An overview of the research and patenting activities that took place in Brazil during the 2010s

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Abstract

A National Innovation System is an interconnected network of public and private institutions that aims at the development and diffusion of new technologies. We use the Derwent Innovations platform to study the patent applications in Brazil between 2010 and 2020, and to identify the main technological areas that have benefited from the research conducted in the country. Our main methodological contribution is to present indicators that measure the technological importance and international scope of Brazilian patents. The results show that private companies rarely resort to intellectual property protection mechanisms and that public universities are responsible for most patent applications. This study concludes that private companies innovate little, and, as a result, academic research tends to act as a substitute for business investments in research and development, especially in software development, pharmaceutical outputs, and scientific instrumentation. On the other hand, Brazilian universities and companies are both being excluded from the global race for the Internet of Things patents that has characterized the fourth industrial revolution.

Keywords: National Innovation Systems; Brazilian public universities; patents.

1. Introduction

A National Innovation System (NIS) is an interconnected network of public and private institutions that interact while aiming at the development and diffusion of new technologies (Nelson, 1993; Freeman & Soete, 1997). In developed countries, such interactions encompass three crucial elements. The private sector is primarily responsible for research and development (R&D) efforts related to the emergence of new marketable products and services, while academic institutions play a central role in generating basic scientific knowledge (Cohen, Nelson, & Walsh, 2002). Moreover, much of the technological innovations are funded by public research funds (Freeman, 1995).

The level of maturity of the NIS has a strong influence on the technological asymmetries between countries (Patel & Pavitt, 1994). This assumption raises concerns about the situation in Brazil. Although the country registers relevant scientific production in some areas, rarely the links between research institutions and private companies are strong enough to make a scientific invention reach the market as an innovative product (Dal Poz, 2006; De Negri, 2018).

The Brazilian NIS presents several distortions relative to the most technologically advanced countries. In these, the business sector leads investments in science, technology, and innovation (S&T&I), and also patent applications. In contrast, few companies in Brazil have developed internal R&D competences so that innovative efforts are limited mainly to the purchasing of machinery, equipment, and software. Consequently, public universities have been leading patent applications (Buainain et. al., 2019).

Several authors recognize the crucial role of Brazilian educational institutions in generating and transferring new technological knowledge to the business sector (De Negri, 2018; Buainain et. al., 2019; Garcia, Araújo, Mascarini, Santos, & Costa, 2020; Suzigan, Garcia, & Feitosa, 2020). However, these studies have primarily focused on the structural factors that hinder university-company interactions, which ended up ignoring other relevant questions: what are the technological areas that Brazilian universities have prioritized in their latest research? How to assess the economic importance of patents derived from such research? What is the international scope of the patents granted to Brazilian educational institutions?

This paper intends to address these research gaps. For this matter, we use the platform *Derwent Innovations* to search for the patent applications filed at the Brazilian National Institute of Intellectual Property (NIPI) between January 2010 and April 2020. We then classified the patents by technological classes using the Derwent platform. The features provided by Derwent also enabled the computation of two patent indicators that were used to assess the technological importance of each intellectual property (IP) document.

The rest of this paper is organized as follows. Section 2 discusses the gaps in the Brazilian NIS. Section 3 describes the methodological procedures used to identify Brazilian patents and compute patent indicators. Finally, Section 4 describes the technological content of these IP documents, and Section 5 concludes the study.

2. Types of the National Innovation System and the specifics of the Brazilian case.

According to Freeman (1995), the studies conducted by German economist Friedrich List were precursors to the concept of NIS. In the 19th century, List proposed the creation of a 'national system for economic policy', that is, the adoption of a set of economic measures to accelerate Germany's technological development and debunk the UK's industrial hegemony. Those public policies should include: i) commercial protection of new economic segments, ii) financing for the constitution of R&D departments in the companies; iii) foundation of universities and research institutes specialized in the transfer of technologies to the business sector.

These policies were successful and, already in 1870, chemical companies in Germany were quite ahead of those in the UK. Several other countries realized that success and decided to replicate the same public policies, which ended up causing a change in industrial development, in addition to the creation of new universities and research laboratories (Schacht, 1999).

