Rômullo da Silva Eduardo

Patents in Brazil: An Econometric Investigation

Rio de Janeiro, Brasil

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Dissertação de Mestrado a ser submetida à banca de Corpo Docente selecionada pelo Programa de Pós-Graduação em Economia, Instituto de Economia da Universidade Federal do Rio de Janeiro. Área de Concentração: Economia Industrial.

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Programa de Pós-Graduação em Economia (PPGE)

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Resumo

Por estarem relacionadas à inovação e ao crescimento econômico moderno, as patentes têm sido o foco de diversos estudos nos últimos anos. A patente concede ao titular o direito de explorar sua invenção exclusivamente por um período determinado de tempo em um dado espaço geográfico. A estimação do valor da patente é uma das preocupações dos pesquisadores no que tange à literatura de patentes. O presente trabalho visa acrescentar a essa literatura apresentando alguns modelos de estimativa de valor de patente para os dados de depósitos de patentes no Brasil de 2000 a 2020. Para atingir esse objetivo, o trabalho foi segmentado em três partes. Na primeira parte do trabalho serão apresentadas estatísticas de concessões e depósitos de patentes no Brasil no período de 2000 a 2020. A segunda parte do trabalho é dedicada à estimação de um modelo de contagem ponderada de patentes como medida de inovação. Por fim, a terceira parte do trabalho preocupa-se em analisar a relação entre a submissão da patente a um contrato e os indicadores tradicionais de patentes. Os resultados destas análises mostram que grande parte dos depósitos de patentes ainda são de titulares estrangeiros, que há uma maior concentração de valor de patentes na indústria farmacêutica, e que patentes que sofreram oposições, foram concedidas e duraram muitos anos são patentes de maior valor, no que tange à submissão a contratos.

Palavras-chave: Patentes, Patentes no Brasil, Inovação, Modelo de Count Data, Modelo de Contagem Ponderada de Patentes, Modelo de Probabilidade de uma Inovação.

Abstract

As they are related to innovation and modern economic growth, patents have been the focus of several studies in recent years. The patent grants the holder the right to exploit his invention exclusively for a specified period in a given geographic space. The estimation of the patent value is one of the researchers' concerns regarding the patent literature. The present work aims to add to this literature by presenting some models for estimating patent value for patent filing data in Brazil from 2000 to 2020. To achieve this objective, the work was divided into three parts. In the first part of the work, statistics on patent grants and deposits in Brazil from 2000 to 2020 will be presented. The second part of the work is dedicated to the estimation of a weighted patent counting model as a measure of innovation. Finally, the third part of the work is concerned with analyzing the relationship between patent submission to a contract and traditional patent indicators. The results of these analyzes show that a large part of patent filings are still held by foreign applicants, that there is a greater concentration of patent value in the pharmaceutical industry, and that patents that were opposed, were granted and lasted many years are patents of greater value, with regard to submission to agreements.

Keywords: Patents; Patents in Brazil; Innovation; Count Date; Weighted Patent Count Model; Probability Model of an Innovation.

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1 Introduction

The determinants of economic growth are one of the main concerns of Economic Science. Several economists highlight the importance of technology as a central component of economic growth theories. In this context, the discussion regarding patents and intellectual property rights arises. Douglas North, a Nobel laureate economist, pointed out that developing intellectual property rights (including patents) is responsible for modern economic growth (Jones and Vollarth, 2013). In addition to North, another economist awarded the Nobel Prize in Economics, Paul Romer, points to the importance of patents in formalizing the relationship between the "Economy of Ideas" and economic growth. According to him, ideas, such as non-rival but partially exclusive goods, are more favorable in environments where intellectual property systems (such as patents) guarantee owners the right to charge for their use, in addition to being able to restrict them for a certain period (Jones and Vollarth, 2013).

The patent, an instrument used to protect an invention and guarantee its owner exclusive rights to use his invention for a limited period in a given geographic space (Nagaoka, Motohashi, and Goto, 2010), is one of the forms of reward for innovation and the inventor/company's research and development work. This fact happens once the patent: provides the owner with exclusivity in the use of the invention; allows the company to establish itself dominantly in the market, as it prevents competitors from using the invention; positively signals to the market, shareholders (if any), and other investors that the company has the technical knowledge and technological capacity; among other advantages (Eckert and Langinier, 2014).

Understanding how the patent system works and how it rewards innovation is a topic of extreme importance for public policymakers since it is from the understanding of these issues that the design and optimal mechanism of a patent. In addition, patents are usually associated with the degree of innovation of a given country since they elucidate inventions, which are often responses to research and development (R&D) work. To understand how the patent system works in a given country is, indirectly, to understand how that country behaves in the face of innovation and how it has been developing over time.

The present work is divided into three parts, each inspired by a work that deals with the relationship between patent filing and innovation in Brazil. The first part of the work presents statistics on patent grants and deposits in Brazil from 2000 to 2020. This part of the work is inspired by the study by Albuquerque (2000). The second part of the work is dedicated to estimating a weighted patent counting model as a measure of innovation, based on the work of Lanjouw, Pakes & Putnam (1998). Finally, the third part of the work is concerned with analyzing the relationship between patent commercialization and traditional patent indicators based on the work prepared by Svensson (2022).

According to Albuquerque (1995), the Brazilian innovation system is small and shows inefficiency when compared to the pattern demonstrated by countries with more mature innovation systems. In addition, it is also possible to identify companies' involvement in Research and Development (R&D) activities, a pattern much lower than that prevailing in advanced economies. In conclusion, Albuquerque (1995) found that there is a low scientific production in the country concerning the average of developed countries, which compromises the creation of externalities for the general economic process; and that the productive sector misuses the resources at its disposal.

Kannebley et al. (2005), when analyzing the characteristics of innovative Brazilian companies, concluded that export-oriented innovation is the primary determinant for innovation in Brazil. Other factors such as company size, the fact that the company is foreign, having a mixed capital origin, and intra-industry differences are also significant. However, differently from what is generally raised in the literature, the size of the company is not the primary variable for innovative activity in a company, export orientation and the origin of capital being mixed are much more relevant factors, which highlights the low-level innovation of national companies, already commented on in Albuquerque (1995), in addition to the dependence on foreigners for the innovative process. Still in this line of thought, Resende and Hasenclever (1998) indicate a low level of innovative effort in Brazil. The authors' analytical approach, which used data from Brazilian companies in 1993 and 1994, reveals that the intensity of R&D varies with the company's size in some sectors but not in others. However, a negative relationship between R&D intensity and firm size was found in the industries in which it varies.

One of the characteristics of the Brazilian patent system is the large presence of individuals and universities (and other educational institutions) in the total number of patents deposited. According to Albuquerque (2000), between 1980 and 1995, the average annual percentage of participation of the two groups was around 38% of the total, the same participation of domestic companies. Domestic and foreign companies together accounted for 72.7%. This characteristic differs from other countries in that the percentage of patents filed by individuals and universities is lower than that of domestic companies. In the United States, for example, data from the *United States Patent and Trademark Office* (USPTO) show that individuals represented, on average, 4% of the total patents granted before 2007, while domestic companies represented 45%. Domestic and foreign companies together accounted for 86.4% [1] of patents granted before 2007 in the United States.

When analyzing all these factors, such as an inefficient innovation system dependent

[1] Available at: <encr.pw/Z2Ld2> Accessed: April 11, 2022.

on the external sector and a patent system with a different composition from the systems of developed countries, the importance of studying the patents and their design in Brazil shows relevance. In addition, Brazil underwent important transformations during the period 2000 to 2020 that influenced the path that innovation and the development of new technologies took in the country. The period was fruitful in actions for innovation in the Brazilian economy, with changes in the technological policy agenda, compared to previous periods, due to the institution of a new legal framework and new stimulus instruments (Bastos, 2012).

Furthermore, the Industrial Property Law, LPI 9279/96, established in 1996, marks an important chapter in the Brazilian patent system and was not incorporated in the study by Albuquerque (2000), which analyzes patents granted until 1995. This is an aspect of material that motivates the analysis of patent statistics for more recent periods, after the creation of the Law.

The structure of this document is divided as follows. Section 2 will be dedicated to reviewing the literature on patents, presenting the concept, and discussing relevant topics. Section 3 will show patent statics in Brazil and a count data model with Brazilian data. Section 4 is dedicated to explaining the database used to carry out this work. In sections 5 and 6, the Weighted Patent Count Model and the Probability Model of Innovation will be presented and explained. Section 7 will focus on the results of the models in the two previous sections. Finally, section 8 aims to conclude the work.

