating both public and private sector research activity, the Fundo Nacional de Desenvolvimento Científico e Tecnológico (FNDCT).**

There was also a vast effort at new types of petroleum exploration on the Brazilian continental involving pioneering efforts in deep sea drilling and a vast programme to tap alternative energy sources, the most important element being the sugar based alcohol programme (PROALCOOL). This latter programme resulted in substantial technological strides in such area as distilleries, adjusting automobile engine designs and the technology involved in organising a new fuel distribution network.[10] This ambitious programme was termed the Second National Development Plan (PND II). In so far as the capital goods

8 Amann (1996)

9 Baer (1995, Ch. 6); Erber (1986).

10 Barzelay (1986).

sector was concerned, much of the technology policy was largely implicit as increased domestic participation in this advanced sector necessarily involved the development enhanced technological competence among emerging producers.

However, it should be recognised that most of the technologies employed in the capital goods sector were already well known and of foreign origin. In most instances, gains in technological knowledge resulted from production and adaptation of capital goods rather than fundamental scientific breakthroughs. Within the capital goods sector, production of made-to-order equipment for Brazil's burgeoning infrastructural projects rose particularly rapidly during this period.[11] From a technological point of view this development was of special significance as the discontinuities and production problems inherent in the manufacture of such equipment gave rise to accelerated learning and technological competence. The increasing importance attached to the capital goods sector by the state was reflected in the **expansion** of specialised research and development institutions. On of the most important of these was the IPT (*Instituto de Pesquisa Tecnológico* or Institute of Technological Research) which **had been established in São Paulo in the 1930s and was granted added independence in the 1970s**. The institute conducted research into many areas including power plant, steel making and alcohol fuel technologies.

It should also be noted that such massive infrastructure projects as Itaipú, designed and executed fully by Brazilian engineers, also enriched the technological knowledge of the country. This was particularly true in the power engineering and civil engineering sectors. Finally, during this period, the 1970s saw the rapid expansion of Embraer, the aircraft construction firm set up by the Air Force. Although initially, most of the technology of this firm was imported it gradually through adaptive measures developed its own technological expertise, which would, in the 1980s and 1990s make it possible for this firm to find an important niche in the world aviation industry.[12]

2.4 Technology during the 'lost decade': 1980-1990

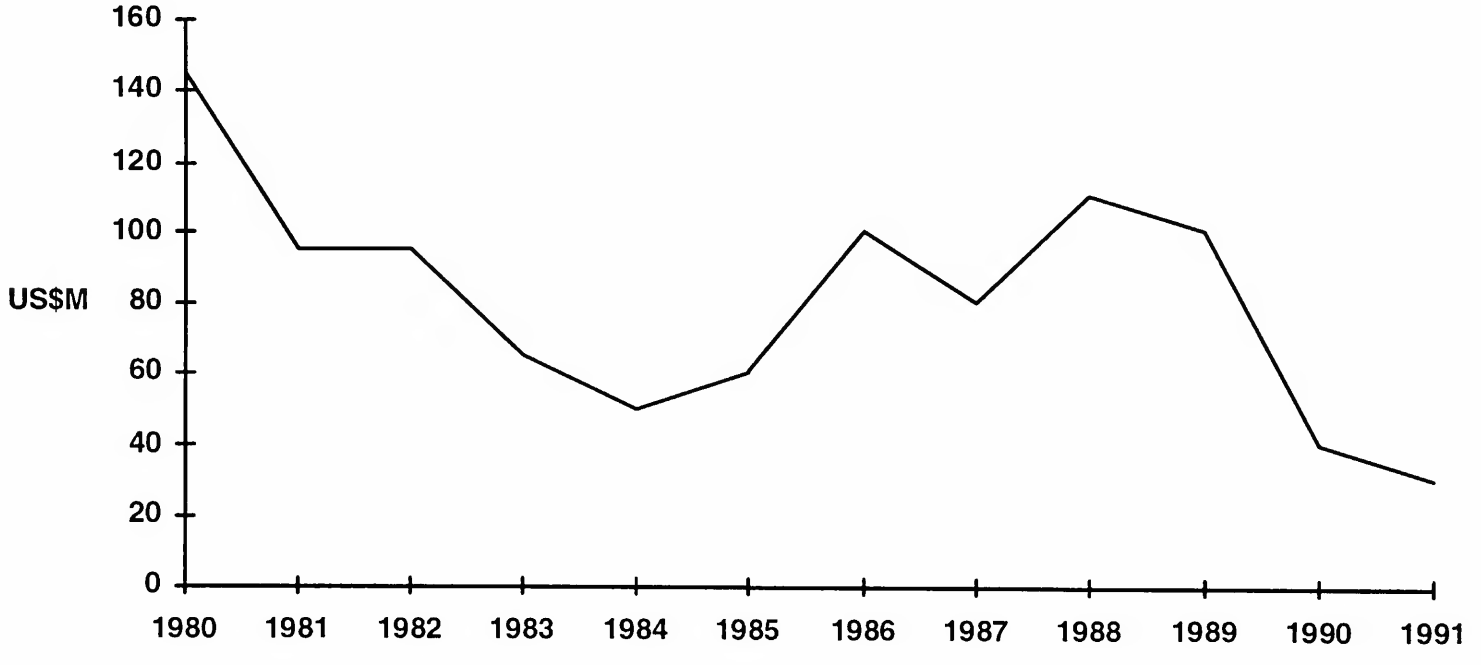
The debt crisis of the 1980s forced Brazil to radically decrease its investments which fell from an average of 25% of GDP in the 1970s to 16% in the 1980s. Lack of investment would lead to increasing difficulties in keeping its productive structure technologically up

