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Roberto Mazzoleni

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Luciano Martins Costa Póvoa

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Accumulation of Technological Capabilities and Economic Development: Did Brazil's Regime of Intellectual Property Rights Matter?[♣]

Roberto Mazzoleni

Hofstra University, Department of Economics

Luciano Martins Costa Póvoa

Universidade Federal de Goiás, Department of Economics

Resumo

Este artigo apresenta uma análise histórica sobre o papel das leis de patentes na acumulação de capacidades tecnológicas da indústria brasileira. Em particular, são analisadas as indústrias aeronáutica, farmacêutica e de extração de petróleo. Embora o Brasil tenha sido um dos primeiros países a conceder patentes a inventores, tanto o processo de industrialização quanto o desenvolvimento de capacidades tecnológicas ficaram atrasados em relação à criação das primeiras leis de patentes. Entre as principais razões para este atraso estão os fracos incentivos para a inovação durante o período de substituição de importação e o papel apenas secundário das patentes em setores em que a acumulação de capacidades tecnológicas foi foco de outros instrumentos de política industrial.
Palavras-chave: Patentes, indústria brasileira, tecnologia.

Abstract

This paper presents an historical analysis of the role of intellectual property rights and the accumulations of technological capabilities in Brazil. The aircraft, pharmaceutical and oil industries are analyzed in detail. While Brazil was then among the pioneers worldwide in recognizing the social value of inventive activities and the importance of protecting and rewarding the work of inventors, both the industrialization of the country and the development of technological capabilities have lagged significantly behind the creation of patent laws. Key reasons for this include the weak incentives for innovation in industries that grew behind the walls of protectionist policies and the second-order significance of IPR in the sectors where the accumulation of technological capabilities was a direct focus of other policy instruments.
Key words: Patents, Brazilian industry, technology.

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1. INTRODUCTION

The development of the Brazilian economy provides a very interesting perspective on the role of Intellectual Property Rights (IPR) in the process of accumulation of technological capabilities. This is because Brazil was one of the earliest adopters of a regime of protection of the rights of inventors. Indeed, it developed a regime of patent laws before Portugal, of which the country was a colony until 1822. While Brazil was then among the pioneers worldwide in recognizing the social value of inventive activities and the importance of protecting and rewarding the work of inventors, both the industrialization of the country and the development of technological capabilities have lagged significantly behind the creation of patent laws.

Accounts of Brazilian economic development identify in the last quarter of the nineteenth century a first phase of progress in the transformation of its productive activities. However, a sustained process of industrialization began only after the Great Depression, when the collapse of an economic model based largely on the export of primary goods, most notably coffee, promoted the adoption of national economic policies whose intended purpose was to enable the growth and diversification of the industrial sector of the country. These policies, pursued more or less throughout the following half a century, coincide with a substantial increase in the rate of growth of GDP per capita beginning in 1930 and lasting until the early 1980s. Using Maddison's data, Pinheiro et al. (2001) estimate the annual growth of GDP per capita to have increased from 0.92% during the 1891-1929 period, to 3.03% during the following half a century. The debt crisis of the 1980s mired the country in economic stagnation and even after the widespread implementation of policies aimed at economic liberalization in the 1990s, GDP per capita growth has continued to be sluggish.

When looked at through the lens of GDP per capita growth, Brazil's economic performance through the last two centuries does not offer solid ground to describe its development process as "catching up". Using Maddison's estimates, Figure 1 shows that the ratio between the GDP per capita of Brazil and the U.S. has followed a U-shaped pattern between 1870 and 1980, only to suffer a sharp decline between 1980 and 2003. It would appear then that the clearest phase of convergence between Brazil's GDP per capita and the U.S. is represented by the decades between 1950 and 1980. The same Figure chart shows how Brazil's GDP per capita has fallen from a level substantially identical to Japan's around the time of the Meiji Restoration in the latter country to about 25 percent today.

Whereas the country's economic performance lagged behind that of the advanced economies, Brazil was among the world pioneers in the adoption of IPR legislation. Inventors' privileges were first recognized in 1809, and Brazil's first patent law dates back to 1830. This law held that foreign inventions could not be patented in Brazil, a provision that was abolished formally in the revised patent law of 1882, which adopted the Paris Convention principle of national treatment. Even then, technologies patented in Brazil had to be worked in the country subject to forfeiture of patent rights until 1923 and to compulsory licensing since then. Brazil exploited also the freedoms provided by the Paris Convention in the direction of identifying non-patentable subject matter. Thus, since 1945, inventors of chemical products, food preparations, and medical procedures were excluded from the patent privileges. Chemical processes were added to this list in the 1969 patent law. These exclusions were modified again in 1996 in order to comply with the TRIPS agreement. The most important modification concerned the patentability of chemical processes and products.

While Brazil adopted relatively early a comprehensive regime of protection of IPR, the working requirement placed foreign firms at a relative disadvantage, insofar as importation of patented goods into Brazil was not considered an acceptable form of meeting the requirement at least until the patent reform of 1996. The law therefore attempted to strike a balance between providing incentives for invention and promoting the diffusion of technological advances in domestic production activities. As we will argue in the rest of the paper, the history of Brazil's economic development suggests that the regime of IPR played historically a weak role either facilitating or hindering the learning processes by which domestic firms have mastered key technologies from abroad. Key reasons for this include the weak incentives for innovation in industries that grew behind the walls of protectionist policies and the second-order significance of IPR in the sectors where the accumulation of technological capabilities was a direct focus of other policy instruments.

2. AN OVERVIEW OF BRAZIL'S ECONOMIC DEVELOPMENT

Brazil's economy grew very rapidly during the first three quarters of the twentieth century (Figure 2). During that period the technological capabilities of the country's business enterprises progressed unevenly, and only a few sectors of the Brazilian economy 'caught up' with the technological frontier. Among the latter, we highlight aerospace, where Embraer has emerged as one of the world's technological leaders, and oil exploration and drilling, thanks

to the rapid increase in the technological capabilities of the erstwhile national oil company, Petrobras. For most other sectors, the process of catching up is still a work in progress. We will comment further on this unevenness in the remainder of this section, after reviewing briefly the kinds of government policies that influenced the country's industrial development. Drawing from existing studies, we present below an overview of indigenous innovative activities and of the mechanisms which promoted the absorption of foreign technological knowledge. This will set up a discussion of the current differences in the intensity and sectoral distribution of domestic innovative activities between Brazil and the advanced economies.

2.1 - Government policies and industrial development

The acceleration of aggregate and per capita GDP growth rates between 1930 and 1980 was accompanied by a substantial change in the structure of the Brazilian economy. At the beginning of this period, the agricultural sector accounted for 36.3% of GDP and nearly two thirds of employment. Corresponding figures for industry were 17% and 13.6%, respectively. By the end of the period in 1980, agriculture's share of output had fallen to 10.1%, and industry's had risen to 40.9%. Both sectors accounted for about 30% of national employment.[1]

Before 1930, industrialization had made only modest progress in the Brazilian economy. Early waves of industrial investment focused on the production of non-durable consumer goods (including cotton fabrics, hats and shoes, grain and sugar processing, breweries, and matches), metal processing, machinery, and paper processing. Indigenous production of cement, steel, electrical machinery, agricultural and construction machines, rubber products, chemical and pharmaceutical products, began in the 1920s and enjoyed a period of modest expansion until the economic depression of the 1930s.

Because coffee sales accounted for about 80% of all the export receipts, the collapse of the coffee market had drastic consequences for the country's balance of payments, aggravated by the reduced access to foreign financial capital during the decade. Efforts to resolve the country's debt crisis through exchange rate controls and currency devaluations provided incentives for import substitution through the growth of domestic industrial production. In addition, the government invested directly in industrial sectors deemed to have

[1] Since 1980, both the agricultural and industrial sectors have seen their share of national employment decline at the same time that their share in the country's GDP has either risen (agriculture) or remained nearly constant (industry).

strategic significance during the 1930s and 1940s. These efforts lie behind the establishment of the Companhia Siderurgica Nacional (CSN) in 1941, of the Companhia Vale do Rio Doce (CVRD) in 1942, and the development of the country's energy and transportation infrastructure.

Concerns with the country's industrial development dominated government policy during the postwar period. Indeed, an important goal of the 1945 patent law reform was promoting the growth of specific industrial sectors, such as chemicals, pharmaceuticals, and food processing. More generally, since the 1950s Brazilian policy makers pursued the country's industrialization based on import substitution (Baer, 2002). Suzigan and Furtado (2006) argue that this phase of industrial development was characterized by the emergence of a broad division of labor among the public sector, foreign and domestic capital. The State was the key actor in the development of infrastructural sectors, and base industries. Foreign capital dominated the dynamic industries, and indigenous capital focused instead on traditional industries and on the activities that were complementary to those of the industries dominated by either the state or foreign capital. The government acted as a coordinator, planning, financing, and organizing the industrial investments. Even then, it should be noted that the pursuit of long term industrial policy objectives by the Brazilian government was weakened by the recurrence of inflationary conditions during the 1960s and the political turmoil that brought about the establishment of a military regime in 1964 (Suzigan and Furtado, 2006).

Key policies of the period from 1950 to 1980 were the Plan of Targets (1956-1960) and the Second National Plan of Development (1974-1979) (Suzigan, 1996). The former targeted the development of energy and transportation infrastructure through public and private investment (national and foreign), implemented protective tariffs and exchange rate controls whose purpose was to support domestic firms and to induce foreign firms' direct investment in Brazil. These measures –the hallmark of Brazil's strategy of import substitution industrialization—succeeded in promoting more rapid industrial growth and foreign direct investment, particularly in the automotive and pharmaceutical sectors. The latter built upon the strong growth record during the period 1968-1973.[2] In the aftermath of the first oil crisis, the Second National Plan of Development (II NPD) laid out a development strategy targeting intermediate and capital goods sectors, and advanced technology industries (telecommunications, aircrafts, nuclear energy, and informatics). Industrial development goals

[2] During the years of the "Brazilian economic miracle" GDP grew at an average 11,2% annual rate, thanks to macroeconomic policies oriented to the promotion of investments and exports.

played also an important role in the 1969 reform of the patent law. In particular, the expansion of the definition of non-patentable subject matter –which came to include pharmaceuticals processes as well as products, chemical products, and metallic alloys – was intended to foster the growth of domestic industries. By the end of the 1970s, Brazil's industrial structure had already become quite diversified but the growing internal and external debt, and increasing inflation, became the nearly exclusive concern of policy makers for the following decade. Industrial policy was once again relegated to the sidelines.