2 Patents

Overview

As one of the oldest forms of intellectual property protection, patents aim to foster a society's economic and technological development. According to WIPO (2011a), a patent is a document that details an invention and creates a legal situation in which the invention can be exploited only with the patent holder's authorization. Otherwise, a patent protects an invention and grants the owner exclusivity to use his invention for a limited period in a particular country. Upon request, a governmental agency (usually a Patent Office) grants a patent. Any natural or legal person can file a patent, as long as it complies with the rules, being called an applicant.

Also, according to WIPO (2011a), the purpose of a patent is to reward not only the creation of something new but also the improvement of previous inventions, to make the idea feasible from a technological and commercial point of view. This incentive encourages companies and individuals to continue developing new technologies, making them marketable and valuable to society.

Several reasons can be pointed out as favorable to the agents' decision to patent, such as: the fact that the patent grants exclusive rights that allow the holder to use and exploit it; the possibility of the company establishing a solid market position, since the patent grants the holder rights to prevent third parties from using the invention, reducing competition and marking a position in the market; the opportunity for greater profitability of the capital invested, since the holder can commercialize, license or assign the patent in order to obtain a greater return on the investment made; the reward for the inventor to enjoy the fruits of his research without worrying about the chance of having his idea usurped; the improvement of the company's image for investors and for the market in general, since patents are a way of demonstrating a high level of technical knowledge and the company's capacity; the dissemination of knowledge to society, since the patent elucidates knowledge that could be protected by industrial secrecy; encouraging competitors to seek alternative innovations for a given problem; facilitating the monitoring of competitors' research activities; and prevention of research and development duplication (WIPO, 2021a).

Following the international convention, it is possible to obtain patents for any inventions, whether of processes or products, in any technology area. However, according to the legislation of each country, some objects cannot be patented. The human genome, for example, cannot be patented. With rare exceptions, materials that already exist in nature cannot be patented either. A perpetual motion machine, which defies the laws of nature, cannot be patented either (WIPO, 2021a).

Once granted, a patent must be exercised, traded, or abandoned, like other forms of property. Rockett (2010) reports that trade contracts are pretty standard, representing around 10% to 20% of patent issues. Patents differ from other forms of protection in that they are temporary rather than permanent rights. Patent protection lasts for a maximum of 20 years from the filing date. However, statutory protection need not last this long, as periodic renewal payments are often required to maintain the right up to its maximum term. Regularly, patents are allowed to lapse. Rockett (2010) details that only 8% of all patents go to a full time in Europe.

Economic interpretation of patent process

As Rockett (2010) explained, the basic features of the US patent system and those of other countries are pretty similar, so the focus here will be on the US structure only for convenience. The Brazilian structure will be further explored in the next chapter. We will now use the US system issues about the interpretation of the patent process that determines the basic building blocks for a modeling approach.

The US Constitution, as well as the laws of several countries, asserts that the objective of the intellectual property right system is the progress of "Science and the Useful Arts." If one were to take this in its words, one would not automatically want to use social welfare as the standard of optimality in an intellectual property rights system model. Alternatively, one might wish to use the rate of innovation or the speed of research and development spending.

The author continues to shed light on the interpretation of "progress" in "Science and the Useful Arts". Plenty of models capture the significance of patented innovation by some value created for society. In some models, this value is interpreted as a private market value. But, the actual patent approval process doesn't make such a direct link between commercial and scientific or technical value. The patent document does not go further to determine any monetary value. Protection is not tailored *ex-ante* to such a notion of market value.

While the link between the value that a profit-maximizing firm and value could capture in terms of technical progress could be tenuous, as a practical matter, they are intimately closed. Since patents are expensive to obtain, inventors worried that their profits would not apply to patents if they anticipated no resulting private commercial value. Scotchmer (1999) and Cornelli and Schankerman (1999) aim that applicants have information about whether or not a patent will generate private market value, even if the patent office has little information on this count. The applicant's information is revealed by its patenting behavior. In particular, applicants with higher private value may precisely be those observed to be patented and where that patent is observed to be renewed despite renewal fees. In consequence, patent protection is correlated with innovations that have higher private value in their inventors' eyes.

At last, there is a question of *when* the value is realized for society or the inventor. La Manna (1994) shows that if the patent right is granted early before the majority of the expenditure to develop the innovation has been incurred, then the exclusionary right guarantees the applicant that he can reap the exclusive reward to its expenditure before that expenditure is incurred. If the right is granted late, and many firms can compete for that right, then the potential applicant only faces an expected benefit at the time of his research investment. The differences between these two scenarios can affect the incentives to invest. It is essential to emphasize that a patent's social and private value doesn't need to flow directly from the patented technology but may be largely derivative.

Rockett (2010) states that there are two main ways one can assume that the patent right could promote the progress of science. The first mechanism is the establishment of a private reward for innovation. This is occasionally called the "reward theory" of patent protection and is presented in Nordhaus's (1969) work. The argument is that exclusivity provides remuneration for successful innovators by generating potential monopoly power. If the cost to generate innovation is privately borne, then the anticipation of such private compensation is a necessary "reward" to instigate innovation in a market setting with profit-maximizing agents. If exclusive rights were not available to the innovator and if the underlying knowledge were a pure public good, any party could use this information to replicate the innovation and compete with the patent holder to provide it to purchasers. This kind of competition could reduce the rewards for innovation. Consequently, the patent system promotes innovation that would otherwise be underprovided by the market due to a positive informational externality.

Despite the points presented, it cannot be said that the system of temporary exclusion rights necessarily generates socially insufficient incentives to innovate. Exclusivity also generates forces that can create socially excessive incentives to innovate. The right guaranteed by the patent does not designate any party allowed to attempt the innovation; anyone can potentially compete for the intellectual property right and its benefits. It turns out that if there are many potential innovators who can compete for the right to earn the reward for innovation, there may be socially strong incentives to invest in innovation. Each potential innovator is incentivized to win the prize to gain market share compared to its competitor. Otherwise, competitors for this award do not consider a negative externality that each exerts on the others in striving to win, leaving the losers with nothing to show for their efforts. Thus, even in the context of a single innovation, if there is more than one innovative potential, the market can generate socially excessive incentives to innovate (Rockett, 2010).

This thinking concludes that the basic assumptions formulated about the conditions of entry into new research paths are likely to affect the conclusions about the incentives to innovate. If ways are publicly known, and the resources to achieve them are freely available, concern about excessive innovation incentives is justifiable. On the other hand, if ideas are uniquely revealed to innovators, then worry about socially excessive entry into a "common pool" may be irrelevant. There may be a need to increase incentives to innovate in this case of "private information".

The second mechanism by which patent exclusion rights can generate benefits from the invention and "promote the progress of science" is present in the idea that when innovations are created, so is information. This can be specific information about the nature of the innovation, or it can be in the form of showing that a particular approach to a problem is possible and fruitful. The cost of creating this information is high for the private sector, but it is socially helpful since it can facilitate innovation for others. The user may be in entirely different fields or markets, so the reward for private innovation need not fall below the investment cost. Still, there is a positive externality exerted by the creators of information. This creates a gap between private and social incentives to exert inventive effort, suggesting that the supply of information needs to be encouraged, as it will tend to be underprovided in the market.

Thus the dissemination of information is an explicit objective of the patent system. The "contract theory" of patenting sees patents as "contracts" between inventors and society, in which the patent right is granted in exchange for the dissemination of information. Patent documents create an open-access library of this information.

Rockett (2010) summarizes that the "reward" and "contract" theories of patents form the basis of how patents generate scientific progress. Reward and information benefits can be seen as underlying both single-innovation patent design and multiple-innovation models.

Economic Literature: Patents and Patent Offices

A patent office is a government agency responsible for organizing and enforcing patent matters. The *Instituto Nacional da Propriedade Industrial* (INPI), the United States Patent and Trademark Office (USPTO), and the European Patent Office (EPO) are examples of patent offices, managing patent issues in Brazil, the United States, and Europe, respectively.

In response to questions concerning backlogs, pendency times, and concerns over the quality of granted patents, economic literature focusing on the patent process and procedure has emerged recently. Eckert and Langinier (2014) present this literature, which deals with how patent rules affect the decision to apply for a patent and the preparation of the application, the examination of the patent, and the subsequent litigation process.