11 Amann (1996).

12 Ramamurti (1987).

to date. One observer stated that "after 1980s the science and technology sector entered a period of great instability and uncertainty, characterised by institutional turmoil, bureaucratisation, and budgetary uncertainty...In 1985 the National Fund for Scientific and Technological Development...was just one fourth of its 1979 value" [13] During this period, even research institutes of state enterprises were adversely affected by the prevailing economic stagnation. For instance, CEPEL, the research institute of Eletrobras had to substantially curtail its research activities and by the end of the decade, much of its equipment was obsolete.[14] From 1980 to 1985, there were sizeable reductions in disbursement of FINEP funds across the board resulting from the twin phenomena of budgetary cutbacks and an unwillingness of enterprises to undertake research and development given depressed and uncertain market conditions.

Chart 1
Treasury Financing of the National Science and Technology Development Fund,1980-1991



Source : Financiamento Público para a Ciência e Tecnologia no Brasil: A Experiencia da FINEP (1967-1991), Rio de Janeiro: Interbusiness (1993, Table 3.7). Reproduced in Motta (1994, p. 44)

During the 1980s the *modus operandi* of INPI remained substantially unchanged in that

13 Schwartzman *et alii* (1995, p. 14).

14 Erber & Amaral (1995, p. 352).

it continued to regulate technology transfer on the basis of taxing royalty payments and scrutinising contracts according to the long established criteria mentioned in the previous section. However, there is evidence to suggest that during this period, INPI's role as a pro-active promoter of technology through the close supervision of technology transfer contracts became increasingly subordinated to its revenue raising function.[15]

The only sector in which some new technological initiatives were attempted was in the information technology industry. The policy essentially consisted of trying to make the country more self sufficient in the generation of computer technology at the low end of the market. The basic policy used was protection, euphemistically termed the 'market reserve', combined with and extensive series of fiscal incentives.[16] This turned out to be a gigantic mistake as the products produced consisted of outmoded, reverse engineered computers and peripherals. This policy was also extended at absurd length. As one observer noted, "*By the mid 1980s* ...(the mandate of the agency in charge of this policy)... *had spread to numerically controlled machine tools, instruments, computer aided design and industrial robots...The old charge of controlling inflows of electronic components...affected the inputs used by the manufacturers of automobiles and household appliances.*"[17] The policy was also flawed in that it tended to promote the development of mini computers and their operating systems at a time when IBM-PC machines were beginning to establish market dominance.

2.5 Technology in the era of globalisation: the 1990s

Beginning with the administration of President Collor, and extending through the governments of Presidents Itamar Franco and Fernando Henrique Cardoso, Brazil adopted a policy of rapidly opening its economy to world trade and capital flows. It also adopted a Neo Liberal agenda whose principal characteristic was the privatisation of state industries and public utilities. What did this imply for the country's technological development?

In an attempt to accelerate the technological upgrading of industry induced by trade liberalisation, in the early 1990s the government formulated three major programmes. The first was called the *Programa de Capacitação Tecnológica* (PCT), which was supposed to

15 Amann (1996).

16 Fajnzylber (1994, p. 31).

17 Evans (1995, p. 123).

strengthen the technological capacity of industry. The programme offered very little by way of additional resources or concrete policy initiatives. Instead it consisted of a group of guidelines aimed at awareness building and the encouragement of the dissemination of technological information concerning management know-how through a variety of institutional arrangements. Although provisions were made for the financial support of R+D within enterprises, budgetary cut backs and the financially straightened condition of enterprises greatly restricted their effects.

In similar fashion *Programa Brasileiro de Qualidade e Produtividade* attempted to bring about improvements in enterprise efficiency and technological achievement through a mixture of official exhortation and centrally developed guidelines. Of more concrete significance were a number of measures embodied in the *Programa de Competitividade Industrial* (PCI). Among its most important features were fiscal stimuli, the elimination of the computer market reserve policy, a decrease of local content rules for public sector procurement, and more resources for human capital formation.[18] Although the PCI eventually withered, the policy measures concerning computers and public sector procurement were rapidly implemented at the start of the 1990s.