Friedrich List's pioneering contributions influenced the contemporary view on NIS. This concept comprises an interacting network composed of public and private institutions aimed at developing and disseminating new technologies (Nelson, 1993; Freeman & Soete, 1997). In dynamic NIS, such interactions encompass at least three key players: i) private companies that tend to support applied research activities aimed at developing new products, processes, and marketable services; ii) universities active in exploratory research capable of generating upstream inventions (Cohen et al., 2002); iii) public institutions for the financing of business and academic research.

In contrast to dynamic NIS, Patel and Pavitt (1994) also highlight the existence of short-sighted systems where their parts do not see the difference between technological investments and other types of entrepreneurial investments. This implies lower R&D spending when compared to mature systems. Thus, in "myopic NIS", the connections between research institutions and private companies are not strong enough to have scientific inventions reach the market in the form of innovative products. The authors conclude that the degree of maturity of the NIS has strong influence on the technological asymmetries that exist between countries and on the effectiveness of public policies aimed at closing such gaps.

Several recent studies have emphasized the gaps in the Brazilian NIS. According to De Negri (2018), the credit sources currently available in Brazil are insufficient to finance scientific and technological development. In addition, investment in human capital and infrastructure in the country is lacking, and a regulatory environment favorable to research activities and collaborations between universities and companies is rarely observed. According to De Benedicto (2020) the existing bureaucracy in the academic environment limits the knowledge diffusion that could be transformed into new commercial applications.

Moreover, historical resistance from the Brazilian business community to autonomous R&D programs exists. Such a trend was confirmed by the 2014 PINTEC/IBGE survey. Only 15% of the companies surveyed declared that internal S&T&I activities are important. Besides, PINTEC/IBGE also confirmed that innovative efforts are mainly restricted to 'external R&D spending', a euphemism for the acquisition of machinery and equipment (Buainain et. Al., 2019).

The level of maturity of the SNIs also seems to influence the culture of protection for the IP. In mature NISs, patents are seen as appropriability mechanisms capable of providing competitive asymmetries to companies in the cutting edge of innovation (Ferrari, Silveira & Dal Poz, 2019). However, in the Brazilian case, companies rarely innovate 'in the areas in which they operate and few of them rely on intellectual property protection mechanisms' (Buainain et. Al., 2019, p. 14).

3. Methodology

The platform chosen for carrying out patent searches was the *Derwent Innovations Index* – DII (Web of Science/ Clarivate Analytics). Derwent was accessed through the Capes Portal, which is available at *http://www-periodicos-capes-gov-br.ez128.periodicos.capes.gov.br/.* The survey covered the period extending from January 2010 to April 2020. Objectively, it sought patent registrations with the prefix 'BR' in their numbering, i.e., the prefix that indicates the IP documents granted or revalidated by the Brazilian NIPI. We then classified the patents by technological classes using the *Derwent Class Codes*. The features provided by *Derwent* also allowed us to compute two proxies for measuring technological importance of patent documents – the indicators for forward citations and patent families.

3.1 Forward citations

A methodological procedure frequently used to identify patents of high economic value consists of counting the number of later citations. According to Trajtenberg (1990), the citations that a patent receives from more recent ones represent a proxy regarding the technological importance of inventions disclosed on the patent that was cited. Similarly, Harhoff, Scherer, and Vopel (2003) found that the number of forward citations that a patent receives is positively correlated with the monetary value attributed to it by its inventors.

3.2 Size of patent families

A priority number is automatically generated when an inventor applies for a patent for the first time, which guarantees the assignee the exclusive right to apply for protection of the technology in other countries through extension patents for one year. Therefore, a single invention can be protected by its original patent and by its extension patents, forming a so-called patent family, that is, a set of IP documents that share the same priority number (Ferrari & Pacheco, 2020).

The size of a patent family is equivalent to the number of nations in which a specific invention has obtained patent protection. Whenever an original patent is extended, the inventor bears the filing and maintenance fees stipulated by the country responsible for revalidating the document. As emphasized by Harhoff, Scherer, and Vopel (2003), due to the additional costs generated by each reissue application, companies prioritize the extension of the most technologically solid patents that exhibit the greatest chance of generating royalties. Thus, the authors herein highlight the correlation between the size of a patent family and the monetary value attributed to the respective invention by its owners.