After the restoration of democratic rule in 1988, the main objectives of national economic policy were controlling inflation and promoting liberal reforms in the economy, including trade liberalization and the privatization of several state enterprises. This policy orientation was mirrored in the 1996 patent law reform, which eliminated the restrictions on patentability of pharmaceuticals, chemicals, and food processing, in compliance with the TRIPS agreement. According to Suzigan and Furtado (2006), the greater openness to foreign direct investment and trade liberalization changed the economic environment for indigenous firms. Weakened by years of stagflation and protection, these firms were poorly equipped to deal with the competitive pressures brought about by imports and foreign investments. As a result, Brazilian firms were forced to restructure, and to seek productivity and quality improvements at a time when the national government was not pursuing an active industrial policy. Only in 2003, President Lula's administration formulated the Industry, Technology, and Trade Policy (PITCE) aimed at fostering national competitiveness through technology development and innovation.

2.2 – Indigenous technological learning and inward technology transfer

The accumulation of technological capabilities by domestic firms that accompanied Brazil's economic development reflected for the most part efforts at acquiring and mastering technological knowledge originating from abroad. Indigenous efforts at developing globally innovative products and processes have so far played a much lesser role, although the balance between these modes of knowledge acquisition has been changing over time and presents substantial variation across industrial sector based on the extent to which foreign technologies could address adequately the technical challenges faced by local firms. In the following sub-sections we will sketch an overview of the historical evidence regarding patenting activity in

Brazil and several characteristics of inward technology transfer processes. The historical review will set up a brief discussion of current patterns of innovative activity.

2.2.1 – Patenting activity in Brazil

Although Brazil adopted a patent system since early in the nineteenth century, the evidence on patenting activities is rather incomplete. Consequently, existing studies shed light only on patenting during the nineteenth century and then again only in the 1980-1995 period. With respect to the former period, patenting activity has been found to mirror quite closely the structure of industrial activities (Cruz and Tavares, 1986; Rodrigues, 1973), with three sectors (foodstuffs, metal products, chemicals) accounting for about 60% of all patents granted between 1830 and 1891. We note here that Brazilian law stipulated until 1882 that prizes would be awarded (but not patents) to individuals or firms who introduced technologies already available abroad. Moreover, the 1830 patent statute required that inventors exploited their patents domestically. These provisions weakened substantially the incentives for foreign firms to seek patent protection in Brazil.[3]

Figures 3 and 4 illustrates the available data on the number of patent applications since 1883. A break in the secular growth of patent applications occurred around the mid-1960s and lasted until the mid-1990s, when the 1996 TRIPS-compliant patent law was enacted. The increase in the number of applications after 1996 is almost entirely attributable to non-resident applicants, who account for more than 80% of the applications filed in 2006. Additional insights on the character of patenting activities in Brazil since 1980 can be gleaned from Albuquerque (2000). Among his results, we find the following to be especially noteworthy:

a. There is a strong positive correlation between R&D spending and patenting activity at the sectoral level.

b. More than half of the patenting activity between 1980 and 1995 is concentrated in four leading industrial sectors: machinery, metallurgy, electrical equipment, and chemicals.

[3] There is no record of any prize ever been awarded to first adopters of foreign technologies (Rodrigues, 1973). It appears however that patenting of foreign technologies became accepted practice sometime before the legal restriction was abolished by the 1882 patent law. However, this law (and all the subsequent revisions to this day) upheld the working requirement, and thus continued to limit the attractiveness of Brazilian patents for foreign enterprises. A more detailed discussion of these developments can be found in section 3.

c. While on average a bit more than 200 firms received one patent in any given year, only thirty-five firms received at least one patent each year. Thus, patenting is for most firms not a routine activity. While these firms might still be innovative, this fact suggests that stable technological activities are a characteristic of only a handful of firms in Brazil.

d. Analysis of the technology areas covered by patents granted to firms in any given sector suggests a substantial degree of technological diversification of the leading firms' technological activities, and thus a modest degree of division of innovative labor among specialized firms.

e. Comparison of the patenting behavior of national firms (private and state-owned) with that of foreign-owned subsidiaries and associates of multinational corporations indicates that the latter receive more Brazilian patents per R&D dollar, and their share of the National Institute of Industrial Property (INPI) patents granted to residents is less than the share of USPTO patents granted to Brazilian residents. As noted by Albuquerque (2000), these data suggest then that foreign-owned firms' technological activities are more likely to focus on adaptive innovations aimed at the local market.

2.2.2 - Inward technology transfer

While patenting data are an important source of information concerning the innovative activities of domestic firms, the process of inward technology transfer that supported Brazil's industrial development relied upon alternative mechanisms. Among the market-mediated channels, the importation of capital goods was in all likelihood dominant. Foreign direct investment (henceforth, FDI) was an important source of access to foreign technologies, one that has been often argued to be sensitive to the strength of IPR protection in the host country. The link between IPR and FDI inflows is complicated further in Brazil by the working requirement for the validity of patents, and by the effects of other policies that strengthened the incentives for FDI independently of the strength of IPR. Note, for example, that the limits to the patentability of pharmaceutical processes and products sanctioned in the patent laws of 1945 and 1969 did not deter FDI by pharmaceutical firms. Indeed, in the aftermath of the 1969 reform, FDI in pharmaceuticals grew from US$ 113 million in 1971 to US$646 million in 1979, more rapidly than in other sectors of the economy (Gereffi, 1983).

Patents appear to have played a minor role in the context of the technology transfer agreement between resident and non-resident firms. As shown in Table 1, payments for technology transfer agreements (including royalties for patent licenses) increased very rapidly since World War II, more so than capital goods imports or FDI.[4] However, a government study found that patent licensing agreements were not a dominant form of inward technology transfer for Brazil's industrial firms (Biato et al., 1970).[5] Only 10.5% of the contracts for technology transfer were accounted for by manufacturing and patent licensing agreements. Technical assistance agreements represented the most common type of technology transfer contract (47%), followed by engineering services agreements (23.6%), and trademark licensing agreements (13.2%). At a sectoral level, only a few industries appeared to be characterized by greater reliance on manufacturing and patent licensing agreements (tobacco products, furniture, textile machinery and components), but they accounted for only small shares of all such agreements. In contrast, the share of technical assistance agreements, trademark licensing, and manufacturing and patent licensing in the pharmaceutical and medicinal products sector were respectively 61.5%, 26.7%, and 11.8%. The analysis of the technology transfer payments made between 1965 and 1970 produced similar results.[6]

The observation that patent licensing agreements represent a small share of the registered technology transfer contracts in this study has to be tempered by two considerations. First, the small volume of licensing agreements might be due to the multinational firms' reluctance to patent and license technologies in an environment characterized by weak enforcement of patent rights, something about which we can only speculate. Second, subsidiaries of multinational corporations were prohibited by law from

[4] As a percentage of GDP, payments for technology transfer rose from 0.12% in the 1947-1953 period to 0.31% in 1970. Moreover, their growth outpaced the growth of the imports of capital goods from 1950 to 1970, going from 3.5% of the latter's value in 1950-1953 to 15.9% in 1969.

[5] This study analyzes nearly 2,000 technology transfer contracts registered between 1963 and 1970 with the Bank of Brazil in compliance with a 1962 law regulating technology transfer contracts requiring payments to foreign entities. Such contracts were subject to regulatory approval) and to legal constraints on royalty payments and the assignment of IPR on the result of the licensees' future inventions. Although the study excluded contracts relative to the primary and tertiary sectors, and refined oil products, the industrial sectors within its scope accounted for between fifty and sixty percent of the technology transfer agreement payments recorded in the international balance of payments on account of technology transfer agreements during the period 1965-1970. About two-thirds of the contracts were accounted for by five sectors (Metal Products, Chemicals, Mechanical Equipment, Electrical and Communications Equipment, and Transportation Equipment). These same sectors plus textiles also accounted for two-thirds of the 729 enterprises represented in the database. All of these industrial sectors had experienced a substantial expansion as a result of the import substitution policies pursued by the governments since 1950.

[6] Manufacturing and patent licensing agreements accounted for a significantly larger share of total payments only in: tobacco products (57.8%), intermediate products for plastics, resins, synthetic fibers, and detergents (41.3%), and textiles (40.5%). The last two sectors accounted for little more than 30% of all licensing royalties. In contrast, the pharmaceutical and medicinal products' sector accounted for only 1.4% of these royalties. Most (92.4%) of this sector's payments for technology transfer originated from technical assistance agreements.

making royalty payments to their mother company abroad on account of patent licenses, so that technical assistance agreements might have served as a way to carry out implicitly a royalty payment. While payments for licensing agreements between subsidiaries and parent companies would be understated as a result, our examination of the data suggests that the effect is qualitatively small.[7]

A parallel investigation focused instead on the production of technological knowledge at firms and public research institutions located in Brazil (Biato et al., 1970). The investigation of technological activities carried out in the period 1967-1969 was based on questionnaire responses by 454 of the largest 500 business firms in Brazil and 46 research institutions.[8] Only 64% of the responding firms (61% of domestic firms and 75% of foreign ones) indicated that they had conducted some industrial research during the survey period. Moreover, for two-thirds of them the research concerned adaptations of existing technologies, whereas only 16% of them reported working on creating new product or process technologies. At the industry level, around 80% of respondents reported carrying out research activities in the machinery industry, transportation equipment, electrical and communications equipment, and metal products. Exploiting the database of technology transfer agreements described above, Biato and Guimaraes (1973) established that firms carrying our at least some R&D were more likely to also seek opportunities for technology transfer agreements with foreign firms.

Interactions between firms and research institutions made only modest contributions to the accumulation of technological capabilities by the former. These interactions were not very diffuse, they focused on routine activities such as testing. By the same token, only one-third of the technological activities carried out by research institutions represented the response to specific demands from industrial firms, and these consisted for the most part of routine testing tasks to be performed on behalf of firms in the metal products, foodstuffs, and transportation equipment industries. These sectors, together with chemicals and paper products, accounted also for 85% of the research activities carried out by the surveyed institutions.

[7] Agreements between subsidiaries and parent companies accounted for about 40% of all manufacturing and patent licensing payments, which in turn represented less than one tenth of all payments for technology transfer (18.4% for foreign firms' agreement with independent firms, 7.9% for national firms' agreements, and 5.1% for foreign firms' agreements with parent companies).

[8] According to these data, 62% of the responding firms reported that they relied upon foreign sources of know-how in order to establish their activities. Moreover, this share was higher for younger firms. Know-how from domestic sources was relied upon by 51% of national firms, but only by 15% of foreign firms. Among the firms that relied upon foreign sources of know-how, 38% required adaptations of the relevant technologies which were carried out either domestically (21%) or abroad (12%) or both domestically and abroad (5%).