Eckert and Langinier (2014) point to at least three types of agents in this framework: patent applicants, patent examiners, and third parties. These agents are expected to differ in their objectives and in the information they possess. Applicants may know more about the patentability of their innovation than examiners, and examiners may have a better knowledge of their skills and efforts than the patent office. Such information asymmetries can lead to strategic behavior on the part of the more informed party. Patent offices are organizations that employ many examiners, and it seems unlikely that patent offices and examiners have congruent objectives. One type of agent's behavior affects the other agents' behavior. Changes to examiner incentives that lead to a more stringent examination process may affect the number and type of applications submitted. Changes in the incentive to an application by inventors may increase demand for examiner services and reduce examination quality. Finally, policies that encourage third-party participation impact patent quality.

Even though manuals and legislation partially standardize the patent prosecution process, Eckert and Langinier (2014) report that the behavior of individual examiners affects the outcome of the patent examination. In general, the examination of an application begins with a review of legal formalities and an analysis of the claims. In this process, the examiner analyzes the information submitted by the applicant, looks for relevant information, such as related to state of the art, and determines whether the innovation meets the patentability requirements. As individual examiners influence the outcomes of the patent system, it is essential to understand how they respond to the incentives provided by patent offices. The USPTO, for example, often uses targets in a formal bonus and award system based on whether examiners exceed predetermined output with few errors.

Langinier and Marcoul (2012) show that determining incentives for examiners involves a balance between quality and quantity since an examiner can devote more effort to searching for invalidating information, increasing the examination quality at the expense of processing fewer applications. Furthermore, establishing appropriate incentives for quality versus quantity is complicated once defining, measuring, and verifying exam quality is problematic. Because of this, it is hard to develop incentive contracts that include a targeted rate.

Regarding depositor behavior, Eckert and Langinier (2014) divided it into two issues: filing strategies, such as where to apply, and the effect of examination rules and procedures on broader decisions such as whether to innovate and whether to apply for patents on innovations of a given quality.

First, analyzing the filing strategies, in the light of Eckert and Langinier (2014), it can be said that a depositor faces a range of decisions that can impact the outcome of patenting. The applicant must decide which agencies to apply to and in what order. Several strategic choices are also involved in the drafting of the application, such as the number of claims and the length and readability of the application. After the application is made, the applicant faces another series of decisions: whether and when to apply for the examination, how to respond to feedback, whether to amend the application, and whether to withdraw the application.

The literature identifies two implications of these different decisions: the time spent in the examination process and the disclosure and concealment of private information by candidates. In their work, Stevensborg and van Pottelsberghe (2007) divide application filing strategies into four categories based on considerations of duration and information revelation: goodwill and fast track, goodwill and slow track, lousy will and slow track, and deliberately abusing the system. A longer filing duration can be encouraged by applying under the PCT and compiling a complicated application with many claims. Shorter durations can be achieved through national applications, drafting a clear and accurate document, advance examination requests, and rapid responses to agency feedback. These decisions affect the information disclosed by the requester and the timing of disclosure. Complicated applications with many claims can hide the real invention. The nature of the invention may be obscured by not reporting the relevant prior art or, in fact, not correctly searching for it. Uncertainty about whether the patent will be granted and the scope of the patent can be extended in time through drafting and other strategies that prolong the duration needed for the patenting procedure.

Much of the empirical literature that studies the time lag between the application and the outcome of the patent process is focused on the determinants of delay and whether more valuable patents experience more (or less) delays than less valuable patents. When studying applications made to the EPO between 1982-1998, Harhoff and Wagner (2009) found that more valuable patents are granted in a shorter time than those of inferior quality and that the duration of the examination communicates patent information to rivals. Régibeau and Rockett (2010), when studying deposits made at the USPTO for genetically modified crops between 1983 and 1999, noticed that the delay is shorter for more important patents, controlling the filing date.

Regarding the effect of patent system rules on applicant behavior, Eckert and Langinier (2014) mention that the various patent policies influencing applicants' strategic decisions have been subject to theoretical and empirical studies. Changes in patenting fees will change the behavior of applicants, which in turn will affect the examination process. Van Pottelsberghe and François (2009) empirically demonstrated a negative relationship between the patent cost per claim *per capita* and the number of claims. This demonstration supports the idea that differences in patenting rates in different countries are related to differences in fees.

Several surveys highlighted the importance of fees for patent applicants. De Rassenfosse and van Pottelsberghe (2011) argue that the increased propensity to patent in Europe is caused by its lower fees. Some researchers have studied the optimal fee schemes, stand as Eckert and Langinier (2014). Cornelli and Schankerman (1999) show that when there is *ex-ante* uncertainty in the RD effort and the inventor has more information about the *ex-post* value of innovation, it might be optimal for the patent office to offer a list of patent durations and associated lump-sum fees. The current renewal fee system rises at too slow a path. If costs and benefits are unobservable, Scotchmer (1999) argues that the patent renewal system is equivalent to a direct mechanism where higher-value inventions should get longer patents.

Another approach considers the efficiency impact of increased patent fees. For example, Atal and Bar (2010) show that increasing patenting fees will lower the net expected benefit of bad patents and likely increase the prior art search intensity of applicants.

An alternative way to change the fee structure is making the applicant choose between two exam types: more expensive and more thorough examination or standard and cheaper. Lemley *et al.* (2005) argue that a two-speed system (or gold-plate system) has been under consideration at the USPTO. As Atal and Bar (2014) show, such a policy could reduce the number of applications once only suitable applicants apply for the gold plate in equilibrium.

At least, we will deal with third-party behavior. Eckert and Langinier (2014) say that because of the uncertain nature of the validity of any patent, third parties can intervene in the patenting process, and their behavior will likely affect the patent outcome. Graham and Harhoff (2006) claim that third parties are typically competitors who may have information regarding an innovation's novelty, obviousness, and technological development.

There are different ways to challenge a patent to exist. In some offices, like EPO, a patent may be challenged within patent offices through a post-grant review mechanism. Alternatively, in the USPTO, litigation is the primary approach to challenging a patent. If EPO grants a patent, any third party can file an opposition. The opposing party has to prove that the patentability requirements were not fulfilled. The outcome of the opposition system can be to nullify the patent, amend it or do nothing (Eckert and Langinier, 2014).

Harhoff and Reitzig (2004) study a model of opposition in which the patent holder and opponent have differing assessments of the probability of opposition being successful in determining when opposition proceedings are expected and when the parties will negotiate a settlement. They consider two cases. In the first case, the opposition is successful, and the opponent can enter the patent holder's monopoly. In the second case, the opposition protects the opponent's monopoly from entry. Opposition proceedings are expected when the total profit from settlement net of settlement costs is less than the combined expected profits from the opposition proceedings. Based on this model, Harhoff and Reitzig (2004) conclude that opposition proceedings are more likely to be observed when: there are differences in the beliefs of the parties about the possible success of opposition; the asymmetry of information across the parties increases; the overall stakes increases; and oppositions costs falls relative to settlement costs.

Patent Cooperation Treaty (PCT)

Created in 1970 and in force since 1978, the Patent Cooperation Treaty (PCT) is a treaty administered by WIPO, which provides for the filing, research, publication, and preliminary examination of international applications (WIPO, 2021a). The PCT simplifies obtaining patents in contracting countries through a single filing of an international application, which can then be processed at the various designated national or regional offices of the PCT member states.

According to WIPO (2021a), the national patent system requires filing individual patent applications for each country in which protection is intended. The applicant must adapt his application to the current legislation of the country he chooses to obtain the patent, promote translation in the respective languages and establish representatives to represent them in these countries, remembering to bear the service fees charged in those countries. For the applicant, all these charges arise at a time of uncertainty, in which the feasibility of granting the patent and the possibility of commercializing the invention is unknown.

The PCT has as its fundamental objective to simplify and make more efficient and economical the previous methods of applying for invention patent protection in several countries, in the interests of the users of the patent system and of the Institutes that are responsible for managing it. It is important to note that Brazil is a signatory to the PCT.

To send the application via PCT, the applicant must first file an application with the Receiving Office (Patent Office of the PCT Member State), which is normally the office of the country of his/her nationality or residence, or, still, make the deposit directly with the International Bureau (WIPO, 2021a).