4. Results

The patent search identified 252,061 distinct patent families. In Brazil, approximately 80% of patent applications made during the 2010s were submitted by non-residents, the vast majority of cases being patents obtained by foreign companies in other countries that were subsequently revalidated by the NIPI. Thus, the ranking of the main patent holders in Brazil is led by seven US multinationals and five European conglomerates in addition to two Japanese and one Chinese company (Table 1).

Table 1. Top Brazilian Patents Holders (base of 252,061 patent families covering January 2010–April 2020).

TOP 15 Foreigner Assignees			TOP 15 National Assignees		
Assignee	General Ranking	Patents	Assignee	General Ranking	Patents
QUALCOMM INC (USA)	1	3892	USP UNIVERSITY OF SÃO PAULO	54	634
PHILIPS (Netherlands)	2	3012	UNICAMP STATE UNIVERSITY OF CAMPINAS	59	590
BASF (Germany)	3	2935	FEDERAL UNIVERSITY OF MINAS GERAIS	72	508
DOW (USA)	4	2914	PETROBRAS	74	504
GENERAL ELECTRIC (USA)	5	2785	FEDERAL UNIVERSITY OF RIO GRANDE DO SUL	79	468
HALLIBURTON ENERGY S (USA)	6	2463	FEDERAL INSTITUTE OF EDUCATION, SCIENCE AND TECHNOLOGY	100	359
BAYER (Germany)	7	1642	FEDERAL UNIVERSITY OF PARANA	103	355
HUAWEI (China)	8	1606	FEDERAL UNIVERSITY OF PARAIBA	187	211
3M (USA)	9	1506	FAPESP	218	186
SIEMENS (Germany)	10	1473	FEDERAL UNIVERSITY OF CEARA	229	179
SONY (Japan)	11	1439	VALE DO RIO DOCE CO.	265	163
JOHNSON (USA)	12	1414	TECHNOLOGY FEDERAL UNIVERSITY OF PARANA	294	145
HOFFMANN LA ROCHE (Switzerland)	13	1377	FEDERAL UNIVERSITY OF SERGIPE	308	140
TOYOTA (Japan)	14	1345	SEB AS	319	135
PROCTER & GAMBLE (EUA)	15	1294	FEDERAL UNIVERSITY OF PELOTAS	323	134

Source: Derwent Innovations Index – DII (Web of Science/Clarivate Analytics)

The Brazilian economy is the ninth-largest in the world, registering a GDP of 1.6 trillion dollars in 2019. The second-largest consumer market in the Americas has historically attracted the interest of the main global economic conglomerates. Thus, the efforts of foreign corporations listed in Table 1 – and many other multinationals that were not shown in the same table due to the lack of space – in protecting their technological assets in Brazil have transformed the country into an important stage for the patent races that have characterized the economic segments where such transnational companies operate (e.g. chemical, pharmaceutical, computing, and automobile).

In contrast, Brazilian corporations stayed out of the technological races that characterized the decade of 2010. As shown in Table 1, Petrobras is the only business company to appear in the ranking of the top 100 Brazilian patent holders. In the Brazilian case, public universities were responsible for most patent applications made to the NIPI by residents. This situation differs completely from that in developed countries, where a certain balance between applications made by residents and non-residents exists, and the domestic business sector leads patent filings.

Such evidence suggests that academic research in Brazil tends to assume a greater role in the NIS when compared to developed countries, thus justifying a deeper study of the technological relevance of university patents. However, a remark must be made. Simply counting patents filed by universities, as shown in Table 1, ignores the strongly asymmetric nature of patent documents. A few rare patents are economically relevant and represent significant technological developments. In contrast, most patented technologies are not embodied in commercial applications (Trajtenberg, 1990).

As emphasized in Section 3, counting forward citations is a methodological device often used to identify the most technologically relevant IP documents (Hall, Jaffe, & Trajtenberg, 2001). By adopting this procedure, the present study found that only six Brazilian universities have patents that were referred to by younger ones. Table 2 shows that the highly cited patents belong mainly to the University of São Paulo (USP), the State University of Campinas (UNICAMP), and the Federal University of Minas Gerais (UFMG).