In 1993 Law 8661 providing fiscal incentives for technological development was approved. Its objective was to transfer to private firms some of the role of the creation and diffusion of technology which formerly resided mainly with government agencies. The law deals with technological and R+D activities in the industrial and agricultural sectors covering basic and applied research and technological support services. The law stresses the need to develop linkages between research institutes and universities on the one hand, and private enterprises on the other. In its first two years 40 firms benefited from this law. These were mainly large firms based in four sectors: electrical and electronic equipment, metals production, chemicals and mechanical equipment.[19] The largest single take up for fiscal incentives under the new legislation was the electronics sector which invested over US$ 300m in R+D and according to the industry and commerce ministry (MIC) had reached a technological level equal to advanced industrial countries by 1997 [20] The information technology sector, despite the end of the market reserve, benefited from the removal of the

18 Meyer-Stamer (1997, p. 263-266).

19 Matesco & Tafner (1996, p. 312-313).

20 MICT (1998).

Industrial Products Tax on items containing significant locally added value. Only firms whose R+D expenditures exceeded 5% of gross sales were able to take advantage of this measure. Of R+D expenditure, at least 40% needed to be linked to enterprise-university joint research projects.[21]

The 1990s also saw the revitalisation of the PADCT (Programme for the Support of Scientific and Technological Development). This programme, one of whose aims is to finance the execution of technological projects within Brazilian industrial enterprises, is to undergo a phase of rapid expansion. Resources to support this development are to be drawn partly from the World Bank (*Gazeta Mercantil*, 23/7/97). Thus, after a period of some crisis, technology policy within Brazil is experiencing a cautious renaissance. The new approach to technology policy typified in Law 8661 which represents a departure from many earlier policy initiatives. Principally this is because the new approach places the key decisions concerning technological choice in the hands of the private sector. In addition, the new policies represent a departure in their encouragement of links between the private sector, its clients and research institutes.

The changing character of technology policy in the 1990s is strongly reflective of the liberalising context in which it operates. However, it is also influenced by recent developments in the theory of innovation. These stress the benefits of decentralisation, the non-linear character of the innovative process and the consequent benefits to be obtained from institutional and user-producer linkages.[22] In particular, contemporary theory is supportive of the creation of a network of such links - termed a National System of Innovation - in order that a country's innovative potential can be fully realised. Within this context, the state has a role to play in overcoming the informational problems and externalities implicit in the establishment of such a system.

The changed policy objectives in the 1990s involving a shift in the responsibility for technological development to the private sector raises three important questions. The first concerns the extent to which domestic technological effort might have been favourably or adversely affected by this process. Another major question surrounds the extent to which privatised state enterprises will continue the pattern of relatively high R+D expenditures established under state ownership. The final question concerns the role of the public sector

21 MICT Infomatica (1998, p. 7).

22 Freeman & Soete (1997).

in an increasingly liberal setting and its ability to influence the level and direction of the country's technological development. In order to address these questions, it will be useful to make a quantitative survey of the country's past and present R+D activity with a particular emphasis on the events of the last fifteen years.

3 Brazil's technological efforts: a quantitative survey

From Table 1a it will be noted that the share of industry in GDP has increased substantially in the 1950-1995 period. In Table 1b which shows the structure of manufacturing industry it can be seen that there have been substantial increases in those sectors incorporating technologically advanced products and processes. For instance, machinery whose share in 1949 was 2.2% increased to 12.5% by 1992; electrical equipment rose from 2.2% to 6.8%; transport equipment from 2.3% to 7.1%; chemical products from 0% to 13%.

Table 1a
Industry as a Proportion of GDP

Year	Industry as a Percentage of GDP
1950	24.1%
1960	32.2%
1970	35.8%
1980	40.6%
1990	34.2%
1995	42.0%

Source: Anuário Estatístico (various years).

Table 1b
Changes in Brazil's Industrial Structure: Gross Value Added
(percentage distribution)

	1949	1963	1980	1992
Nonmetallic Minerals	7.4	5.2	**5.8**	4.7
Metal Products	9.4	12.0	11.5	11.9
Machinery	2.2	3.2	10.1	12.5
Electrical Equipment.	1.7	6.1	6.3	6.8
Transport Equipment	2.3	10.5	7.6	7.1
Wood Prods	6.1	4.0	2.7	1.2
Furniture			1.8	0.9
Paper Prods	2.1	2.9	3.0	3.7
Rubber Prods	2.0	1.9	1.3	1.4
Leather Prods	1.3	0.7	0.6	0.5
Chemicals			14.7	13.0
Pharmaceuticals	9.4*	15.5*	1.6	2.3
Perfumes, Soaps, Candles	n.a.	n.a	0.9	1.1
Plastic Products	n.a.	n.a.	2.4	2.2
Textiles	20.1	11.6	6.4	4.6
Clothing & Shoes	4.3	3.6	4.8	3.2
Food Pds.	19.7	14.1	10.0	13.6
Beverages	4.3	3.2	1.2	2.1
Tobacco	1.6	1.6	0.7	1.4
Printing & Publishing	4.2	2.5	2.6	2.6
Miscellaneous	1.9	1.4	4.0	3.2
TOTAL	100.0	100.0	100.0	100.0

Source: Baer (1995, p. 364).