2.2.3 – From the acquisition of foreign technological knowledge to indigenous R&D efforts

The government's tight regulatory control over technology transfer agreements in place since the early 1960s was vanquished by 1993. This policy shift was consistent with the progressive liberalization of markets pursued by the Brazilian government since the late 1980s. More specifically, the liberalization of international technology flows was held to be necessary in order to promote the future development of national firms' technological capabilities and thus their innovative performance. Whether the loosening of restrictions to international technology flows is promoting or hindering such outcome depends largely on the extent to which firms will treat access to foreign technological knowledge as a substitute for, instead of a complement for, their own technological efforts.[9] It is useful then to review the contemporary characteristics of innovative activities carried out in Brazil. We do so on the basis of the Industry Technological Innovation Survey carried out in 2000 (henceforth, PINTEC 2000) by the Brazilian Institute of Geography and Statistics (IBGE).

About one third of the country's industrial firms reported to have introduced innovations, but only around 10% carried out internal R&D activities. Only about half of the latter did so in a continuous manner. A considerable share of the country's R&D is carried out by government labs, private and public universities or research centers, so that the private sector accounted in 2000 for only one third of the national R&D performed. While R&D intensity among all manufacturing firms is estimated at 1.5% of value added, lower than in most OECD countries, international comparisons at the sectoral level highlight the fact that the low overall level of R&D intensity for Brazilian manufacturing industries is not simply the result of the different pattern of productive specialization in the national industry.

While the structure of the country's industrial value added reveals a pattern of productive specialization in sectors with low and medium-low technological intensity, Furtado (2005) emphasizes the presence of substantial differences across the R&D intensity of medium-high and high technology sectors of Brazil and other OECD economies. In the year 2000, for example, R&D intensity in the pharmaceutical sector was only 1.5% in Brazil, but 19.9% in the U.S., 27.6% in France, and 54.2% in the U.K. These differences are

[9] Using patent applications as a measure of firms' innovative capabilities, Johnson (2002) establishes that the relationship between firms' R&D and patenting is mediated by the firms' prior experience of technology licensing and the strength of the knowledge spillovers in the relevant areas of technology.

explained by Furtado in terms of: (a) the presence and importance of the activities of multinational corporations; (b) the level of local content in the industry output; (c) the tacitness or codified nature of core technological knowledge; and (d) the sectoral effects of government policies. Accordingly, he suggests that the low R&D intensity of the local pharmaceutical industry is the result of the dominant role of multinationals, the dependence on imports of high-value-added inputs, the low level of tacitness of the relevant technological knowledge which reduces the importance of local efforts at developing innovative capabilities, and the absence of government policies providing strong incentives for domestic R&D. Given these structural features of the industry, it could be argued that the strengthening of the IPR's regime might reduce further the opportunities for the development of advanced technological and innovation capabilities at local firms (whether national or foreign), rather than stimulating it.

The framework of analysis proposed by Furtado provides an interesting backdrop to the case studies that we will present in sections 4, 5, and 6, of this chapter. Before we turn to these case studies, the next section reviews the key features of the history of Brazilian patent law.

3. THE EVOLUTION OF BRAZILIAN PATENT LAW

The historical origins of Brazil's system for protection of intellectual property can be found in the early nineteenth century when the country's economy consisted mostly of agricultural activities dominated by coffee and sugar cane. Reversing a long standing policy stance designed to stifle the development of any branch of industry in Brazil, the Portuguese rulers – inspired by similar legislation in the U.K. and the U.S.—signed a decree in1809 establishing that exclusive privileges be granted to "inventors and first adopters of any new machine or invention in the arts."[10] The decree provided for the examination of inventors' or adopters' petitions and established a working requirement whereby inventors had to practice the invention locally within two years or lose the patent privilege. The impact of the regime

[10] During the colonial period, the Portuguese rulers discouraged the development of industry in Brazil. The most drastic measure was taken in 1785 by Queen Maria of Portugal, barring all manufacturing activities in the fields of metal products, textiles, and the processing of gold. When the royal family fled from Portugal under British naval protection in 1808, Brazil became the political center of the Portuguese kingdom for a thirteen-year period. Only then, the conditions of Brazil's cultural and economic development began to receive greater attention, and a number of legislative measures were taken in order to promote the modernization of the country.

created by the 1809 decree was modest. Only 26 privileges had been granted by 1830 when the first Brazilian patent law came into effect (Rodrigues, 1973).

While preserving many basic features of the existing system (novelty and usefulness requirements), the 1930 law changed the duration of patents (between five and twenty years depending on the significance of the patented invention) and provided for the patentability of improvements over existing techniques. Another novelty was the substitution of the exclusive commercial privileges for first adopters of foreign inventions (whether patented abroad or not) with a monetary prize. If, as argued by Rodrigues (1973), the Brazilian government never made any budgetary allocation to provide these financial rewards, the provision eliminated any legal incentive to the adoption of technologies invented and patented abroad. To be sure, dissatisfaction with the legal bar against granting patents on foreign inventions built up since the 1860s and patent grants to foreigners, as for example in the case of Thomas Edison in 1879 (RODRIGUES, 1973 p. 662.), were being made even before the provision was repealed in the new patent law of 1882.

The new law –drafted while Brazil participated in the meetings of international delegates that produced the Paris Convention in 1883 –incorporated the key principles of the convention, including rules on priority claims and the principle of national treatment of foreign inventors (GRANSTRAND, 2005). As a result, foreign inventions could be patented in Brazil. In addition to minor changes in patent duration and details of the working requirement, the new law abolished the examination procedure for all patent applications except for those concerning food products, chemicals and pharmaceuticals. These changes contributed to a drastic increase in the number of patents granted. Under the rules of the 1830 law, 677 patents were granted in 52 years. During the first nine years of the new patent regime, 1247 patents were granted. This increase was driven not only by the more favorable conditions of patentability and the extension of patent privileges to foreigners, but also by the increase in the volume and range of industrial production in Brazil since the 1870s (CRUZ & TAVARES, 1986).

During the first half of the twentieth century the regime of IPR was altered twice, in 1923 and 1945. The 1923 patent law restored the examination procedure for all applications, and mandated the publication of invention summaries at the same time that it outlined an external opposition procedure. It also created for the first time the “utility model” patents for minor inventions with duration of ten years. More importantly, it established that the importation of goods protected by domestic patents constituted a violation of the rights of

patent holders. The Code of Industrial Property ratified by the Brazilian government in 1945 modified the working requirement, outlining a procedure for the granting of compulsory licensing after two years of inaction by the patent holder. It also introduced new restrictions on the definition of patentable subject matter. Patent rights were denied on foodstuffs, and materials or substances obtained by means of chemical processes, thus including pharmaceutical drugs. According to CASSIER & CORREA (2007, p. 85), these changes aimed at promoting the development of specific sectors of the national economy. In particular, the bar on the granting of patents on pharmaceutical preparations reflected President Vargas' twin goal of promoting the progress of public health and of the domestic pharmaceutical industry. These policy goals were also central to the changes in the IPR's regime wrought by the 1969 patent law, when the military government broadened the definition of non-patentable subject matter to include pharmaceutical processes, as well as products, surgical and therapeutic techniques, as well as any use of microorganisms. With this reform, patent protection ceased to be available altogether for the pharmaceutical industry until 1996.

The 1996 patent law reflects fundamental changes in the overall orientation of national economic policies in response to the economic stagnation of the 1980s and to the growing pressures from the country's trading partners toward market-oriented reforms and a greater level of protection for the rights of foreign inventors. The inclusion of the TRIPS agreement in the WTO treaty left Brazil with no choice but to revise the national patent system. But it is noteworthy that, unlike other developing countries, Brazil complied with the TRIPS standards of patent protection in 1996, almost a decade earlier than required by the agreement. The decision to comply with the TRIPS agreement ahead of schedule has been argued to reflect the economic pressures brought to bear by the U.S. on the Brazilian government since the late 1980s. Indeed, a legislative proposal had already been formulated in 1991 contemplating a reform of the patent law that allowed the granting of patents on pharmaceuticals (GRANGEIRO & TEIXEIRA, 2007).

The most significant changes wrought by the 1996 reform concerned the definition of patentable subject matter. The restrictions on the patentability of pharmaceuticals and food products were lifted, while computer programs per se, surgical and therapeutic methods, living organisms and biological materials and processes found in nature, were identified as non-patentable subject matter. The duration of utility model patents was extended to fifteen years from filing date (with a minimum of seven years from the grant date), at the same time

that they were made subject to an inventive step requirement. Exploiting the flexibilities afforded by the TRIPS agreement, the 1996 law identified national medical emergencies and failure by the patent holder to supply adequately the domestic market as legitimate reasons for granting compulsory licenses on patented inventions. These stipulations informed the conflict between the Brazilian government and foreign pharmaceutical companies holding patents on antiretroviral drugs (ARVs) covered by domestic HIV/AIDS public health program (see infra, section 5).

This brief historical overview of Brazil's patent law is clearly focused on the rights of inventors as they are defined by the letter of the law. This approach was motivated by the limited availability of data, and by the lack of prior historical research in the area of IPR enforcement. While it is inadequate for the purpose of evaluating the strength of the protection of inventors' rights over time, this approach provides at least a coarse map of the concerns and goals behind the legislative reforms. In this sense, one can observe that several aspects of the system of patent protection manifest the Brazilian government's keen interest in promoting the diffusion among domestic firms of technologies developed abroad. Others, particularly those concerned with pharmaceutical inventions, signal the subordination of patent laws to the goals of industrial policy and public health policy. In light of the government's broad commitment to the industrialization of the Brazilian economy, the weaker protection afforded to pharmaceutical and chemical inventions for much of the last century may appear to be puzzling. It turns out, as shown in the following case studies, that patent rights played an insignificant role in other sectors either promoting or hindering the process of inward technology transfer. In such sectors, weakening them was unnecessary in light of the availability of other, more effective, policy options.

4. THE ACQUISITION OF TECHNOLOGICAL CAPABILITIES IN THE OIL SECTOR: THE RISE OF PETROBRAS

Oil exploration and drilling is undoubtedly one of the sectors wherein Brazilian firms are today on the global technological frontier. This successful instance of technological catching up is associated centrally with the activities of the erstwhile public enterprise Petroleo Brasileiro (henceforth, Petrobras). This company monopolized the oil sector since its inception in 1953, completing a process begun fifteen years earlier that transferred to the public sector the control over the exploration and exploitation of the country's oil resources.

These had been nationalized in 1938, when the government created the Conselho Nacional do Petroleo (CNP). While CNP was the only entity carrying out exploration activities during the following years, it did so with the assistance of foreign firms (Dias and Quaglino, 1993).[11] After the end of World War II, Brazil's political leaders promoted greater participation by private investors in the development of the oil sector. This process came to a halt in the early 1950s when the newly elected president Getulio Vargas placed the industry under exclusive control of a newly created public enterprise, whose remit was to develop an integrated and self-sufficient oil industry in Brazil. Petrobras was born from the alignment of the interests and aspirations of heterogeneous political groups, whose nationalistic ideals coalesced around the slogan "O petroleo é nosso" (transl: "*the oil is ours*").