Table 2. Data on Brazilian university patents that received forward citations and/or have been revalidated in other countries.

	Forward Citations				**Extension Patents**		
UNIVERSITY	At least 1 citation	At least 5 citations	At least 10 citations	Most cited patent	Patents revalidated at USPTO and EPO	Revalidated in at least 5 countries	Revalidated in at least 10 countries
UNICAMP	105	12	9	17	16	15	1
USP	47	7	1	28	13	9	2
UFMG	97	9	3	21	22	19	3
UNIVERSITY OF RIO GRANDE DO SUL	35	5	0	7	10	5	5
UNIVERSITY OF PARANA	3	1	0	8	3	3	0
UNIVERSITY OF PARAIBA	1	0	0	1	0	0	0

Source: Derwent Innovations Index – DII (Web of Science/Clarivate Analytics)

The analysis of the extension patents complements the previous analysis on forward citations. Column 6 of Table 6 adds up the number of Brazilian university patents that have been revalidated by both the United States Patent and Trademark Office (USPTO) and the European Patent Office (EPO). Due to the predominance of these markets in the commercialization of technological products, thousands of inventors from other countries have shown strong interest in protecting their inventions in the US and Europe (Hall, Jaffe, & Trajtenberg, 2001).

However, Brazilian universities do not follow this global trend. Only 64 out of 3,858 university patent families registered in Column 4 of Table 1 contain both North American and European extension patents. Therefore, most patent families have their validity restricted to Brazilian geographic territory, which makes difficult to commercialize the technologies developed by Brazilian universities in other countries and, at the same time, to transfer these inventions to the business sector through licensing agreements. Besides, extension patents are concentrated in only 3 institutions: USP, UNICAMP, and UFMG (Table 2).

We use the *Derwent Class Codes* (DCC) to technologically compare the Brazilian patents owned by foreign companies with the IP documents belonging to UNICAMP, USP, and UFMG. In practical terms, the cell color scheme in Table 3 shows whether the technologies described in Column 2 are part (columns in yellow) or not (columns in white) of the Top 15 technological classes that received the most patent applications from the institutions listed in Line 1. Furthermore, the numerical values in the cells show the position of each technology in such rankings.

Table 3 highlights the interest of foreign companies in protecting the applications related to the Internet of Things (IoT) in Brazil. This concept refers to a series of complementary technologies that digitally enable inanimate objects to collect and share data with each other, perform new functions, and improve their performance (Atzori, Iera, & Morabito, 2010). Class W01, which includes networked data transmission and sharing systems, had the second-largest number of patent applications made by foreign companies, due in part to the fact that the world's leading IoT solutions company – QUALCOMM INC – also occupies the position of the principal owner of Brazilian patents (Table 1). In contrast, Brazilian companies and universities do not even appear on the IoT patent map and in technological applications for electric cars (class X22).

The same perspective did not occur in the case of technologies related to the oil/gas sectors (class H01, 8th in the ranking of foreign companies) and mining (class Q49, 10th in the ranking of foreign companies). The patents granted to the universities listed in Table 3 did not prioritize such economic segments. Nevertheless, Brazilian companies Petrobras and Vale do Rio Doce have developed solid research and patenting skills in technological fields covered by classes H01 and Q49.

On the other hand, unlike the giants Petrobras/Vale do Rio Doce and the main foreign corporations operating in Brazil, UNICAMP, USP, and UFMG directed a significant portion of their patent applications to more traditional economic segments, such as the food industry (class D13), the sectors producing cosmetics and disinfectants (class D22), and basic sanitation services (class D15).

Table 3. Ranking the Top 15 Derwent Class Codes (DCC) that received most patent applications: i) aggregated portfolio of IP documents belonging to the top 100 foreign holders of Brazilian patents; ii) portfolios from UNICAMP, USP, and UFMG.