* In 1963-49 and 1963 Pharmaceuticals included Chemicals, Perfumes-Soaps- Candles, and Plastic Products.

Table 2
Commodity Composition of Brazil's Imports

	1948-50	1960-62	1972
Capital Goods	38.8	29.0	42.2
Intermediate Goods	28.0	31.0	42.7
Consumer Durables	8.0	2.0	6.6
Consumer Nondurables	7.0	7.0	7.7
Other	19.0	31.0	0.8
TOTAL	100.0	100.0	100.0
	1968-72	1981	1992
Machinery & Equipment	37.6	18.2	30.4
Crude Oil & Derivaties	10.0	51.3	20.4
Pig Iron and Steel	6.2	3.3	4.1*
Nonferrous Metals	5.0	2.2	n.a.
Chemicals	5.3	3.6	17.0
Other	35.9	21.4	28.1
TOTAL	100.0	100.0	100.0

Source: Baer (1995, p. 212).

* In 1992 Pig Iron and Steel includes Non-ferrous Metals.

It will be noted in Table 2 which contains data on the composition of imports, that machinery and equipment, which incorporates a substantial amount of new technological knowledge stood at over 37% in 1968-72; it declined dramatically in the late 1970s, reaching 18.72% in 1981, reflecting the results of import substitution of capital goods in the 1970s. The continued low proportion of such imports in 1985 was due also in part to the stagnation of fixed investment in that period. The rise to over 30% in the early 1990s reflects the new opening of the economy and once again an increased reliance on imported technology.

Table 3a
R+D Expenditures (% of GDP) in Selected Countries, 1990-1995

Countries	1990	1991	1992	1993	1996
Germany	2.76	2.63	2.5	2.48	2.48
United States	2.72	2.86	2.81	n.a	2.48
Japan	3.08	3.05	3	n.a	2.78
Canada	1.45	1.51	1.51	1.5	1.48
Italy	1.3	1.32	1.38	1.41	n.a
Brazil	0.72	0.69	0.56	0.77	0.87
Argentina	0.33	0.34	0.36	0.39	0.46

Sources: Matesco & Hasenclever (1996, p. 467), Brazilian Ministry of Science & Technology (1998, p. 1), Gabinete Científico-Tecnológico (1997, p. 78), Schwartzman *et alii* (1995 p. 9).

Table 3b
Brazil: Expenditures on Science and Technology 1980-1990 (in millions of 1991 US$)

Year	Federal	State	Public and Private Enterprises	Total	Total Expenditures as a % of GDP
1980	824.5	496.8	330.3	1651.6	0.43
1981	1519.6	672.4	548.0	2740.0	0.74
1982	1863.3	654.6	629.5	3147.4	0.85
1983	1475.4	462.6	484.5	2422.5	0.67
1984	1426.9	500.7	481.9	2409.5	0.64
1985	1953.9	501.9	613.9	3069.7	0.75
1986	2288.6	651.3	735.0	3674.9	0.84
1987	2556.1	466.9	755.5	3778.7	0.83
1988	2506.4	396.7	725.8	3628.9	0.80
1989	2147.1	512.5	664.9	3324.5	0.71
1990	1679.0	672.2	587.8	2938.9	0.72
1991	2286.1	607.9	n.a	2893.0*	0.69
1992	1741.6	587.9	n.a	2329.5*	0.56
1993	2463.0	826.2	1196.2	4485.4	0.77
1994	2467.5	725.4	1571.0	4763.9	0.77
1995	2677.1	1239.8	1764.4	5681.3	0.88

Source: Schwartzman *et alii* (1995, p. 9), MCT (1995).

* Does not include expenditures by public and private enterprises.

Table 3a provides some comparative indicators of technological effort. While the data for Brazil refer to science and technology expenditures and thus preclude direct comparison with data for other countries, the data clearly indicate that Brazil has devoted a relatively low amount of resources to technological effort. The real impact of this lag is greater than the figures suggest because of the greater absolute size of the advanced industrial countries and their faster growth rates during the 1980s. Despite some closing of the gap after the early 1990s, Brazil still remains substantially behind other major industrial economies in terms of its absolute and relative expenditures on **technological activity.**

In 1990 of resources spent on R+D, only 18% were spent by the directly productive sector. Comparing this to the US, France and Canada 40-48% was carried out by the productive sector. In Germany, Japan and Switzerland this fluctuated between 65 and 79% (Schwartzman, 1995 p.60). At the beginning of the 1990s it was found that Brazilian researchers were distributed in the following manner : 68.52% in educational institutions, 20.54% in research institutes and only 3.98% in state and private enterprises. In OECD countries about 60% of researchers work in productive enterprises. Brazil's growth share of published scientific articles was 0.21% in 1973, 0.38% in 1981 and 0.35% in 1986 (p. 61).