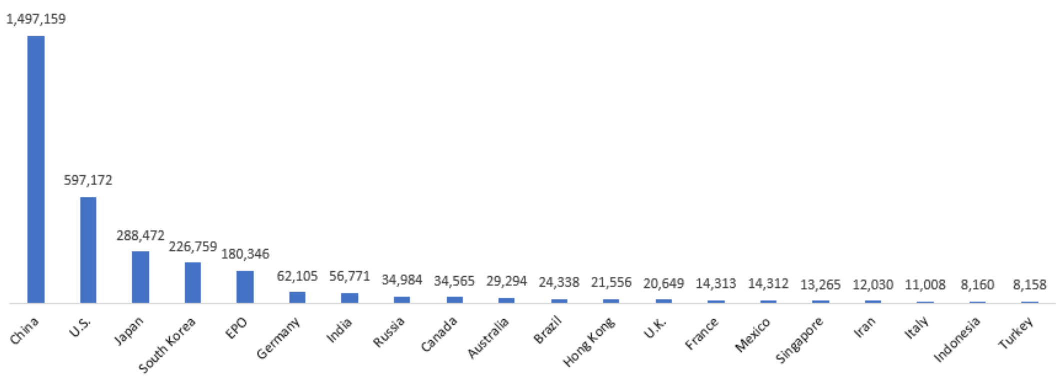
The PCT system consists of two phases. The first phase, called the international phase, comprises three main steps and an optional fourth. These are filing, carrying out the international search and writing the written opinion, international publication, and, optionally, the international preliminary examination. After that, the second phase, the national phase, begins when the applicant will deposit his application in each country where he wants to obtain the patent. There are currently 153 member states that are part of the PCT. It is important to emphasize that the international and national phases of the PCT are distinct. The process of applying for patents in different countries only materializes with the entry into the national phase in each of them (WIPO, 2021a).

International Statistics

The World Intellectual Property Organization (WIPO) annually produces a collection of relevant intellectual property information for the previous year. In this subsection, the 2010 and 2020 yearbooks will be analyzed, highlighting the similarities and differences of the data over ten years.

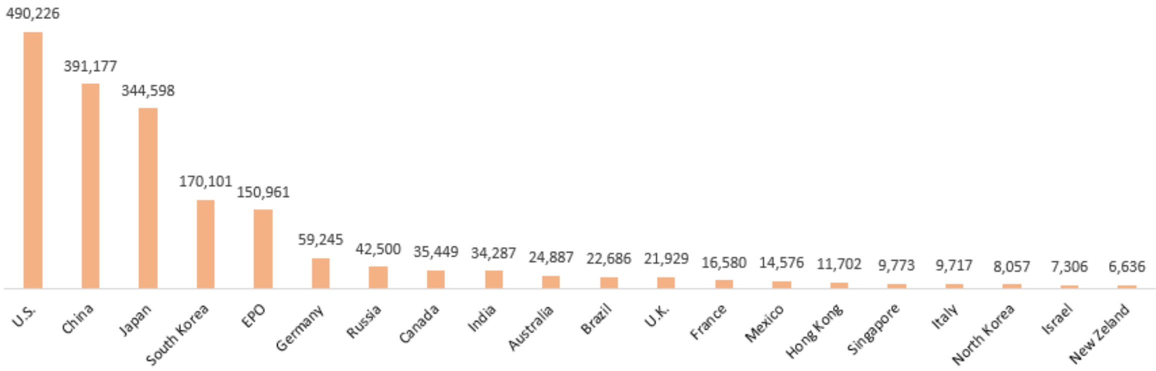
Firstly, concerning application data, the total number of applications of the top 20 offices increased by 69% in 2020, compared to 2010 data, which can be seen in figures 1 and 2 below. Another factor that stands out when analyzing the graphs is China's leadership in 2020, overtaking the United States, the leader in 2010, with more than twice as many applications. Japan, South Korea, and the European Patent Office (EPO) complete the top 5 in both years. Some countries that appeared in the list of the 20 most prominent offices in the number of applications in 2010, such as Israel and New Zealand, gave way to other countries, such as Indonesia and Turkey, in 2020. Brazil remained in 11^{th} place in both lists.

Figure 1 – Patent application at the top 20 offices (2020)



Source: World Intellectual Property Organization (WIPO). Author's elaboration.

Figure 2 – Patent application at the top 20 offices (2010)



Source: World Intellectual Property Organization (WIPO). Author's elaboration.

Regarding the division of investments by region, Table 1 below illustrates this division, in which the dominance of the Asian continent can be seen, which already received most of the applications in 2020 (52%) and grew by about 15 percentage points, starting to receive 67% of all applications made in the world. North America occupies the second position, receiving 19.3% of all applications, a decrease from the percentage registered in 2010. Europe, Latin America, Africa, and Oceania also lost space in percentage terms in the total of applications carried out in 2020, compared to those in 2010.

Table 1 – Patent application by region (2010 and 2020)

	Number of application		Share of world total (%)		Average growth (%)
Region	2010	2020	2010	2020	2010 - 2020
Africa	12,700	16,400	0.6	0.5	2.6
Asia	1,028,700	2,183,400	51.5	66.6	7.8
Europe	343,300	357,900	17.2	10.9	0.4
Latin America and Caribbean	55,400	52,200	2.8	1.6	-0.6
North America	525,700	631,700	26.3	19.3	1.9
Oceania	31,600	35,100	1.6	1.1	1.1
World	**1,997,400**	**3,276,700**	**100.0**	**100.0**	**5.1**

Source: World Intellectual Property Organization (WIPO). Author's elaboration.

In turn, Table 2 compiles application data by field of technology. The dominance of the Electrical Engineering field is remarkable, representing about 30% of the total applications. The Electrical Engineering field is followed by the Chemistry and Mechanical Engineering fields, with about 21% of the total. Finally, the areas of Instruments (16%) and Others (12%) complete the list. Among the sub-fields, "Electrical machinery, apparatus, energy" and "Furniture, games" stand out, with more than 6% of the total applications.

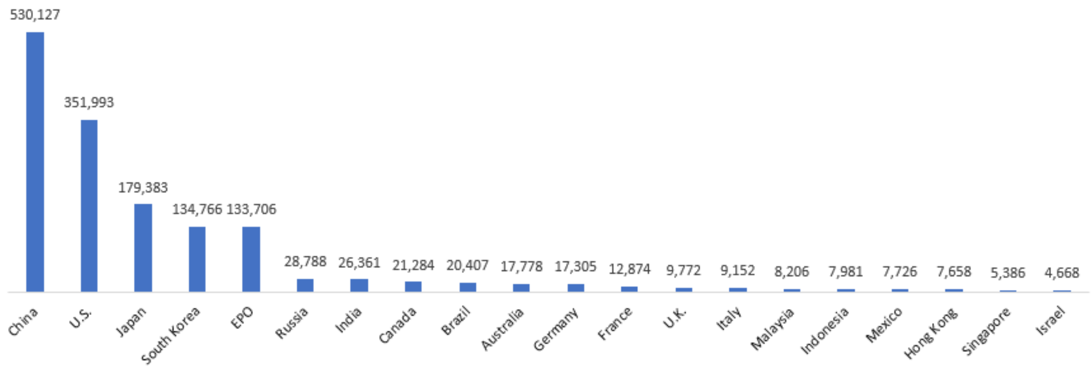
Table 2 – Published patent applications worldwide by field of technology (2009, 2014 and 2019)

		Number of published applications			Share of total (%)	Average growth (%)
Field of technology		2009	2014	2029	2019	2009-2019
Electrical engineering	Electrical machinery, apparatus, energy	111,980	172,934	210,429	6.6	6.5
	Audio-visual technology	83,019	76,268	86,827	2.7	0.4
	Telecommunications	60,237	52,058	57,973	1.8	–0.4
	Digital communication	73,146	115,628	155,011	4.9	7.8
	Basic communication processes	17,147	16,931	17,670	0.6	0.3
	Computer technology	131,516	188,469	284,146	8.9	8.0
	IT methods for management	24,698	41,372	77,523	2.4	12.1
	Semiconductors	77,777	87,859	93,337	2.9	1.8
Instruments	Optics	69,336	64,784	75,040	2.4	0.8
	Measurement	76,685	114,007	182,612	5.7	9.1
	Analysis of biological materials	11,909	14,547	19,745	0.6	5.2
	Control	29,395	43,425	78,422	2.5	10.3
	Medical technology	78,793	106,647	154,706	4.9	7.0
Chemistry	Organic fine chemistry	55,245	58,896	65,540	2.1	1.7
	Biotechnology	38,403	50,185	70,520	2.2	6.3
	Pharmaceuticals	73,865	90,655	96,737	3.0	2.7
	Macromolecular chemistry, polymers	28,877	40,932	53,901	1.7	6.4
	Food chemistry	27,416	57,073	56,343	1.8	7.5
	Basic materials chemistry	43,244	70,992	81,429	2.6	6.5
	Materials, metallurgy	35,695	58,723	76,570	2.4	7.9
	Surface technology, coating	32,643	40,905	48,716	1.5	4.1
	Micro-structural and nano-technology	3,222	5,053	5,724	0.2	5.9
	Chemical engineering	36,375	53,859	91,855	2.9	9.7
	Environmental technology	24,535	36,993	63,462	2.0	10.0
Mechanical engineering	Handling	43,376	60,461	99,202	3.1	8.6
	Machine tools	40,731	66,581	103,286	3.2	9.8
	Engines, pumps, turbines	48,489	62,345	63,404	2.0	2.7
	Textile and paper machines	32,685	36,404	46,688	1.5	3.6
	Other special machines	48,393	76,095	127,302	4.0	10.2
	Thermal processes and apparatus	27,652	38,854	54,797	1.7	7.1
	Mechanical elements	47,500	63,919	77,066	2.4	5.0
	Transport	70,844	96,819	142,882	4.5	7.3
Other fields	Furniture, games	43,943	58,633 80,049	2.5	6.2	
	Other consumer goods	32,379	46,012	59,532	1.9	6.3
	Civil engineering	55,477	81,760	120,436	3.8	8.1
	Unknown	5,847	3,786	3,790	0.1	–4.2
Total		1,742,474	2,350,864	3,182,672	100.0	6.2