Two critical and related challenges confronted Petrobras. First, a considerable investment had to be made in exploring the country's sub-soil for the presence of large and economically viable oil fields. Second, this exploratory effort required the employment of human capital and technological capabilities not available in the country, both in terms of quality and of quantity. Remedying these deficiencies was a task made all the more pressing by the expectation that Petrobras would succeed quickly in reducing the country's dependence on foreign oil and thus contribute to improving its trade balance. Petrobras assigned the task of completing the geological survey of the country to a U.S. geologist, Walter Link (formerly chief geologist at Standard Oil Co. of New Jersey). Carrying out the survey provided an important training opportunity for Brazilian geologists. Unfortunately, Link and his team concluded that Brazil's economically useful oil resources did not extend beyond what had already been found in the Reconcavo basin.

Link's conclusions were strongly contested by several Brazilian geologists, and regarded by nationalist political and social groups as one more instance of the effort by foreign trusts to prevent the country from exploiting its own oil resources.[12] Most importantly, the limited success of onshore exploration and drilling activities, and the country's growing dependence on imported oil, led Petrobras to develop a strategic plan that emphasized the exploration of the continental platform off the coast of Brasil, a task that required technological capabilities not available in-house. The acquisition of these capabilities

[11] Standard Oil of Brazil attempted repeatedly to get involved in exploration activities by proposing the creation of partnerships with private Brazilian investors and the government agencies. These attempts were rebuffed most strongly by the military and the CNP leadership on grounds of national security (Smith, 1972).

[12] Link's report was the source of considerable tensions, which led to his resignation in 1961, even though another report by the Brazilian geologists Pedro de Moura and Decio Oddone reached similar conclusions to Link's (Dias and Quaglino, 1993).

relied on a three-pronged investment in: (a) the coordination of consortia of foreign and domestic specialized contractors performing exploration and development activities; (b) internal R&D at the newly formed research department (CENPES); and (c) the accumulation of human capital geared to the needs of the oil sector.

At the time when the firm was established, Petrobras did not have a formal R&D unit. Research and testing activities on behalf of Petrobras were carried out since 1956 in a small laboratory organized within CENAP (a public institution created in 1950 to provide graduate training in geology). The growing technological challenges inherent in the exploration and production activities of the company led to the creation of a specialized research department, the Centro de Pesquisas e Desenvolvimento (CENPES) in 1963. CENPES became the organizational core of the firm's in-house R&D activities, as well as of its diffuse network of scientific and technological collaborations.

A collaborative pattern of technological learning has been a key feature of the firm's interactions with foreign suppliers of equipment and specialized services. Training activities carried out by these firms supported the acquisition and mastery of operational knowledge related to existing technologies, especially in the areas of off-shore platform design, drilling and production systems. Beginning in the late 1960s, the firm's human capital strategy became increasingly concerned with acquiring in-house expertise in geology and petroleum engineering, which would increase its absorptive capacity and its ability to formulate and conduct R&D projects. Accordingly, Petrobras forged a growing web of relations with domestic and foreign academic institutions. For example, Petrobras began sending a few of its staff geologists to the University of Texas at Austin in order to complete their graduate degrees in Geology. A total of 58 Brazilian geologists received academic training in Austin during the period 1968-2003. At the same time, leading scientists from Austin developed working relationships with Petrobras and were frequently invited to Brazil as consultants (Bird, 2007). Similar ties evolved with other foreign and domestic academic institutions.[13] Learning through collaborative research and promoting the development of national

[13] Examples include collaborative research projects with the Universidade Federal de Ouro Preto, the Lamont-Doherty Earth Observatory of Columbia University, and the French Institute of Petroleum in the field of structural geology and tectonics, thanks to which Petrobras acquired advanced capabilities in basin analysis. These capabilities supported Petrobras's 1994 development of three-dimensional basin simulators in collaboration with IBM and domestic academic partners (Dantas and Bell, 2006). Since the launch of its first research program on exploration and production of deep water fields (PROCAP) in the mid-1980s, Petrobras developed particularly close collaborative research relationships with COPPE, a center for research and post-graduate academic work in engineering at the Universidade Federal do Rio de Janeiro, and two research institutes at the Universidade Estadual de Campinas (Erber and Amaral, 1994; Oliveira, 2006; Suslick, 2007).

technological capabilities have been key characteristics of the R&D activities carried out by Petrobras throughout the past four decades.

Early on, R&D efforts at CENPES focused on acquiring technical knowledge related to imported exploration and production equipment (Dantas and Bell, 2006; Ortiz Neto and Dalla Costa, 2007, Furtado and Freitas, 2004). Suppliers and contractors were requested to train Petrobras's personnel, and the trainees were requested to disseminate the technological knowledge they acquired by running internal courses at CENPES. Technological collaborations continued to be the dominant mode of learning when the discovery of the Campos basin in the mid-1970s made exploration, drilling, and production in deep waters the dominant goal of the firm's R&D strategy. Thus, the firm's development of floating semi-submersible platform systems for both drilling and production during the late 1970s and early 1980s was carried out in collaboration with foreign partners such as Kerr-McGee and Gotaverken Arendal, and domestic shipyards (Ortiz Neto, 2006). Research collaborations were also a prominent feature of the PROCAP (Programa de Capacitacão em Águas Profundas) research programs undertaken since 1986, shortly after the discovery of deep-water oil fields in the Campos Basin (Estrella, 2003).[14]

During the first phase of PROCAP, Petrobras carried out 116 R&D projects, many of them involving collaborations with domestic and foreign firms, universities, and research institutes. The development of collaborative relations with these entities has been identified as one of the key indirect benefits of these projects (Furtado et al., 1999; Furtado and Freitas, 2001). Foreign firms were typically involved as sources of technologies that Petrobras wished to license or master through technical collaborations. In some instances Petrobras went so far as to promote the diffusion of the relevant technological knowledge to domestic firms. This strategy was intended to promote the emergence of in-house capabilities and of Brazilian firms that could reduce Petrobras's dependence on foreign firms for future supply and service contracts.

The second phase of PROCAP (1993-1999) – targeting water depths of up to 2,000 meters – represented Petrobras's first R&D effort at the technological frontier.

Whereas 80% of the projects carried out under PROCAP 1000 focused on incremental improvements of existing technologies, 80% of the PROCAP 2000 research budget (US$750

[14] PROCAP was articulated over three phases (1000, 2000, and 3000) defined by the target level of water depths The timing of these phases was: (a) PROCAP 1000: 1986 – 1992; (b) PROCAP 2000: 1993 – 1999; and (c) PROCAP 3000: 2000 – 2006.

million) was allocated to globally innovative projects that targeted the short term needs of the company as it began the exploration and development of off-shore oil fields identified at unprecedented water depths of nearly 2,000 meters (Ortiz Neto and Dalla Costa, 2007). The most notable technological achievements was the development of a Floating Production Storage and Offloading (FPSO) system with Dynamic Positioning (DP). Such a system consists of an oil tanker converted into an off-shore platform, whose accurate positioning in the ocean rests upon the use of a complex set of engines whose operations are determined by positioning data from seabed sensors and GPS. The realization of this production system depended on the development of many component technologies (for example, technologies for anchoring the platforms to the seabed installations, or for reducing the build-up of paraffin on the pipeline walls) whose innovative content made it possible for Petrobras to accumulate a growing portfolio of domestic and international patents. Over time, Petrobras achieved a position of technological leadership in off-shore technologies, as witnessed by the Distinguished Achievement Award that the firm received at the Offshore Technology Conference in 2001.[15]

Petrobras's successful development of technological capabilities and its substantial record of innovation in offshore technology were the result of a carefully planned strategy of technological collaboration with outside entities. As noted by several scholars, the role of Petrobras within the innovative networks and the nature of its R&D activities changed significantly over time. After an early focus on absorbing operational knowledge related to "off-the-shelf" technologies from suppliers and contractors, Petrobras became a more active partner of R&D collaborations aimed at incremental adaptions of existing technology during the 1980s. By the 1990s, Petrobras' growing technological capabilities made the firm a highly desirable R&D partner for other oil companies and supplying firms.

A growing portfolio of domestic and international patents indicates that Petrobras operates now at the global technological frontier. However, there is little evidence that patents represent an important aspect of the appropriability regime today, nor that they did constitute

[15] The last phase of the PROCAP program included not only projects building upon the research trajectory undertaken during the previous phases, but also geological studies aimed at modeling the formation of oil fields and the development of software and hardware for four-dimensional seismic imaging of oil flows. In addition to PROCAP, Petrobras's recent R&D activities included a successful program (PRAVAP) for the development of technologies aimed at enhancing the oil recovery rates from existing fields, and another (PROPES) aimed at resolving the technical challenges of production from the heavy oil reservoirs found at ultra-deep locations in the Campos and Santos basins.

an important element of the institutional environment within which the company acquired its technological capabilities. The monopolization of the sector in 1953 restricted considerably the opportunities available to foreign firms for the exploitation of their technological advantages in Brazil, since they could only operate in the country as suppliers or contractors for Petrobras. Arguably, this setting helped Petrobras to negotiate for access to foreign technologies, technical assistance, and personnel training. Moreover, Petrobras's commitment to promoting the diffusion to national firms of the technological knowledge it garnered from the interactions with foreign partners, led over time to the creation of a domestic industry that could compete with foreign firms in the production of capital goods and the delivery of various services (Furtado and Freitas, 2004).

Intellectual property rights did not constitute in this industry an important obstacle to the accumulation of technological capabilities and the adoption of key technologies, which could be accomplished by importing capital goods and interacting with foreign firms. The existence of multiple sources of technology and of multiple technological approaches to common problems prevented any hold-ups in the industry. When Petrobras closed in on the technological frontier, the character of its collaborations with outside institutions changes but a considerable share of its R&D continued to be carried out in the context of industry projects and collaborative agreements, now including also major oil companies. This institutional feature of the industry appears to indicate the prevalence of a pattern of collective learning that relegates IPR's to a marginal role. These conjectures seem supported by the available evidence on the management of IPR's at Petrobras. For example, the Director General of COPPE at the Universidade Federal do Rio de Janeiro, Angela Uller, was quoted as reporting few direct financial benefits for her institution from the co-ownership of more than seventy Brazilian and foreign patents held jointly with Petrobras. It should be noted in this respect that Petrobras has been a key investor in new facilities at domestic academic institutions and a supporter of their R&D activities.[16]

The main use of patents by Petrobras is said to be for defensive purposes, while the underlying technologies are generally not commercialized or licensed to third parties (Oliveira, 2006). The available evidence indicates that whereas Petrobras has often established ownership (exclusive or joint) over the technologies resulting from technological collaboration with such firms, the resulting patents have not been an important mechanism for

[16] For instance, Petrobras accounts for 80% of the R&D investment in activities of CEPETRO at University of Campinas (Unicamp) (Suslick, 2007).

appropriation of the returns from the R&D efforts. Petrobras has instead sought to facilitate the diffusion of technological knowledge among these firms in order to promote the development of their capabilities and create the conditions for further collaboration in addressing future technological challenges (Dantas, 1999). This pattern of behavior appears in fact to have characterized the innovation process in the industry at large (Bell and Oldham, 1988).