Table 4
Patents Granted in Brazil : 1981-1994

	Patents			Invention Patents		
Year	Total	Residents	Non-Residents	Total	Residents	Non-Residents
1981	11538	1713	9825	8229	844	7448
1982	11594	2561	9033	1083	1318	8765
1983	7338	1835	5503	6077	779	5298
1984	5749	1293	4456	4893	584	4309
1985	4926	1454	3472	3934	607	3327
1986	3804	1189	2615	2935	442	2493
1987	3132	1069	2063	2184	289	1895
1988	4230	1452	2778	3040	487	2553
1989	4903	1567	3336	3510	474	3036
1990	4714	1551	3163	3355	464	2891
1991	3385	881	2504	2479	341	2138
1992	2577	862	1715	1822	254	1568
1993	3551	1038	2513	2649	378	2271
1994	4074	1464	2610	n.a	n.a	n.a.

Source: Anuário Estatístico (various years).

Another indicator of R+D and technological development might be the registration of patents. Table 4 contains data on patents granted in Brazil between 1981 and 1994. It will be noted that the great majority of these patents were granted to non-residents which is a general indication of substantial reliance on foreign technology. This has not diminished over time, especially when considering patents for inventions.

Table 5 lists patents granted to residents and according to the category of patent holder. It will be noted that the great majority of these were granted to Brazilian individuals or private enterprises. It is possible, however, that foreign enterprises use individuals to

register some of their inventions. It is also surprising how few patents are registered by universities and research institutes. Again, it is possible that inventions made in universities will be registered either by state or other private enterprises that have contracted out research to them and that many individuals working at universities register inventions under their own names. In addition, state sponsored research has tended to be of a less applied nature, giving rise to fewer opportunities for the registration of patents. To place Brazil's patenting performance in context, in 1991 the United States granted 51184 patents to residents, Japan 30453, Germany 16576, Korea 2553 and Brazil 341.

An important issue, already raised in the context of Brazil's pattern of technological development in the 1950s is that of the role of foreign capital. As was previously suggested, it is generally thought that multinational corporations perform little R+D in their subsidiaries. Relatively little research has been conducted on this issue within the context of Latin America. Using data from the US Department of Commerce for US multinationals, we have been able to draw the following observations for the year 1994:[23]

1) US Multinationals' expenditure on R+D in manufacturing in the parent company amounted to 4.0% of sales, while in subsidiaries it amounted to 2.4% : in industrial chemicals it was 3.7% versus 1.8%; in industrial equipment and machinery it was 6.0% versus 2.7%; in electronic and other electric equipment it was 5.2% versus 2.7% and in transportation equipment it was 4.2% versus 2.7%.

2) US multinational employment in R+D as a percentage of total employment it was 6.0% versus 4.4%, industrial chemicals 6.1% versus 4.3%, industrial machinery and equipment 10.1% versus 3.9%, electronic and other electrical equipment 7.3% versus 4.3%, transportation equipment 6.4% versus 6.7%.

3) US multinational expenditures on R+D in subsidiaries as a proportion of gross sales was 0.4% for Latin America as a whole, 0.7% for Brazil and 1.1% for Europe

The data show that there is a great deal of evidence that there is a tendency for multinationals to concentrate R+D in the home country. It is even possible that most R+D carried on within multinational subsidiaries tends to be adaptive rather than basic. Further data and analysis would be required to substantiate this possibility.

23 US Department of Commerce (1996).

Although the public sector (including state enterprises, research institutes etc.) has, on average, been responsible for 80% of Brazilian R+D expenditures, it was only responsible for 13.13% of patents in 1986, 18.22% in 1989, 16.53% in 1992 and 13.24% in 1993. In 1989 state enterprises spent US$ 300m but only accounted for 13.7% of total patents while private enterprises spent US$ 190m and received 50.5% of patents.(Albuquerque, p. 63)

Table 5
Invention Patents Granted to Residents in Brazil
According to Category of Patent Holder

Year	A	B	C	D	E	F	G	H	Total
1986	158	151	46	42	13	0	0	9	419
1989	148	172	72	66	16	6	0	3	483
1992	81	91	23	27	9	3	0	2	236
1993	107	164	30	33	8	3	3	7	355

Key: A- Individuals, B- Brazilian Private Enterprise, C- Foreign Enterprises, D-State Enterprises, E- Universities and Research Institutes, F- Government Agencies, G-Firm-University Partnerships, H-Others.
Source: Revista de Propriedade Industrial Reproduced in Albuquerque (1996:64).

In the industrial census of 1985, of 55944 firms questioned, only 2117 reported having made expenditures on R+D, patents and transfer of technology contracts. Also, IBGE data showed that out 175652 industrial firms only 1.2% made expenditures on technology in 1985. Of the previously mentioned 2117 firms, 1149 made expenditures on R+D, 662 made expenditures on patents and 413 had transfer of technology contracts. R+D expenditures were basically concentrated in two sectors : chemicals and petrochemicals accounted for 31.4% of these expenditures and mechanical equipment (contains automobiles, electronics, machinery and metallurgy) accounted for 58.7% of these expenditures. According to ANPEI data for 1994, the capital goods sector was investing 1.19% of gross sales in R+D compared to the average for the industrial sector of 0.6%.