Source: World Intellectual Property Organization (WIPO). Author's elaboration.

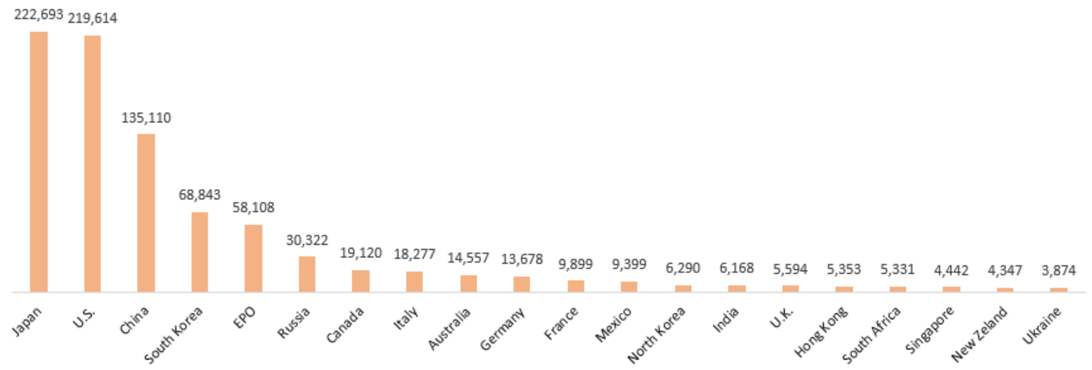
Figures 3 and 4 elucidate patent grants in 2010 and 2020. As can be seen, China, which was in 3^{rd} place in 2010, reached leadership, surpassing the United States and Japan. Interestingly, despite receiving the highest number of applications in 2010, the United States was not the country with the highest number of grants, a position occupied by Japan. Another country that grew considerably in the number of grants was Brazil, which was not on the list of the top 20 offices in 2010 and came to occupy the 9^{th} position in 2020. It is noteworthy that the country has adopted a policy to combat the backlog of patents in August 2019, which consequently increases the number of grants.

Figure 3 – Patent grants for the top 20 offices (2020)



Source: World Intellectual Property Organization (WIPO). Author's elaboration.

Figure 4 – Patent grants for the top 20 offices (2010)



Source: World Intellectual Property Organization (WIPO). Author's elaboration.

Analyzing the grant data by region makes it possible to draw parallels with the application data by region. As with applications, only Asia recorded a growth in the percentage of grants in 2020 compared to the distribution in 2010. The continent represents about 58% of all grants and encompasses 9 of the top 20 offices in grants in 2020, as could be seen in figure 3.

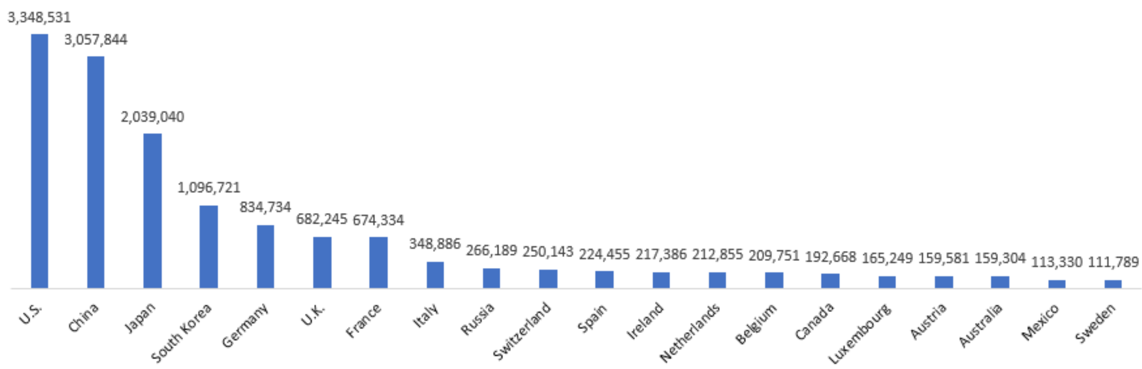
Table 3 – Patent grants by region (2010 and 2020)

	Number of grants		Share of world total (%)		Average growth (%)
Region	2010	2020	2010	2020	2010 - 2020
Africa	9,000	7,000	1.0	0.4	-2.5
Asia	469,600	924,500	51.4	58.1	7.0
Europe	160,800	231,500	17.6	14.5	3.7
Latin America and Caribbean	17,200	36,100	1.9	2.3	7.7
North America	238,700	373,300	26.1	23.4	4.6
Oceania	18,900	19,600	2.1	1.2	0.4
World	**914,200**	**1,592,000**	**100.0**	**100.0**	**5.7**

Source: World Intellectual Property Organization (WIPO). Author's elaboration.

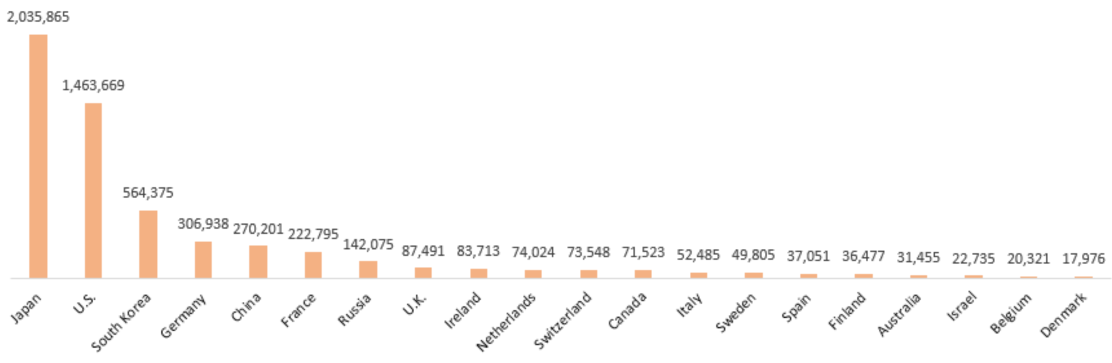
Figures 5 and 6 bring the listings of the top 20 patent offices in force, that is, that are not extinct, for 2010 and 2020, respectively. Although China had the highest number of filings and concessions in 2020, the United States still maintains the lead regarding the number of patents in force. In turn, China's number of patents in force has grown considerably, from 270,201 in 2010 to 3,057,844 in 2021, a growth of 1032%. There is still a large concentration of European countries on the list, even though it has decreased from 2010, as 13 of the 20 are European countries in 2020. Another factor that draws attention is the absence of Brazil in both the 2010 and 2020 listings. Although the country has increased the number of grants, the number of patents in force is not significant to enter the top 20, either because of delay in granting time, which will be seen below, or because patent holders do not maintain their patents until the effective date.

Figure 5 – Patents in force at the top 20 offices (2020)



Source: World Intellectual Property Organization (WIPO). Author's elaboration.