5. THE PHARMACEUTICAL INDUSTRY IN BRAZIL

The development of a pharmaceutical industry in Brazil began during the 1860s, and over the following decades the country experienced a significant growth in the number of laboratories dedicated to the production of various medical preparations. Thirty-five laboratories were active at the proclamation of the Republic in 1889, and their number reached 60 in 1907 when a national census was realized. This period of development was facilitated by the presence of several educational institutions aimed at the training of pharmacists since the first half of the nineteenth century, and the establishment at the turn of the century of several public laboratories whose activities began to encompass research aimed at developing new serums and vaccines. These public laboratories were organized in order to address pressing public health problems, such as the epidemics of smallpox, yellow fever, and malaria, or the need for antiophidic serum. For example, the Butantan Institute was established in 1889 to research venomous animals and to produce antiophidic serum. In 1900, the Manguinhos Institute (nowadays called FIOCRUZ) was founded to produce serum and vaccines against bubonic plague and develop biomedical research. These institutions made significant advances in the understanding and the treatment of tropical diseases and the development of sanitary medicine and biomedical science in Brazil until the 1930s, when they started to face financial constraints (Schwartzman, 1991).

The creation of these institutes made it possible to produce locally vaccines which until then had to be imported. Doing so required knowledge that was not in the public domain that time, as well as efforts to modify, adapt, and standardize production procedures (Schwartzman, 1991). The production of vaccines against the yellow fever was made possible by the scientific and technical work carried out by researchers like Oswaldo Cruz, Vital Brazil, and Carlos Chagas, whose efforts marked the beginning of scientific medical research in Brazil (Stepan, 1981). The public health successes achieved thanks to the research work

were recognized with the award of the gold medal at the 14th International Congress on Hygiene and Demography, occurred in 1907 in Berlin. Notably, Manguinhos´ scientists developed in 1908 a vaccine against a disease that afflicted Brazilian cattle. The patent was assigned to the institute and the profits from the sales became the source of funds needed in order to purchase and maintain laboratory equipment and hire new researchers (Schwartzman, 1991). Manguinhos's effectiveness as a scientific research center declined since the 1930s when reforms introduced by President Vargas brought the Institute under the control of the Ministry of Health and stopped the practice of assigning the profits from the sale of the vaccines to the Institute (Stepan, 1981).

Until the 1930s there were no significant differences between Brazil and other countries with respect to the characteristics of medicines' production. Pharmaceuticals were produced predominantly through the manipulation of natural substances, which were abundant in Brazil, according to small scale processes. The domestic market was accordingly served by many small national firms, although beginning in the late 1910s foreign firms begin to establish affiliates in Brazil. It was only with the advance of synthetic drugs during the 1930s that national firms began to fall behind the global technological leaders. Even the major indigenous pharmaceutical firms did not perform R&D, while U.S. and European firms were advancing in the development of new substances and drugs. As a result, the country was largely dependent on the importation of either formulations or the underlying active principles by the affiliates of foreign pharmaceutical firms (Giovanni, 1980; Quintaneiro, 2002). The outbreak of World War II, and the consequent disruptions to the flow of imports, provided domestic firms (national and foreign) with the opportunity to expand their share of the national market and to develop their exports to Europe and other Latin American markets. It also forced them to reduce their dependence on imported chemicals and finished products (Iffland e Stuttler, 1973 *apud* Giovanni, 1980).[17]

In spite of these developments, local firms continued to neglect carrying out research aimed at the invention of novel drugs and thus to depend on the production of drugs invented abroad. This weakness of the local pharmaceutical industry, and the need to develop domestic capabilities necessary in order to address local public health needs, were key reasons for the decision to suspend the patentability of pharmaceutical products in the 1945 law. The events

[17] The war period also encouraged U.S. multinational firms to enter the Brazilian market. For instance, Merk-Sharp-Dohm settled in 1941, Bristol Myers in 1943, and Shering in 1944. Bertero (1972) *apud* Giovanni (1980) describe the attempt of a Brazilian firm to produce penicillin that time, but a joint venture between two other Brazilian firms and U.S. firms made it not viable.

taking place in the industry during the following decades were however at odds with the goal to promote the growth of the Brazilian pharmaceutical industry.

The process of "denationalization" took place during the 1950s and 1960s confined most Brazilian firms to the market for traditional medicines. Thus, whereas the bulk of medicines sales were realized by national firms in the 1930s, their market share fell to 26% of 1962 sales and to 12% of 1975 sales (Giovanni, 1980). The driving force behind "denationalization" was the acquisition of national firms by foreign multinational groups at a time when changes in pharmaceutical technology appeared to be hurting the creation of new local firms: more than 50 indigenous pharmaceutical firms were acquired by foreign groups between 1957 and 1979 (Brasil, 1980). The surge in foreign direct investment can be attributed to three factors. First, establishing a presence in promising markets was a key aspect of the multinational firms' strategy. Second, rising inflation during the 1950s led to the devaluation of the national currency, making national firms attractive acquisition targets for foreign firms (Brasil, 1980; Machado, 1963). Third, the industrialization policy adopted in the 1950s offered strong incentives to foreign direct investments (Brasil, 1980; Frenkel *et al*., 1978 *apud* Bermudez, 1995; Giovanni, 1980; Machado, 1963). Two policy instruments in particular, Instruction 70 (between 1953/1961) and Instruction 113 (between 1955/1961), provided strong impetus to the multinational firms' takeover of the Brazilian industry.

Instruction 70 classified imports in five different classes according to how essential they were. By allocating foreign exchange to these five classes and letting exchange rates be determined through class-specific auctions, the government could offer varying degrees of protection to the various classes of goods. This exchange rate policy provided strong incentives for multinational corporations to establish subsidiaries in Brazil because imported good that were deemed essential and that could not be sourced from domestic firms received a lesser degree of protection than those that were non-essential or available from domestic sources. Accordingly, formulations that were available from domestic sources received a greater degree of trade protection than active pharmaceutical ingredients and fine chemicals which could not be sourced from domestic firms. This measure created strong incentives for multinational firms to settle in Brazil. According to Bermudez (1995), the share of imported formulations fell between 1953 and 1960 from 70% to almost zero.

Instruction 113 had even more drastic consequences on the relative competitiveness of domestic and foreign firms because it allowed foreign investors to import equipments without foreign exchange coverage, a privilege not available to indigenous firms (Caputo, 2007). In

the pharmaceutical industry, this provision reduced the investment costs of multinationals firms vis-à-vis domestic ones, and favored their dominance of the Brazilian market. As a result, national firms became progressively concentrated in the segments of the drug market holding little interest for multinationals.

The foregoing transformations suggest that while the prohibition of pharmaceutical product patents since 1945 failed to promote a significant process of technological upgrading of the domestic firms, neither did it discourage the entry of multinational corporations. By the beginning of the 1960s, foreign multinationals accounted already for about 80% of sales and their takeover of the most promising among the surviving local firms continued during the following two decades. Giovanni (1980) highlights that the multinational firms' subsidiaries produced drugs that indigenous firms were not capable of producing, like antibiotics and other synthetic drugs. To be sure, foreign firms' activities in Brazil focused mostly on producing formulations, packaging, and distributing imported goods. Few firms produced active pharmaceutical ingredients and their chemical inputs locally, and fewer still carried out local R&D activities. Several surveys found that domestic firms were more likely to introduce product innovation than foreign-owned ones (Evans, 1979).

The failure of the multinational firms to promote a significant accumulation of technological capabilities and growing concerns about the cost of importing basic pharmaceutical inputs prompted a number of initiatives by the military government of the late 1960s. Hoping to increase the competitiveness of indigenous firms, a 1969 decree abolished patent protection for pharmaceutical processes, as well as products. The government also created a fund for providing financial and fiscal incentives for firms' R&D spending, and began to provide funds for R&D activities to be managed by the Central de Medicamentos (CEME). CEME was created in 1971 in order to provide poor patients with access to basic drugs (Lisboa et al., 2001). Some of these were produced at a network of twenty public pharmaceutical laboratories, but many others were purchased from national or foreign-owned firms. While multinational firms did not consider CEME's core mission to be a competitive threat, they responded differently when CEME began in 1973 to sponsor research at various universities on the synthesis of pharmaceutical raw materials (Evans, 1979).

Their reaction was twofold. First, they took steps, however minimal, to respond to the growing political pressures for them to carry out undertake or support local R&D efforts. Second, they exploited persistent conflicts within the military government between those supporting nationalist economic policies and those opposing them, in order to undermine the

research program that CEME had supported. Indeed, CEME gradually lost its financial and political autonomy, and it was closed in 1997.

In addition to promoting growing R&D efforts, government policies and political pressures were aimed at reducing the pharmaceutical industry's dependence on imports of active pharmaceutical ingredients and underlying chemicals. Fiscal incentives on machinery imports were deployed in order to reduce the cost of upstream integration for pharmaceutical firms. Moreover, the government announced that, unless foreign firms started producing raw pharmaceutical inputs locally, the government would have purchased them on the international markets and made them available to any interested firm in Brazil. Since active principles and fine chemicals could be purchased in the world markets at prices substantially lower than the transfer prices paid by subsidiaries to the parent company, the government announcement of the policy together with the carrot of the fiscal incentives prompted foreign-owned firms to begin local production.

Even after the IPR's regime had been weakened further in 1969, the development of the Brazilian pharmaceutical industry continued to be dominated by multinational corporations. Foreign direct investment continued to rise throughout the 1970s, leading to numerous acquisitions of leading Brazilian firms by foreign multinationals. The surviving local firms continued to depend on the trade protection offered by the law of similars. Indeed, only three among the 30 major pharmaceutical firms in Brazil in 1989 were indigenous: Aché, Prodôme and Biolab (Queiroz, 1993). These and other indigenous firms grew in the 1970s "*supported by the approval of the register of pharmaceutical products by similarity to products existing in the Brazilian market*" (Bermudez et al., 2000). The continuing weakness of the technological capabilities of private indigenous firms appears to have been a crucial constraint on their strategic options. It also explains why the lack of any form of patent protection since 1971 did not suffice to reverse the "denationalization" that began two decades earlier.