Brazilian firms spend little on R+D both in relative and absolute terms (Albuquerque p,65). The forecast of MICT (the Brazilian industry ministry), is that investment in R+D should rise from 1.2% of gross sales of productive firms in 1997 to 2.6% in the year 2001, according to the intentions revealed by manufacturers. The data are based on an inquiry by the Brazilian industry and commerce ministry on technology investment intentions of 1012

private sector industrial firms for the period 1997-2001. Out of these firms the results show that these firms still invest only a small amount of resources in technological development although all expressed intentions to increase total investments in the future. 52% of those interviewed invest less than 2% of net sales in technology, 22% stated that their expenditures are between 2% and 5% and 14% that they invest more than 5% of net sales while 12% did not respond to the question (Gazeta Mercantil 23/7/97).

One of the study's researchers stated that "today resources are used more for modernising the industrial park rather than technological development...but some sectors, such as chemicals and printing have engaged in research activities comparable to the best in the world" The researcher also stated that to get around problems of a dearth of research laboratories in productive firms, it is important for these firms to have strong relationships with technological centres and universities. It was also stated that this was the only way for Brazilian firms to match the large multinationals which have large laboratories in their parent firms to serve their subsidiaries.

Table 6 explains the results of a survey by ANPEI, an organisation promoting innovation in enterprises. The first part of the table divides R+D and engineering expenditures into R+D, technological services, licensing and special engineering services. Pure R+D expenditures seems to dominate in such industries as ceramics, transport equipment, chemical, measuring equipment and rubber and plastics. Special engineering services, however, were quite important in such industries as machinery and metal products. In the machinery industry, the complex nature of the manufacturing process gives rise to the need for heavy expenditures on production engineering, hence the greater relative importance attaching to special engineering services. Quite notable is the fact that public enterprises spent the largest proportion on R+D and technological services while both the multinational and private sectors spent more on external technological acquisition.

Table 6
Distribution of R+D and Engineering Expenditures, 1996

	R+D	Technological Consulting Services	Technological Licensing	Special Engineering Services	TOTAL
Food	75.6	5.9	7.8	10.7	100.0
Ceramics	84.8	1.4	11.6	2.5	100.0
Electrical Equipment	57.3	8.5	10.4	23.8	100.0
Transport Equipment	84.1	8.0	2.5	5.4	100.0
Measuring Equipment	75.2	6.8	1.0	17.0	100.0
Machinery	41.0	9.8	15.5	33.7	100.0
Metals	27.0	24.8	22.1	26.1	100.0
Paper/Cellulose.	53.7	7.9	8.3	30.1	100.0
Plastics & Rubber	72.2	5.6	13.5	8.7	100.0
Metal Structures	48.3	8.3	8.6	34.8	100.0
Chemicals	61.8	10.0	8.6	19.6	100.0
Private Domestic	54.2	12.0	12.0	21.8	100.0
Private Multinational	55.5	14.1	11.8	18.6	100.0
Public	61.6	20.0	7.8	10.6	100.0

Source: Calculated from ANPEI 1996.

Tables 7 and 8 describe the type of research being carried out in the 1990s. It will be noted in Table 7 that hardly any resources go into basic research. The large proportion of resources going to applied and experimental research reflects the fact that most R+D in Brazil concentrates on the adaptation of known products and process. This pattern of innovative effort is, in fact, long established and can be traced back long before the onset of policy liberalisation in the 1990s (ECIB, 1993). Table 8 illustrates the division of R+D effort into product and process innovation. This table shows that, despite the wave of plant restructuring and upgrading in the 1990s, the largest proportion of R+D has gone into product development.

Table 7
R+D Activity by Type 1991-3

Year	Applied Research	Basic Research	Experimental Research
1991	33.1%	2.9%	64.0%
1992	34.7%	1.2%	64.1%
1993	37.4%	4.3%	58.3%

Source: Matesco & Hasenclever (1996, p. 474).

Table 8
R+D Activity by Type of Activity 1991-3

Year	Product	Process	Other
1991	56.9%	36.8%	6.3%
1992	52.2%	38.5%	9.3%
1993	55.5%	44.5%	n.a

Source: Matesco & Hasenclever (1996, p. 475).