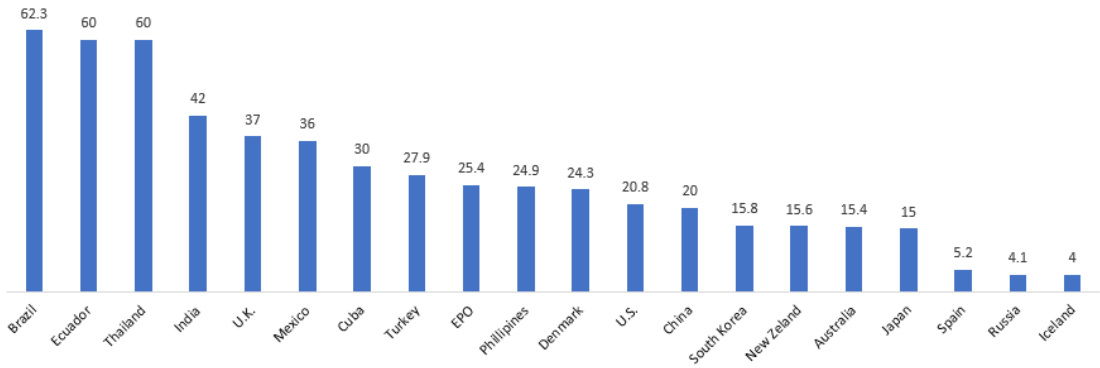
Figure 6 – Patents in force at the top 20 offices (2010)



Source: World Intellectual Property Organization (WIPO). Author's elaboration.

Finally, Figure 7 illustrates the average pendency times data for the first office action and final decision. Brazil ranks first among the selected countries, with an average time of 62.3 months. The country faced a severe problem with the patent backlog and installed a program to combat the backlog in August 2019, as previously mentioned. It is interesting to note that the list is headed by developing countries, such as Ecuador, Thailand, India, and Brazil. Among developed countries, the one with the longest average time is the United Kingdom, with 37 months. Despite receiving the most significant number of applications, the United States and China have an average time of 20.8 and 20 months, respectively.

Figure 7 – Average pendency times (in months) for first office action and final decision at selected offices (2020)



Source: World Intellectual Property Organization (WIPO). Author's elaboration.

Patents and Innovation Activities

According to Nagaoka et al. (2010), innovation can be seen as converting invention, ideas, and knowledge, technological or not, into new products, services, and processes to generate economic returns. Patents can be an input or/and an output of this process. Furthermore, patent statistics can indicate the innovation process, through knowledge spillover and research collaborations, for example. Griliches (1990) points to the fact that patents have been treated as an output of the R&D knowledge production function and input to the production function to explain a firm's performance, such as productivity.

Furthermore, the number of patents can be used as a proxy for knowledge capital, considered input of the firm's production function, as shown by Pakes and Griliches (1984). On the other hand, patents can be used as indicators of productivity and market value of a company, i.e., as outputs, since they are generated through the firm's R&D (Nagaoka et al., 2010).

It is also important to remember that not all patents are used as inputs to firms' production functions. A firm may, for example, retain its patent rights to block competitors' inventions or prepare for future cross-licensing negotiations. Thus, not all patents are considered "stock of knowledge," and some of them have the sole purpose of appropriation. Furthermore, patenting is endogenous to market opportunities and the size of a company's complementary assets, as a company's propensity to patent increases with patenting profitability (Nagaoka et al., 2010).

Nagaoka et al. (2010) point out that not all inventions are patented when relating patent and innovation statistics. The patent system guarantees ex-ante incentives for inventive activities by granting ex-post monopoly rights to enjoy these activities. However, there are other mechanisms for appropriating the returns from innovation. Rapid product development, product design complexity, and control of complementary features are other important mechanisms (Mansfield, 1986; Scherer, 1959).

The study by Nagaoka and Walsh (2009), which uses a survey of American and Japanese inventors, shows that patent is significantly generated outside of R&D. Research suggests that more than 10% of triadic patents, i.e., filed in the US, Japan, and European offices, do not involve R&D. These patents are generated as a by-product of non-R&D tasks such as manufacturing and design and are more significant in small and medium-sized firms.

Since patentability requires both novelty and utility, applied research can be expected to be most likely to result in patents among the three stages of RD: basic research, technology translation or applied research, and development system (Chen Hung, 2016). Basic research may not lead to patents directly, as a patentable invention must have a specific use. Moreover, development may not generate easily patentable inventions, as it contributes less to knowledge production, and acquired knowledge is more likely to be anticipated (Nagaoka et al., 2010). However, this is not the case. Pure development inventions account for nearly half of patents in Japan, and basic research also produces many patents. As pointed out by Hall et al. (1986), while basic research is more productive in terms of the number of patents per RD dollar, patents are produced significantly at each stage of research and development, corresponding approximately to expenditures, which may explain the contemporary movement of patents and R&D.

3 Patents in Brazil

This section presents the characteristics and main statistics of patenting activity in Brazil. For this purpose, data from patent (patents of invention and utility model) filings and concessions between 2000 and 2020 was used. The section is based on the study carried out by Albuquerque (2000).

It is essential to highlight that according to Pavitt (1988), Griliches (1990), Patel and Pavitt (1995), patent statistics are an imperfect indicator of innovation activities. This imperfection increases when domestic patents of developing countries are discussed.

First, less-developed countries like Brazil, Mexico, and India, compared to developed countries, have technological activities of a lower level. Innovative technological activities may be made to foreign technologies, which may be copied or adapted to suit local patterns. These kinds of improvements, although locally relevant, are not straightforwardly translated into patents once local learning may exist without local patenting (Albuquerque, 2000).

Second, different patent laws have critical statistical implications (Albuquerque, 2000). In Brazil, for example, the Supreme Court decided in May 2021 to overturn a provision in the Industrial Property Law that extended the patent term due to the INPI's (Instituto Nacional da Propriedade Industrial - Brazilian National Institute of Industrial Property) delay in analyzing the patent administrative process. This decision affected a thousand patents.

Third, the bulk of technological improvements in developing countries lies in technological transfer mechanisms that are not captured by domestic patent statistics (Albuquerque, 2000).

Despite these limitations, the database of patent filings granted in Brazil remains a valid starting point to understanding the "picture" of technological activities in the country. This point will be better analyzed in the following subsection.

Before showing and analyzing patent statistics, it is necessary to present how the patenting process works in Brazil briefly.

As argued in the previous section, a patent is intended to protect an invention and guarantee the applicant the exclusive rights to use his invention for a certain period and in a particular country. In Brazil, the law that establishes the rules regarding patents is the Industrial Property Law (LPI - Law No. 9279, May 14, 1996). This law provides for two types of patent protection: invention patents and utility model patents (WIPO, 2021a).

An *invention* can be defined as a new solution to a specific technical problem within a particular technological field. An *utility model* is a new form or arrangement in an object of practical use or part of it to improve its use or manufacture. In other words, invention patents are aimed at protecting creations of a technical nature to solve problems in a specific technological area. On the other hand, Utility model patents aim to protect technical-functional creations related to the form or arrangement introduced in an object of practical use, or part of it, giving the object a functional improvement (WIPO, 2021a).

The applicant must ensure that his invention is new before filing a patent application. For this, he must survey the prior art on the question. Then, he must prepare the descriptive report, claims, drawings (if applicable), list of sequences (if applicable), a deposit of biological material (if applicable), and summary. A technician will examine this patent application to meet the essential criteria for patentability. In Brazil, the National Institute of Industrial Property (INPI - Brazilian National Institute of Industrial Property) is responsible for this process, which must comply with Normative Instructions 30/2013 and 31/2013 (WIPO, 2021a).

There are three patentability criteria: novelty, inventive activity, and industrial application.