The market-liberalizing reforms that took place since the late 1980s wrought drastic changes in the industry's structure. The elimination of trade barriers and the reduction of import tariffs from around 60% to 20% resulted in the end of more than 1,700 lines of production of active pharmaceutical ingredients and syntheses in Brazil (Orsi *et al*., 2003, apud Grangeiro and Teixeira, 2007). These changes led to a considerable deterioration of the sectoral trade balance. Between 1990 and 2000, imports of active pharmaceutical ingredients doubled, and those of finished drugs increased by a factor of six (Magalhaes et al, 2003). An

analysis of the active pharmaceutical ingredients imported in 1998 revealed that half of the imports were accounted for by substances that were patented before 1962, and less than 20% represented substances patented after 1977.

The effects of the 1996 patent law reform were particularly significant for the public health program for the free distribution of drugs for HIV/AIDS carriers that the Brazilian government launched only a few months later. Because of its concern with the cost of procuring the needed drugs from multinational corporations, the Brazilian government supported a research program for reverse engineering and establishing the production of needed antiretrovirals (ARVs) at local laboratories. Initially, the public health program provided for the distribution of ARVs developed prior to the 1996 patent reform, and thus, not protected by domestic patents. But later generations of ARVs became available for which patent applications had been filed in Brazil, the procurement of locally produced generic versions clashed with the patent rights of the multinationals and could only proceed under a compulsory licensing arrangement. The Brazilian government had established in a series of decrees that compulsory licenses could be granted for reasons of public interest, as in the case of the continuing viability of the public health program on HIV/AIDS. These legislative actions and the successful imitation of the relevant ARVs at indigenous laboratories lent credibility to the threat of compulsory licensing that the Brazilian government used in order to extract significant price reductions from the multinational corporations whose ARVs accounted for most of the HIV/AIDS program budget.[18]

While both public and private laboratories were involved in the imitative work, the public laboratory FIOCRUZ (the descendant of the Manguinhos Institute) played a central role in the development of indigenous research and production capabilities related to the synthesis of generic versions of ARVs. Interacting with universities and private labs, the scientists at FIOCRUZ successfully reverse-engineered several ARVs, and collaborated with indigenous firms and other public laboratories in order to begin production of these molecules under the procurement contracts awarded by the Health Ministry. Although the initial focus of this research was on imitation of existing ARVs, the resulting technological learning has supported more distinctly innovative efforts. In fact, part of the profits earned from the sales of generic ARVs made it possible for indigenous laboratories to invest further in their R&D capabilities thanks to the recruitment of scientific personnel and the acquisition of modern

[18] While the threat of compulsory licenses was effective in obtaining price discounts from patent-holding pharmaceutical companies, the Brazilian government never really issued compulsory licenses until May 4, 2007, when compulsory license was issued for the production of a generic version of Merck's Efavirenz.

research equipment. Within a few years then, both public and private labs were not only better able to reverse–engineer existing molecules, but also to develop innovative chemical substances (Cassier and Correa, 2007).[19]

Another important policy change occurred in 1999 when the government enacted a law regulating the production and commercialization of generic drugs. Several governmental actions, including financial incentives and the purchase of generic drugs by the government for its public health programs, supported the growth of local production of generics by Brazilian firms, as well as the entry by foreign firms. In 2005, the four major pharmaceutical firms producing generic drugs were indigenous, and accounted for 76.5% of sales (Quental et al., 2008). Those changes contributed to strengthen the Brazilian pharmaceutical industry, whose share of total sales rose from 12% in 1975 to 40% in 2005. It has to be noted however that the generics manufacturers are mostly oriented to the national market (only the two largest manufacturers of generics have pursued exports), operate on a scale that is vastly inferior to global leaders like Israel's Teva or India's Ranbaxy, and unlike these global leaders have so far refrained from producing the necessary active pharmaceutical ingredients, for which they continue to be dependent on imports.

6. THE AIRCRAFT INDUSTRY AND THE EMBRAER CASE

Created by the government in 1969, the Empresa Brasileira de Aeronáutica S.A. (Embraer henceforth) is one of the major commercial aircraft manufacturers in the world, behind Boeing and Airbus, specializing in the production of jets for regional transportation. Beginning in 1969, Embraer developed a series of aircrafts, ranging from defense to commercial and executive jets, achieving a high standard of technology and quality. While Embraer is amongst Brazil's leading exporters, it is also one of the leading importers, a fact that reveals its strategic focus on system integration.

The recent success of Brazil's aircraft industry is the culmination of a century long history of efforts at addressing evolving technological and commercial challenges. An important source of inspiration for these efforts was the role played by Alberto Santos Dumont, a pioneer of aviation. Already a famous "airship" inventor in Europe (he designed

[19] Just when these local innovators were beginning to seek patent protection on their inventions, the House of Representatives approved a bill in June 2005 that would suspend the patentability of all HIV/AIDS-related drugs. While this bill was not ratified into law, it is likely that such a measure would have weakened perhaps the incentives for local labs to engage in innovative projects rather than on imitative ones.

and built dirigibles and won a prize for having circled the Eiffel Tower in 1901), Santos Dumont made his first flight in Paris in October 1906.[20] In the following years, he designed a smaller and faster airplane, called Demoiselle. Santos Dumont never patented his inventions, never undertook the commercial production of aircraft, choosing instead to make the drawings and details of the Demoiselle's design freely available to interested manufacturers. While he was a source of inspiration and national pride for Brazilians, the commercial production of aircraft had to await the stimulus of government procurement during the Vargas era in the 1930s.

President Vargas was enthusiastic about developing a national aircraft industry and thought of air transport as an instrument of national integration. At that time, the small size of the Brazilian market was one of the factors impeding this development. Government orders and investment were crucial to induce the first attempts. Among the pioneering firms, we signal the Companhia Nacional de Navegação Aérea (CNNA), a private firm that began production of a biplane designed for pilot training in 1935 (Forjaz, 2005), and the Companhia Aeronáutica Paulista (CAP), founded in 1942. According to Viegas (1989), CAP bought the rights to develop a copy of the U.S. model Taylor Club in the 1940s, and worked together with the Instituto de Pesquisas Tecnológicas de São Paulo (IPT) to develop the model denominated CAP-4, best known by its nickname Paulistinha. This aircraft had some commercial success both at home and in export markets, including Argentina, Chile, Italy, Paraguay, Portugal, U.S., and Uruguay (Forjaz, 2005).[21] The IPT began a research program focusing on the use of indigenous wood materials for the development of prototypes and aircraft components, often in collaboration with CAP. However, the fledgling domestic industry could not keep pace with the technological advances taking place in the sector during the war period. After the end of World War II, the national government failed to protect the domestic firms which succumbed to the competitive pressure from imported aircraft. The demise of national producers of aircraft also affected the aeronautics research activities performed by the IPT, whose capabilities in the field faded gradually (Viégas, 1989).

[20] As reported in the New York Times ("Santos-Dumont Flies," October 24, 1906), his 14-Bis airplane took off by its own means, flew for a few seconds, and landed. It was "the first wheeled landing-gear flight" (Davis, 1997, p. 1).

[21] The most important national private company was conducted by the entrepreneur José Carlos Neiva. His firm was a licensed manufacturer of the Paulistinha, and only in 1963 it started the production of an aircraft with metallic structure. Neiva's company depended highly on military orders, and was acquired by Embraer in 1980 (Viégas, 1989).

While its aircraft orders did not protect local manufacturers against foreign ones, the Brazilian government decided in the aftermath of World War II that the country ought to pursue the development of aeronautical technology at a national research institution and the creation of aeronautical technical school. Thus, the Centro Técnico Aerospacial (CTA) and the Instituto Tecnológico da Aeronáutica (ITA) were established during the late 1940s. ITA was an engineering school organized around the model of U.S. institutions like Caltech and MIT (Schwartzman, 1991). MIT professor Richard Smith was the first president of ITA, whose faculty included many other international researchers, making English the "official" language in the institute in its first years. The tight connections between ITA and MIT, as well as other foreign academic institutions, provided Brazilian students with access to first-rate graduate programs abroad (most in U.S.) and helped ITA achieve a high standard level of education in the very first decade of existence. Its graduates made it possible over time to reduce the dependence on foreign faculty. Moreover, since 1953, professional opportunities for ITA graduates came to include employment at the Instituto de Pesquisa e Desenvolvimento (IPD) created within CTA in order to perform research on economic and technical problems related to aeronautics and national aviation.

An important problem for Brazilian aviation began to take shape since the late 1950s, when domestic carriers began to adopt new and larger aircraft designs for which profitable operations required higher load factors and larger airports. As a result, smaller route markets and towns served by airports with rudimentary runways were being eliminated from the service network of domestic airlines. The number of cities served by regular services declined from almost 350 cities in the late 1950s to less than a hundred by the mid-1960s (Viégas, 1989; Bonelli and Pinheiro, 2008).

In 1965 CTA hired the French aeronautical engineer Max Holste as a technical consultant. Holste submitted a proposal to IPD for the development of a twin-engine turbo-prop transport aircraft, which represented a modification of the piston-engine regional aircraft that he had designed during the late 1950s for his own company, Max Holste SA. A team of engineers led by Captain Ozires Silva elaborated further the proposal in order to build a robust aircraft that could operate on all kinds of runways, and the project began in the same year with sponsorship of the Ministry of Aeronautics. A prototype of the aircraft, named Bandeirante, made its first successful flight in 1968, and efforts began to promote the commercial production of this aircraft. Having failed to persuade private firms to embrace the project, the Ministry of Aeronautics decided in 1969 to promote the commercial production of

the Bandeirante by creating a new corporation, Embraer, with majority ownership by the Brazilian government. The company was established in São José dos Campos in close proximity to ITA and CTA. Not only Captain Silva was named the first president of the company, but also scores of engineers and technicians from ITA and CTA were reassigned to Embraer.

The first exemplars of the Bandeirante (in both its military and civilian versions) were delivered in 1973, and within two years Embraer began receiving orders for export sales. During the following years, Embraer expanded greatly its portfolio of aircrafts and did so often by forging collaboration and licensing agreements with foreign firms. Among these we signal Embraer's cooperation with Piper Aircraft (U.S.) for the production of several light aircraft models, with Aermacchi (Italy) for the production of the trainer jet Xavante, and with Aermacchi and Aeritalia (Italy) in the AMX Program for the design and construction of a combat aircraft. Among the projects carried out independently of foreign partners, we signal the development of the agricultural aircraft Ipanema, and of the successful combat aircraft Tucano in 1980. From the viewpoint of technological capabilities, the expansion of Embraer's activities was supported by its ties to CTA and ITA, as well as by its cooperation with foreign aircraft manufacturers. These cooperation and licensing agreements enabled Embraer to "absorb critical production knowledge in tracing technology, assembly of planes, organization of procurement of materials, quality control, technical documentation, organization of assembly lines" (Frischtak, 1992, p. 18).