It is also interesting to compare expenditures on R+D against those on production engineering. The latter represents expenditures realised on the implementation of designs, mainly based on existing technologies. It may be noted in Table 9 that in most cases R+D expenditures are substantially smaller than expenditures on production engineering. The data are especially interesting in that they bridge the phase of profound policy liberalisation that occurred between 1989 and 1992. While increases in R+D expenditure occur in all but one sector, it must be noted that the changes involved are very small. To put things further into perspective Teixeira & Ferraz (1997) note that "in international technology based industries, 5-10% R+D to sales expenditures are common" In Brazil such industries experienced a decline in this ratio from 2.3% to 1.8% between 1987-89 and 1992" [24]

24 Teixeira & Ferraz (1997, p. 13).

Table 9
R+D and Engineering Expenditures (% of Total Sales)

Categories	Capital Goods		Commodities		Durable Goods		Traditional Goods	
	87-89	1992	87-89	1992	87-89	1992	87-89	1992
R+D	2.3	1.77	0.4	0.46	0.66	0.7	0.51	0.59
Production Engineering	2.05	1.86	1.26	1.94	1.79	2.21	0.52	0.47

Source: Ferraz, Kupfer & Haguenauer (1996).

4 Privatisation and technological effort

As Brazil's privatisation process went into high gear in the mid 1990s there has been concern about the implications of this trend for the country's R+D efforts. In an article dealing with the changing role of the state in Brazil's economic development, Baer & Villela (1994) hypothesised that there was a risk that the privatisation programme would result in a decline in national R+D efforts. This hypothesis was based on a study of a sample from the 1985 industrial census, which found that the amount of research and development expenditures per employee was 2.5 times larger in state than in private enterprises.[25] In similar vein, Erber and Amaral (1993) expressed their concern that future privatisation in the fields of petroleum and petrochemicals, electricity and telecommunications would result in a decline of the research done by the state enterprise research centres in each of these fields.

Armando Castelar Pinheiro (1996) organised a special survey to examine the validity of these hypotheses. From a sample of 25 enterprises that had undergone privatisation a variety of data was collected on technological effort. The preliminary findings of this survey were that in the period immediately following privatisation there was no reduction in R+D even though the total number of employees in each enterprise declined. Thus there was an increase in R+D expenditures per employee. It is difficult to conclude from these findings, however, that privatisation will inevitably have a positive impact on R+D activities. Also, these findings were based on responses to questionnaires in which each firm had to fill out their estimate of what they spent on R+D. It is far from clear what each firm's definition of R+D was. Hence substantially more research needs to be undertaken within such a framework.

In 1997 the present authors conducted interviews with representatives of two recently

25 Baer and Villela (1994, p. 14).

privatised firms (the largest in their respective sectors), and one major research institutes undertaking projects for privatised enterprises and a major state agency charged with conducting the privatisation programme. These interviews have led us to the following observations which, hopefully, could be more rigorously tested at a future date when more systematic information is forthcoming:

Firm 1

1) The firm stated that in 1996/97 it spent about 0.4% of gross sales on R+D.

2) A large proportion of its new technology is acquired through the machinery it purchases

3) A large proportion of its new technology is bought outside of the firm.

4) Some new technology is acquired through technology exchange agreements with firms in other countries in the same sector.

5) A substantial proportion of its research is outsourced to university research institutes.

6) The company's research institute suffered substantial manpower cuts when efforts were made to restructure the firm, based on recommendations from an international consulting firm. This involved substantial discontinuities in research activities.

7) A large proportion of the research is of an assistential nature; that is, to solve specific problems of clients.

8) Little of the research is done at the frontier of knowledge in the firm's field of specialisation.

9) At the time of the interview the firm had just been privatised and its senior researchers expressed concern about the support they would get from the new owners.

Firm 2

1) Following privatisation, the enterprise had engaged in a substantial programme of modernisation.

2) Like Firm 1, a programme of personnel cuts had been implemented in the R+D

department in the period up to, and immediately after privatisation.

3) The majority of R+D effort is focused on the adaptation and implementation of newly acquired capital equipment to suit local production conditions.

4) Much of the technological advances enjoyed by the firm were the direct result of technological improvements embodied in newly purchased equipment. Despite the domestic origin of some of this equipment, the vast majority of the embodied technologies were of foreign design.

5) Although adaptive R+D had made some strides in the post privatisation period, the scope of more ambitious basic R+D had been reduced.

6) As in the case of Firm 1 increasing use was being made of external sources of technological competence, principally among university research institutes.

7) The technological heterogeneity of the sector in which Firm 2 operates was stressed. One other major enterprise in the sector, in contrast to the firm interviewed has maintained and enhanced a more ambitious programme of technological development, embracing a greater degree of self reliance.

8) Despite the existence of interesting exceptions, the majority of enterprises in the firm's sector remained highly technologically dependent, particularly on foreign sources of technology. Trends within the capital goods industry supplying the sector were only serving to intensify this tendency.

The Research Institute

1) Representatives of the institute stated that the outsourcing of technological projects had sharply increased following privatisation. University-firm linkages were now much stronger than they had been in the past.

2) A number of reasons underlay this development. First, current management practice among privatised enterprise had embrace the concept of outsourcing as enterprises strove to achieve cost savings in the light of intensified competition. Perhaps more significantly, Law 8661 and the PDTI had positively encouraged firms to outsource technologically given the nature of the fiscal incentives on offer and the conditions attaching to them.