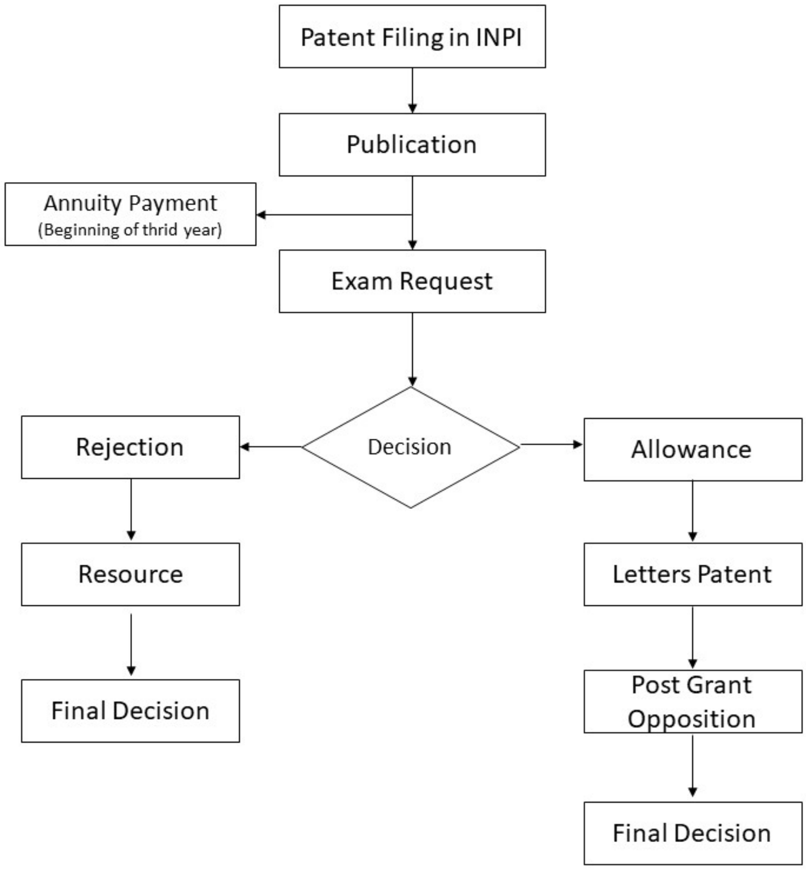
The novelty criterion is related to the invention/utility model never being performed, executed, or used before (WIPO, 2021a).

To assess whether a patent is new, it is necessary to know the state-of-the-art, defined as everything made available to the public before the filing date of the patent application. The grace period guarantees that disclosures made by the inventor himself or by third parties will not be considered as part of state-of-the-art provided that they have been made up to 12 months before the filing date of the claimed priority (WIPO, 2021a).

In the case of patents of inventions, the criterion of inventive activity is that the invention must represent a sufficient development of the prior art before its realization to be considered patentable. As for the case of the utility model, the criterion is defined by the inventive act. In other words, the model must present a functional improvement in the prior art's use or manufacture before its realization is considered patentable (WIPO, 2021a).

The third criterion is that of industrial application; that is, the invention must be capable, in some way, of being applied in the industry (WIPO, 2021a).

After filing, the patent application will be processed. This process can be summarized in Figure 1.



Source: INPI. Author's elaboration.

Figure 8 – Summarized flowchart of the processing of a patent application in Brazil.

As defined in the image, after the publication of the application, the patent holder must pay a fee annually to keep the patent in force. If he does not make this payment in one of the years, the patent expires.

So far, only the procedural aspects of patents in Brazil have been presented. The following subsection will present the country's statistics and characteristics of patenting activity.

3.1 INPI's Statistics

This subsection presents INPI data of patent filings and grants between 2000 - 2020. These data are divided into five categories, according to their ownership structure, as follows: (1) individuals; (2) universities and research institutions (UNV); (3) government agencies (GOV); (4) state-owned firms (STA); and (5) privately-owned firm (FIR).

Tables 1 and 2 present patent concession and filing data for residents, while tables 3 and 4 present the same information for non-residents.

Table 4 – Patents granted to Brazilian residents, by the INPI, by ownership structure (totals, averages annual shares, standard deviations of annual shares, and coefficients of variability (2000-2020))

Ownership structure	Total	Average annual share	Standard deviation	Coefficient of variation
FIR	9,419	0.469	0.054	0.003
IND	8,202	0.410	0.043	0.002
UNV	2,382	0.077	0.066	0.004
STA	891	0.042	0.014	0.000
GOV	74	0.002	0.003	0.000

Source: INPI, author's elaboration

Table 5 – Patents filings by Brazilian residents, in the INPI, by ownership structure (totals, averages annual shares, standard deviations of annual shares, and coefficients of variability (2000-2020))

Ownership structure	Total	Average annual share	Standard deviation	Coefficient of variation
IND	104,933	0.629	0.074	0.005
FIR	43,352	0.260	0.017	0.000
UNV	17,000	0.101	0.065	0.004
STA	1,334	0.008	0.003	0.000
GOV	248	0.001	0.001	0.000

Source: INPI, author's elaboration

Table 6 – Patents granted to non-residents, by the INPI, by ownership structure (totals, averages annual shares, standard deviations of annual shares, and coefficients of variability (2002-2020)

Ownership structure	Total	Average annual share	Standard deviation	Coefficient of variation
FIR	91,231	0.942	0.021	0.000
IND	4,089	0.051	0.022	0.000
UNV	770	0.007	0.002	0.000
GOV	14	0.000	0.000	0.000

Source: INPI, author's elaboration

Table 7 – Patents filings by non-residents, in the INPI, by ownership structure (totals, averages annual shares, standard deviations of annual shares, and coefficients of variability (2000-2020))

Ownership structure	Total	Average annual share	Standard deviation	Coefficient of variation
FIR	398,274	0.945	0.010	0.000
IND	15,308	0.038	0.011	0.000
UNV	7,070	0.017	0.003	0.000
GOV	44	0.000	0.000	0.000

Source: INPI, author's elaboration

As can be seen, the distribution of patent deposits and grants by ownership structure has different characteristics of the applicant's nationality. When analyzing the cases of applicants residing in Brazil, it can be seen that there is a close representation of grants between privately-owned companies (on average, 47% of concessions per year) and individuals (on average, 41%), and, in the case of deposits, a surplus of deposits from individuals (on average, 62%). Universities and research institutions also have particular relevance in this universe, representing around 8% of concussions per year and 10% of deposits.

On the other hand, when analyzing the situation of non-resident applicants, one can see a large concentration of deposits in privately-owned companies, reaching a mark of 94% of grants and deposits per year. This dominance of private companies can also be seen in the ranking of the main non-resident applicants, all privately owned companies.

Tables 5, 6, 7, and 8 show the top 20 patent applicants in the country by the number of filings and number of grants, grouped into residents and non-residents. Applicants were classified according to their Economic Activity [1], in the case of residents, and by Industry [2], in the case of non-residents.

The tables highlight interesting features regarding patenting activity in Brazil. One of the facts that draws the most attention is the significant presence of universities among the leading patent applicants and the applicants with the most patent grants in the period. Of the 20 leading national depositors, 13 are universities, which highlights the importance of this type of institution for developing inventions (and, consequently, for innovation) in the country. In this respect, São Paulo has the most significant number of universities in the top 20 applicants (UNICAMP, USP, and UNESP).

Another curious aspect is the presence of two individuals among the 20 primary holders who have been granted patents in Brazil.

Among the privately-owned companies present in both rankings, it can be seen

[1] Based on the Major Categories of the National Classification of Economic Activities (CNAE) of the IBGE (Brazilian Statistics Institute).

[2] Based on Bloomberg's Industry.

Table 8 – Top 20 Brazilian residents firms/institutions patenting in INPI (2000 - 2020)

#	Applicant	Ownership	Total of Patents	Economic Activity
1	PETROBRAS	STA	730	Manufacturing Industries
2	UNICAMP	UNV	397	Education
3	USP	UNV	265	Education
4	SEMEATO	FIR	239	Manufacturing Industries
5	VALE	FIR	216	Extractive industries
6	USIMINAS	FIR	164	Extractive industries
7	UFMG	UNV	164	Education
8	SEB DO BRASIL	FIR	124	Manufacturing Industries
9	WHIRLPOOL	FIR	121	Manufacturing Industries
10	MÁQUINAS AGRÍCOLAS JACTO	FIR	120	Manufacturing Industries
11	DURATEX	UNV	79	Manufacturing Industries
12	AGCO DO BRASIL	FIR	64	Manufacturing Industries
13	NELY CRISTINA BRAIDOTTI	IND	63	-
14	CNEN	GOV	62	Public administration, defense, and social security
15	GIUSEPPE JEFFREY ARIPPOL	IND	57	-
16	ARNO	FIR	57	Trade
17	EMBRAPA	STA	53	Professional, scientific, and technical activities
18	DUCHACORONA	FIR	51	Manufacturing Industries
19	FUNDACAO CPQD	UNV	48	Professional, scientific, and technical activities
20	BRASKEM	FIR	48	Manufacturing Industries

Source: INPI, author's elaboration

Table 9 – Top 20 Brazilian residents firms/institutions applicants in INPI (2000 - 2020)

#	Applicant	Ownership	Total of Patents	Economic Activity
1	PETROBRAS	STA	1,177	Manufacturing Industries
2	UNICAMP	UNV	1,028	Education
3	WHIRLPOOL	FIR	901	Manufacturing Industries
4	USP	UNV	883	Education
5	UFMG	UNV	651	Education
6	UFPR	UNV	476	Education
7	UFPB	UNV	443	Education
8	VALE	FIR	382	Extractive industries
9	UFCG	UNV	318	Education
10	UFRGS	UNV	309	Education
11	UNESP	UNV	302	Education
12	SEMEATO	FIR	296	Manufacturing Industries
13	UFC	UNV	290	Education
14	FUNDAÇÃO CPQD	UNV	287	Professional, scientific, and technical activities
15	USIMINAS	FIR	248	Extractive industries
16	UFPEL	UNV	242	Education
17	UFPE	UNV	229	Education
18	BOSCH	FIR	210	Manufacturing Industries
19	UTFPR	UNV	201	Education
20	UFS	UNV	192	Education

Source: INPI, author's elaboration

that most of them belong to the manufacturing industry, in addition to two representatives from the extractive industry (Vale and Usinimas).