DCC	Description	Ranking DCC – foreign holders	Ranking DCC UNICAMP	Ranking DCC – USP	Ranking DCC – UFMG
T01	Digital computers, data processors, interfaces, and program control	1	4	8	9
W01	Communication: data transmission systems and data networks	2			
D16	Microbiology and fermentation	3	2	2	2

A96	Medical, dental, veterinary, cosmetic derived from polymers	4	5	3	3
B04	Pharmaceuticals or veterinary compounds	5	1	1	1
W02	Communication: broadcasting, radio, and line transmission systems	6			
A97	Papermaking, detergents, food and oil derived from polymers	7	14	15	11
H01	Petroleum	8			
S03	Scientific instrumentation	9	3	4	4
Q49	Mining constructions	10			
D21	Preparations for dental or toilet purposes	11	8	5	
W04	Audio/video recording and systems	12		10	
P31	Diagnosis, surgery	13			
X22	Electric power engineering – automotive	14			
S05	Electrical medical equipment	15	15	9	10
D13	Foodstuffs and animal feed		6	12	
J04	Chemical engineering		7	13	7
B07	General: tablets, dispensers, catheters		9	6	5
B05	Pharmaceuticals: aromatics, aliphatic, organo-metallics		10	7	6
J01	Evaporation, crystallisation, chromatography, dialysis, and osmosis		11		
D22	Cosmetics and disinfectants: sterilising, bandages, skin-protection agents		12		15
D15	Treating water, industrial waste, and sewage		13		14
P32	Dentistry and prosthesis			11	
A89	Photographic, laboratory equipment, optical			14	12
C06	Biotechnology: including plant genetics and veterinary vaccines				8
B02	Pharmaceuticals: fused ring heterocyclics.				13

Source: Derwent Innovations Index – DII (Web of Science/ Clarivate Analytics)

Notwithstanding the differences in the previous three paragraphs, the present study found several points of similarity between the institutions presented in Table 3. Rows 2–11 in the table show the ten technological classes with more patents from foreign companies. The predominance of yellow in these rows suggests a certain technological convergence between such transnational corporations and Brazilian universities. The technological classes that include software development (class T01), microbiology and fermentation (class D16), production of pharmaceutical drugs and veterinary products (classes A96 and B04), paper and cellulose (class A97), scientific instrumentation, and hospital equipment (classes S03 and S05) were highlighted in all the research programs in Table 3.

Technological convergence proved to be even stronger among the three Brazilian universities. The patenting activities of UNICAMP, USP, and UFMG have mainly prioritized the same DCCs. This study identifies only three individual exceptions (i.e. three exclusive classes): UNICAMP has favored the chemical processes for separating organic compounds (class J01) while USP has developed technologies in the field of dentistry (class P32). Furthermore, UFMG has shown interest in researching new plant biotechnologies (class C06).

5. Conclusions

The findings of this study tend to reinforce two propositions present in Buainain et al. (2019). The authors had already verified the leadership of Brazilian universities in patent applications made by residents and the absence of domestic companies in the worldwide patent race that has involved several contemporary economic segments. Our results demonstrate that Brazilian inventors are also not participating in the global race for IoT applications, which further increases the risk that Brazilian companies and universities will be entirely excluded from the fourth industrial revolution.

On the other hand, the evidence presented here does not support the proposition that Brazilian universities' patenting activities are more linked to the 'old economy' (Buainain et. al. 2009). Several points of technological convergence were identified between UNICAMP, USP and UFMG, and the group formed by the top 100 foreign holders of Brazilian patents. In both cases, a significant portion of the patent filings was directed to software development, microbiology, pharmaceutical outputs, and scientific instrumentation. Hence, our results seem to be in line with those of Garcia, Araújo, Mascarini, Santos, & Costa (2020) according to which, owing to the lack of private R&D efforts in Brazil, academic research tends to act as a substitute for business investments in S&T&I, which contributes to direct university activities towards applied research.

Finally, the original contribution of this work is in determining that most university patent families have their legal validity restricted to the Brazilian geographic territory. We emphasize that this situation could potentially: i) hinder commercial exploitation in other countries of technologies developed by Brazilian universities; ii) restrict the diffusion of these inventions to the business sector through licensing agreements; iii) limit the royalty revenues derived from such contracts. However, these proposals must be confirmed by specific studies on technology transfer agreements signed between Brazilian universities and private companies.

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