3) The institute was currently engaging in a large number of consultancy projects with many privatised enterprises, particularly in the steel sector. Among important projects had been the development of a pulverised materials injector and the conversion of an electric arc furnace into a plasmatic arc furnace.

4) Within the steel sector, a new fund has been set up under the ABM (the Brazilian Metallurgy and Materials Association) to fund more ambitious R+D projects. To some extent, this might ease some of the pressure exerted on basic R+D by cutbacks at the enterprise level.

5) For representatives of this research institute, the trend towards outsourcing of technological projects was seen as likely to continue into the future.

What would be one's *a priori* expectations about the impact of R+D of a shift in the ownership structure of industry towards the private domestic and multinational sector? As shown above, the multinational companies have a bias for strategic reasons towards concentrating their R+D in the parent company´s home country. At the same time, domestic Brazilian firms have had little tradition in placing a substantial amount of resources into R+D. Moreover much of their R+D effort has tended to focus on minor technological adaptations. On this basis, there is reason to suspect that R+D efforts might well come under pressure following privatisation. We have shown that the Pinheiro's survey, based on questionnaires, would tend to reject this hypothesis. Our field interviews, however, support it. Substantial further research needs to be undertaken to arrive at a more definite conclusion.

5 Concluding points

In this survey we have first traced the evolution of Brazil's various technology policy régimes. We have shown that in the classic ISI period of the 1950s and early 1960s, the implicit policy of that time was to establish domestic industries with little concern about their technological content. A large proportion of these initial industries were established with imported second hand equipment which often meant that the initial technology was not of the latest generation. The efforts to diversify exports in the late 1960s and 1970s led many sectors to upgrade their capital equipment in order to compete internationally. In the second half of the 1970s the programmes of import substitution in capital goods deepened national technological capabilities. In the 'lost decade' of the 1980s the country´s technological capabilities were allowed to stagnate as investment dramatically declined while a misbegotten attempt was made to make the country self sufficient in one sector of

the computer industry. Finally, in the economic opening and privatisation of the 1990s long established sources of state support for advanced technology were sharply eroded while the precise technological stance of the newly privatised enterprises remained to be seen.

Throughout the post World War II period , Brazilian expenditures on industrial R+D were very low in comparison with advanced industrial countries. Much of this relatively small research effort was directly or indirectly related to government activities either in the form of subsidies to universities and research institutes or in the activities of state enterprises in selected sectors such as steel, petrochemicals and public utilities. The islands of technological excellence that emerged during this period were exclusively related to the productive activities of the public sector. The private sector, by contrast, remained extremely limited in terms of its overall contribution to the development of greater domestic technological self reliance. This tendency was compounded by the heavy presence of multinational corporations in the technologically more advanced sectors such as automobiles and electronic equipment. For these enterprises, the majority of R+D activity was conducted within the home countries of the parent company.

Our survey of recent Brazilian technological efforts reveals that the onset of liberalisation has done little to intensify attempts to become more technologically self reliant or capable. Although the various performance indicators point to gradual improvements since the start of the 1990s, Brazil still lags a long way behind other industrialised nations in terms of expenditures, patenting activity and basic research. Indeed, the remarkable feature of Brazil's pattern of technological acquisition and development is how little it has changed, despite the magnitude of alterations in the policy environment. In essence this pattern has remained broadly similar since the 1950s, being constituted by a continuing heavy reliance on imported designs allied to the execution of minor local adaptations. The very persistence of this situation is suggestive of the enormous institutional and policy changes which would need to be wrought in order to effect a significant positive impact.

Of course, it may be claimed that a developing country like Brazil should concentrate on improving the efficiency of its industrial sector rather than spending resources experimenting on the technological frontier. Such efficiency improvements would focus on the pursuit of static efficiencies. Any dynamic gains would be effected through the import of technology, whether incorporated in equipment, foreign direct investment or technology transfer agreements. There remains a powerful counter argument to such a policy recommendation, however. This argument rests on the fact that experimenting on the technological frontier has often proved to be a precondition of rapid industrial growth in

many industrial sectors within advanced economies. Indeed, within Brazil, where technological activity has approached or crossed the frontier, the results in terms of sector dynamism and sales growth has been quite impressive. For example, major frontier contributions have been made in deep sea drilling for oil, long distance electricity transmission and banking automation etc. Permanent technological presence behind the frontier and a specialisation in items advanced in the product cycle will not offer such enticing growth prospects.

In the context of an emerging privatised economy, undergoing unprecedented exposure to the forces of international competition, the need for technological competence and a degree of self reliance is as acute as ever. Given the Brazilian state´s retreat from the role of producer, traditional forms of support for R+D activity are no longer sustainable or viable. Instead, the state will have to focus on the provision of other measures to encourage domestic innovative efforts through the selective provision of incentives to the private sector and subsidies to universities and research institutes which would also be conditioned on their having a relationship with the productive sector. There are already numerous signs that the state has begun to move in this direction. Moreover, the preliminary indicators are that these policies are meeting with some success. However, given the low base from which policy makers start, there is a long way to go.

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