Moreover, having begun the local production of light aircraft under license from Piper Aircraft, Embraer could benefit from the tariff protection provisions of the law of similars. The government raised the import tariffs on light aircraft from 7% to 50%, creating the conditions for Embraer to dominate the internal market. Crucially, the firm proved able to sell its aircrafts in foreign markets too. In the early 1980s the Bandeirante had reached a 20% share of the U.S. market. By 1990, about 500 units of the Bandeirante had been sold in 36 countries (Frischtak, 1992). Embraer's success stimulated the birth of other aerospace related companies (mostly created by ITA alumni) in São José dos Campos. These firms' technological capabilities were nurtured by Embraer, which carried out training and technology transfer programs aimed at the development of a network of qualified suppliers.

The company's financial conditions deteriorated sharply since 1988, when the reduction of government support and protection, combined with a drastic decline in aircraft orders from the military and commercial airlines, forced Embraer to downsize drastically. The

company workforce was reduced by 75% between 1990 and 1994, as the government prepared the privatization of the company. This occurred in 1994 thanks to the involvement of a consortium of private investors. Under new management, Embraer completed the development of its first regional jet (ERJ 145) amidst a process of restructuring that led the firm to become a business oriented global player in the aircraft sector (Goldstein, 2001). Within a few years, Embraer regained its leadership position in the market segment of aircraft for regional travel.

Embraer's success can be explained by a series of factors. In the beginning, the governmental orders made possible the initial production and acted as a R&D subsidy. Several cooperative and licensing agreements, associated to high qualified engineers, and the CTA's research support, made possible to learn and absorb the technological knowledge. The first cooperation agreements were designed to facilitate the technology transfer to Embraer and the learning process. Since the development of its first regional jet, Embraer's strategic focus has been on aircraft design, fuselages' production, and assembly of the various subsystems into the complete aircraft. Embraer relies upon a network of international partners and suppliers that contribute to the realization of various subsystems of each new aircraft and shoulder part of the financial risks involved. In essence, Embraer operates largely as a system integrator, a fact that helps us to understand why it has few patents in either Brazil or the U.S. (Goldstein, 2001).

7. CONCLUSIONS

In spite of the rapid pace of industrial development experienced between 1930 and 1980, Brazil's process of technological catching-up with the global frontier is far from complete and displays substantial variation across sectors and technologies. Thus, while Brazilian firms like Petrobras and Embraer have come to be regarded as global technological leaders in their industries, national firms in several other industries have not yet developed the range and depth of technological capabilities of their counterparts in advanced economies. The determinants of these inter-sectoral differences are manifold. Based on the available evidence, it can be argued that the regime of patent protection has not been a significant influence on the rate and direction of the development of technological capabilities. While this regime has been in place for nearly two centuries, Brazil's innovative performance during

this time period has fallen short of that characterizing the history of today's most advanced economies.[22]

An important determinant for this outcome can be identified in the low absorptive capacity of the Brazilian firms, in turn the result of low levels of educational attainment. Only a few engineering schools had been established as late as the mid-twentieth century. Additional schools and programs were created since then, and beginning in the 1970s the government started to send students abroad. Yet, the basic and intermediate educational level in Brazil is to this day rather fragile. The national firms' limited access to qualified human capital rendered the acquisition of foreign technological knowledge a complex challenge for most firms, independently from the presence and strength of IPR.

A second determinant for the poor innovative performance overall of Brazilian industries has to do with the incentive structures created during the phase of rapid industrialization. The import substitution strategy adopted after the 1950s relied on protectionist tariffs, which –together with an exchange rate policy designed to favor internal production over imports – created an industry with a high level of inefficiency, without capacity to compete internally with the multinationals (although they presented inefficiencies too; e.g. the auto industry), and internationally. Until the beginning of the 1990s, with a few exceptions, the Brazilian industry presented "little or no creativity in technology" (Versiani and Suzigan, 1990, p. 41). According to Versiani and Suzigan, the import substitution process contributed to create a "protectionist mentality" in the Brazilian firms, which came to see the protectionism as an end instead of a means to develop a competitive industry. As a result, the processes of technological learning triggered by the country's import substitution strategy proved inadequate as a means to promote the international competitiveness of Brazilian firms, particularly in the rapidly growing markets for innovative products. The defensive characteristic of the industrial policy adopted and its almost complete disconnection to the IPR regime made the patent issue irrelevant for the Brazilian industrialization.

Because of the lagging industrial development during the late nineteenth and early twentieth centuries, Brazil's acquisition of technological capabilities since the 1930s relied extensively upon foreign sources of scientific and technological knowledge. While some of these were in the public domain, market-mediated channels of technology transfer were

[22] This however does not mean that innovative activities were absent. For example, Ribeiro (2006) discusses the numerous patents granted during the nineteenth century for inventions related to the processing of coffee.

essential to the development of indigenous capabilities in many sectors. In addition to imports of capital goods, FDI played an important role in many sectors. While both can be argued to have been favored by the economic policies pursued by the Brazilian governments especially since the 1950s, their impact on the formation of indigenous technological capabilities differed across sectors. At one end of the spectrum we find the automobile industry where the entry into Brazil by foreign multinationals like Volkswagen, Fiat, and others, promoted the emergence of indigenous clusters of parts suppliers. This outcome was the result of the incentives for FDI created by the size and strategic significance of the Brazilian market, and the government's trade and exchange rate policies, as well as by the imposition of local content requirements on the automobile manufacturers. At the other hand of the spectrum are instead those sectors where the inflow of FDI had limited spillovers on the growth of national firms. In these sectors, including most notably pharmaceutical and consumer electronics, multinational firms exploited the artificial profitability of subsidiary operations in Brazil resulting from various government policies (tariffs and exchange rate controls, or the promotion of the export processing zone of Manaus) but invested only in low value-added activities (e.g., formulations and marketing, or assembly and distribution) that had limited knowledge spillovers onto local firms.

Within the complex web of policies affecting sectoral development, IPR policy appears to have had at best second-order effects on the accumulation of technological capabilities, as illustrated by the case of pharmaceuticals. In this industry, the weakening of IPR protection accomplished in 1945 and 1969 was meant to spur imitative efforts by national firms and thus the closing of the capabilities' gap between them and their foreign competitors. While these policies did promote the growth of domestic firms early on, the "denationalization" of the industry followed within a short time, as multinationals acquired the most successful domestic firms. These subsidiaries were then relegated to a marginal role in the global R&D strategy of the parent company, a process that frustrated the development of strong technological capabilities among national firms. The restoration of patent protection for pharmaceuticals in 1996 has not so far brought about a change in the strategy of multinational firms. Instead, renewed government support of (imitative) R&D activities at the public labs and the creation of a regulatory environment for the sale of generic drugs hold the promise of more significant effects on the technological capabilities of national firms than the 1996 reform of the patent law.

Whereas the Brazilian government protected the market for pharmaceuticals, it did not protect domestic firms from foreign multinationals so that even in the absence of IPR protection on foreign technologies national firms failed to develop the technological capabilities necessary to compete with the multinationals in the innovative segments of the market. An interesting comparison can be carried out with developments in the computer industry, a sector that was also dominated for many years by the subsidiaries of multinational firms like IBM and Burroughs, which did not carry out R&D or high-value added activities.

Since the 1970s, the government adopted a set of policies aimed at promoting the growth of national computer firms. It established a national computer firm, Computadores Brasileiros SA (known as COBRA), with the participation of private domestic and foreign capital (Equipamentos Eletrônicos and the British firm, Ferranti), a model of public-private partnership used in order to stimulate firm creation and investment also in other industrial sectors. While COBRA operated under technology licenses from foreign firms, its considerable endowment of human capital supported several successful indigenous technological developments both in hardware and software.[23] In spite of its early commercial successes, COBRA faced increasing competition at home from other national firms, whose entry into the minicomputer market was occasioned by government-run competitions for import licenses.

While ostensibly committed to the development of indigenous computing platforms, the government wavered between this goal and that of providing users with access to globally advanced computer products. An added difficulty was the administrative challenge of monitoring inflows of computer components and of technology across from outside the country. As a result of these contradictions, national firms had weak incentives to engage in costly innovative R&D. Firms like COBRA that did so, and thus contributed to the cost of nurturing domestic technological capabilities received only limited protection from competitive threats of companies that committed no resources to R&D, relying instead upon periodic upgrading of their licensed technologies from foreign firms whose strategic options in the Brazilian market were seriously restricted.

Although the evolution of the computer industry differs markedly from that observed in pharmaceuticals, and so did the IPR regime, firms in both industries were penalized by the inability or failure to engage in a sustained process of technological learning supported by

[23] A notable achievement was the entirely autonomous development of a UNIX-compatible operating system (SOX), which received international certification in 1989.

interactions with foreign firms, and were consequently ill-prepared to the challenges brought about by the market liberalizing reforms of the 1990s. The experiences of Petrobras and Embraer reinforce further the importance of the creation and development of technological collaborations with external partners. Similar patterns of technological learning took place in the steel industry, where state-owned firms like Companhia Siderurgica Nacional, Usiminas, and COSIPA, all benefited from the collaboration of foreign partners during the planning and realization of their major investment projects. In all of these cases, current IPR were not an important constraint for the national firms' strategies. While foreign firms were often ready to license patented technologies as part of broader technology transfer agreements, the case studies we analyzed suggest that the wide array of other policies deployed by the national government in support of industrial development might be an important reason why the IPR regime mattered so little.

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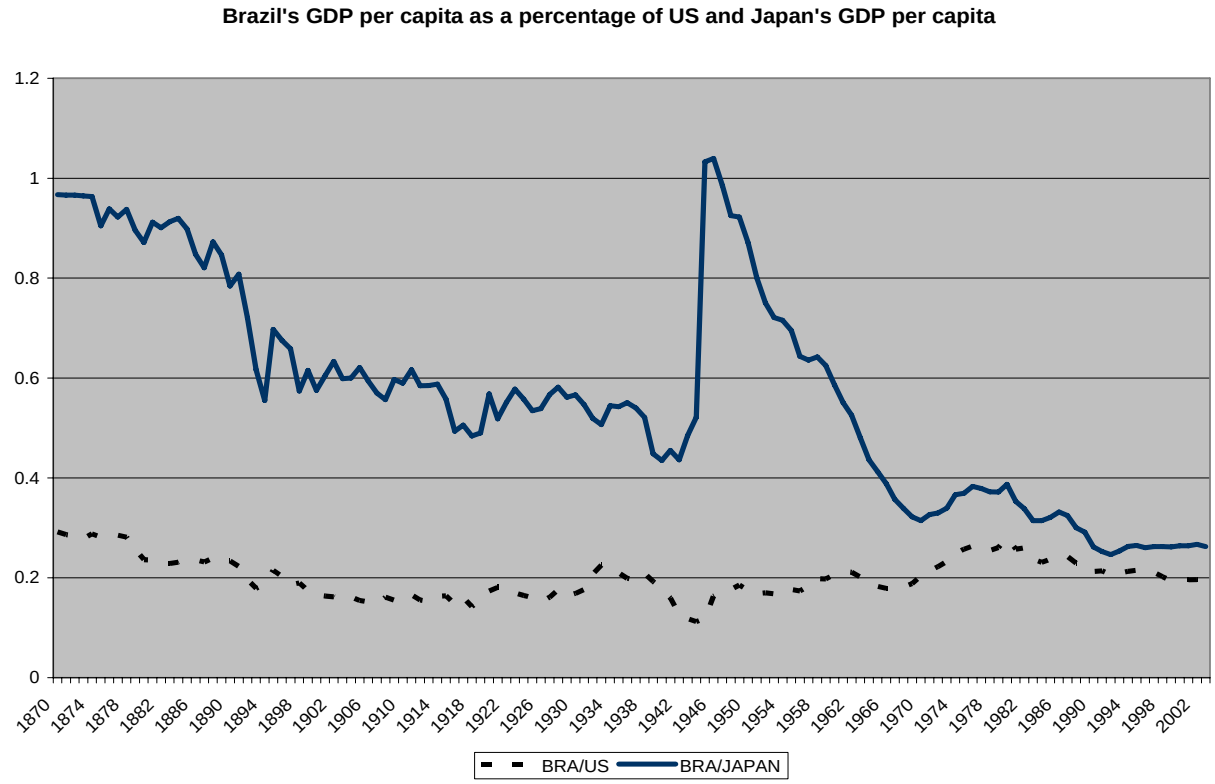
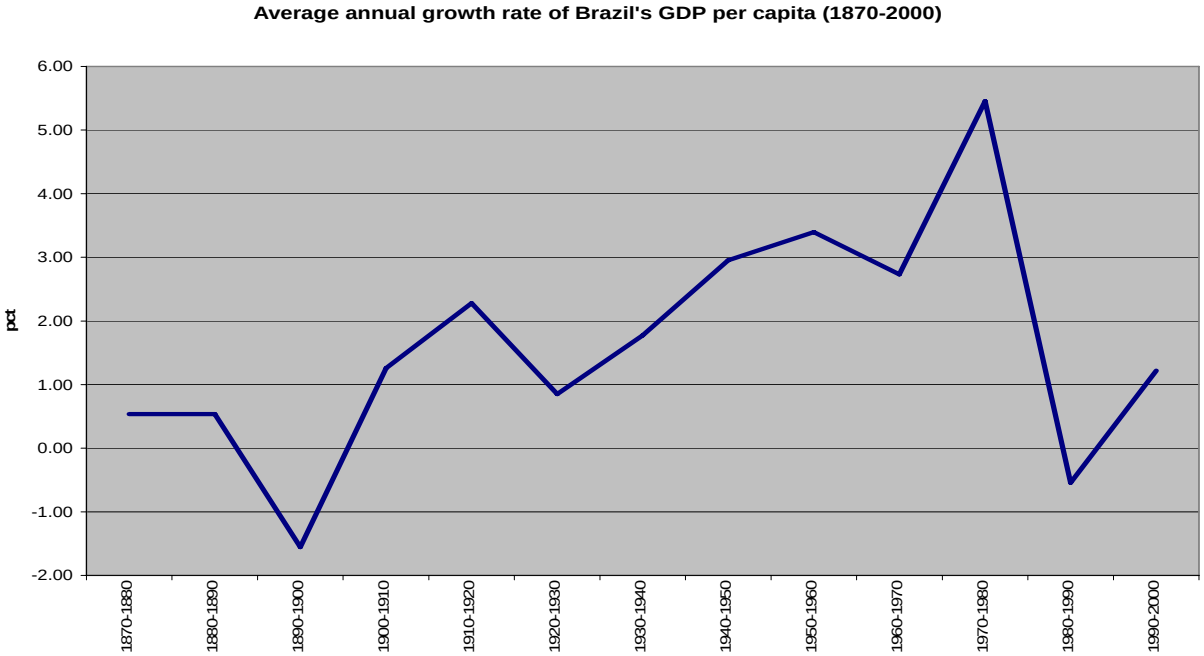
FIGURE 1



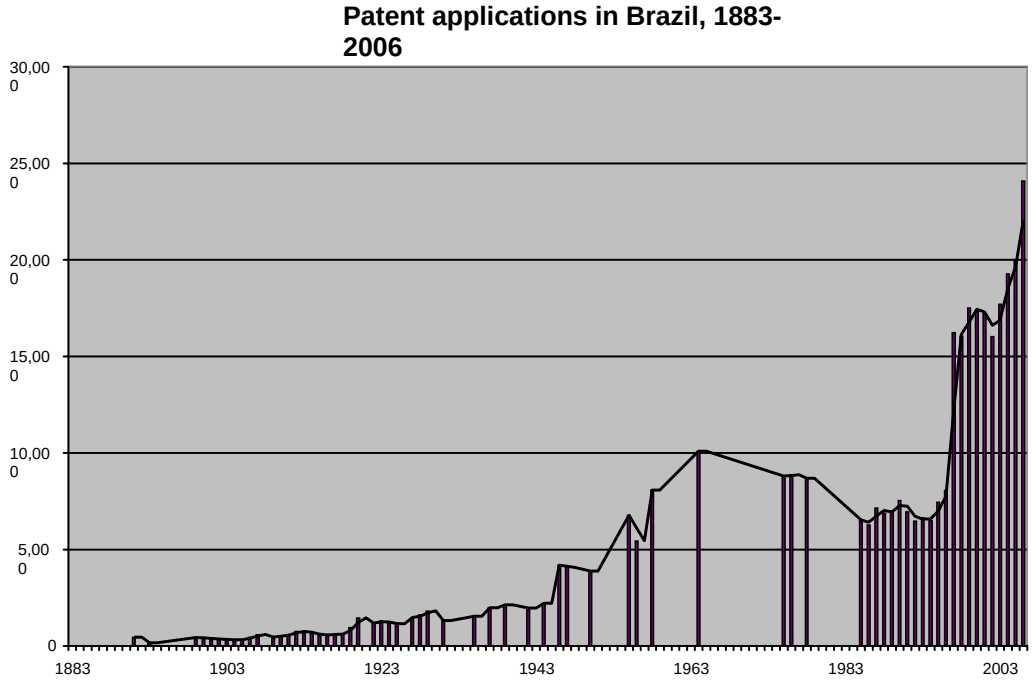
Source: Authors' elaboration, data from Maddison (2003)

FIGURE 2



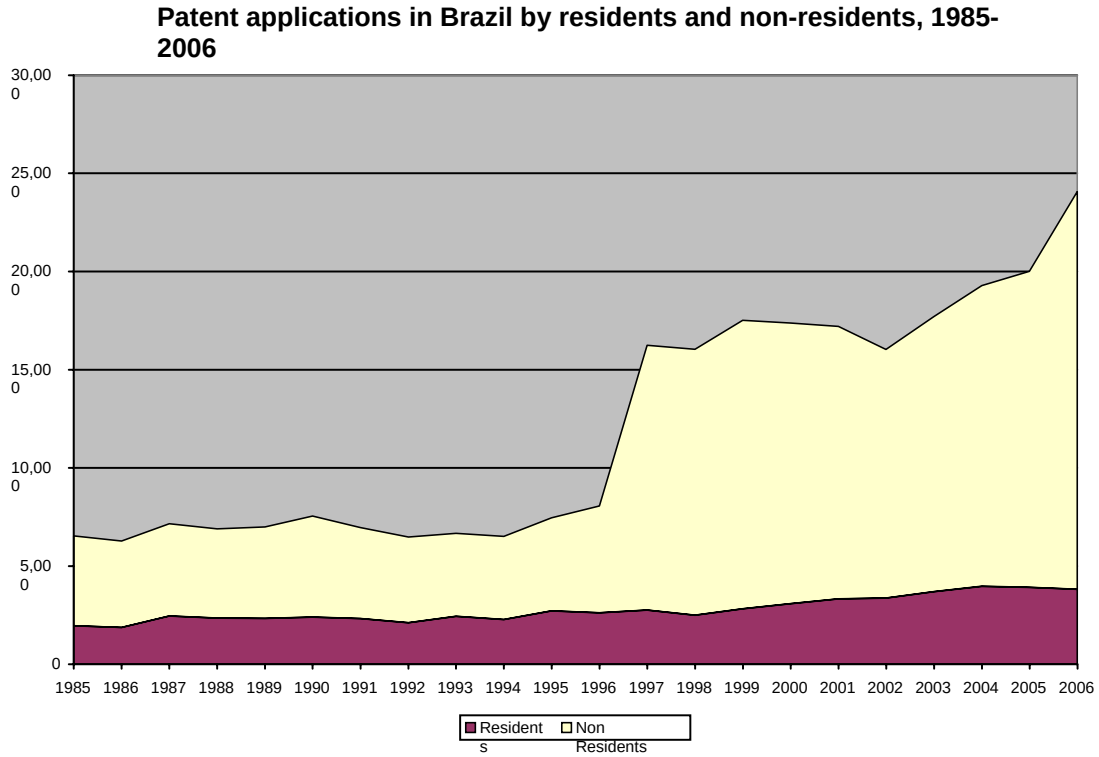
Source: Authors' elaboration, data from Maddison (2003)

FIGURE 3



Source: World Intellectual Property Organization (2008)

FIGURE 4



Source: World Intellectual Property Organization (2008)

TABLE 1 – Payments for contract-based technology transfer (1947-1971)

		Payments for technology transfer as a percentage of		
	Index (1965=100)	GDP	Capital goods' imports	FDI
1947-1953	31.8	0.12	3.5	100
1954-1961	75.8	0.18	9.1	35
1962-1964	34.4	0.06	4.6	35
1965	100.0	0.16	24.6	61
1966	107.8	0.16	16.6	62
1967	147.5	0.22	19.6	82
1968	165.2	0.22	16.3	87
1969	214.1	0.26	17.8	67
1970	244.7	0.27	15.9	81
1971	310.6	0.31		90

Source: Biato et al. (1970).