In comparison with the study by Albuquerque (2000), whose data were from 1980 to 1995, we can notice some similarities and differences. A similarity that can be observed is the large portion of patents granted to individuals, which represented about 38% in the study by Albuquerque (2000) and came to represent 41% in the period 2000 to 2020, reaching second place in both rankings. Another similarity is Petrobras' leadership in ranking the main national patentees. In this ranking of main patentees, some changes can be seen, such as the drop in the number of state-owned companies on the list, which went from 7, in the period 1980 to 1995, to 2, in the period 2000 to 2020. The growth in the number of universities between top patentees is also an observable difference, reaching three between 2000 and 2020, compared to none in the previous period. In addition, two individuals among the main patentees from 2000 to 2020 are highlighted, as opposed to none from 1980 to 1995.

Table 10 – Top 20 non-residents firms/institutions patenting in INPI (2000 - 2020)

#	Applicant	Ownership	Total of Patents	Country	Industry[1]
1	BASF	FIR	1,481	Germany	Chemicals
2	BAYER	FIR	1,221	Germany	Biotech & Pharma
3	DOW	FIR	1,170	USA	Chemicals
4	UNILEVER	FIR	1,160	United Kingdom	Consumer Products
5	HONDA	FIR	942	Japan	Automotive
6	JOHNSON & JOHNSON	FIR	810	USA	Biotech & Pharma
7	NIPPON STEEL	FIR	780	Japan	Iron & Steel
8	QUALCOMM	FIR	765	USA	Semiconductors
9	KIMBERLY-CLARK	FIR	762	USA	Consumer Products
10	PROCTER AND GAMBLE	FIR	708	USA	Consumer Products
11	SHELL	FIR	631	Netherlands	Oil, Gas & Coal
12	ERICSSON	FIR	610	Sweden	Hardware
13	LORÉAL	FIR	599	France	Consumer Products
14	BOSCH	FIR	587	Germany	Automotive
15	DEERE & CO	FIR	583	USA	Machinery
16	BAKER HUGHES	FIR	512	USA	Oil, Gas & Coal
17	GENERAL ELECTRIC	FIR	499	USA	Electrical Equipment
18	LG	FIR	490	South Korea	Hardware
19	XEROX	FIR	469	USA	Tech Hardware & Semiconductors
20	SAINT GOBAIN	FIR	443	France	Retail - Discretionary

Source: INPI, author's elaboration

[1]Based on Bloomberg's Sub-Industry

Regarding non-resident applicants, the data on the main applicants and those with the most patents granted show some patterns. First, the top 20 applicants on both lists are privately-owned companies. Second, companies are primarily North American and European, with Germany standing out in this second group. Third, there are many companies in the Biotech & Pharma segment in the list of principal applicants, with six representatives.

Some points deserve to be highlighted. The presence of Chinese company Huawei is one of those points. The company, which made only one filing in 2000, filed 559 patents in 2019, reaching second place among the most significant applicants that year, just behind Qualcomm, and surpassing big names in the Hardware industry, such as Ericsson.

Another difference is related to the companies' sectors when the main resident applicants are compared to the main non-residents. While residents belong mainly to

Table 11 – Top 20 non-residents firms/institutions applicants in INPI (2000 - 2020)

#	Applicant	Ownership	Total of Patents	Country	Industry[1]
1	QUALCOMM	FIR	7,792	USA	Semiconductors
2	BASF	FIR	6,839	Germany	Chemicals
3	BAYER	FIR	5,184	Germany	Biotech & Pharma
4	DOW	FIR	4,875	USA	Chemicals
5	PHILIPS	FIR	4,085	Netherlands	Medical Equipment & Devices
6	PROCTER AND GAMBLE	FIR	3,979	USA	Consumer Products
7	PFIZER	FIR	3,555	USA	Biotech & Pharma
8	GENERAL ELECTRIC	FIR	3,410	USA	Electrical Equipment
9	UNILEVER	FIR	3,364	United Kingdom	Consumer Products
10	3M	FIR	3,276	USA	Industrial Materials
11	ROCHE	FIR	3,177	Switzerland	Biotech & Pharma
12	HALLIBURTON	FIR	2,925	USA	Oil, Gas & Coal
13	HUAWEI	FIR	2,614	China	Hardware
14	JOHNSON & JOHNSON	FIR	2,606	USA	Biotech & Pharma
15	MICROSOFT	FIR	2,474	USA	Software
16	SANOFI	FIR	2,440	France	Biotech & Pharma
17	NOVARTIS	FIR	2,438	Switzerland	Biotech & Pharma
18	HONDA	FIR	2,425	Japan	Automotive
19	ERICSSON	FIR	2,377	Sweden	Hardware
20	SONY	FIR	2,315	Japan	Hardware

Source: INPI, author's elaboration

[1]Based on Bloomberg's Sub-Industry

the manufacturing and extractive industries, in addition to the significant presence of universities, the leading representatives of non-residents come from the Hardware and Chemical industries, in addition to the Biotech& Pharma, as mentioned earlier, sectors with greater technological intensity. Furthermore, the difference in the number of deposits is significant. Petrobras, the principal national applicant, would not be included in the ranking of the top 20 depositors of the INPI. On the other hand, Qualcomm, the principal non-resident applicant, has more deposits than the top 14 in the ranking of resident applicants (table 6) combined.

Tables 9 and 10 present data are referring to patent grants by technological area. The division by technological field is based on International Patent Classification (IPC). The IPC is the system in which technological areas are divided into classes A to H. Within each category, there are sub-categories, main groups, and groups in a hierarchical system (INPI, 2020a).

Firstly analyzing the concessions for residents, it can be seen that the main areas are linked to the Mechanical Engineering sector, which includes: other special machines; handling; transport; mechanical elements; machine tools, engines, pumps, turbines; textile and paper machines; thermal processes and apparatus. This sector represents about 45% of all grants to residents.

In the case of concessions for non-residents, the main areas are linked to the Chemistry sector, which includes: basic materials chemistry; organic fine chemistry; organic fine chemistry; macromolecular chemistry, polymers; chemical engineering; materials, metallurgy; pharmaceuticals; biotechnology; food chemistry; surface technology, coating; environmental technology; micro-structural and nano-technology. The sector represents about 41% of all grants.

IT methods for management, Micro-structural, and nano-technology are the areas with the lowest number of deposits for residents and non-residents, despite the micro-structural and nano-technology percentage of the chemical sector, the leading industry for non-residents.

Table 12 – Average annual shares of patents issued to Brazilian residents, by the INPI, by technological area (totals, averages annual shares, standard deviations of annual shares, and coefficients of variability (2000-2020))

Technological Area	Total	Average	Standard deviation	Coefficient of variation
Other special machines	2,318	0.111	0.034	0.001
Civil engineering	2,072	0.100	0.023	0.001
Handling	1,808	0.093	0.022	0.000
Transport	1,425	0.072	0.017	0.000
Furniture, games	1,419	0.073	0.021	0.000
Mechanical elements	1,237	0.067	0.021	0.000
Medical technology	1,093	0.048	0.012	0.000
Chemical engineering	1,025	0.047	0.012	0.000
Other consumer goods	932	0.049	0.015	0.000
Electrical machinery, apparatus, energy	809	0.035	0.020	0.000
Measurement	731	0.026	0.017	0.000
Machine tools	695	0.035	0.011	0.000
Thermal processes and apparatus	614	0.034	0.014	0.000
Basic materials chemistry	538	0.023	0.009	0.000
Materials, metallurgy	520	0.026	0.009	0.000
Engines, pumps, turbines	511	0.027	0.012	0.000
Pharmaceuticals	469	0.013	0.017	0.000
Environmental technology	440	0.022	0.008	0.000
Textile and paper machines	290	0.015	0.006	0.000
Audio-visual technology	273	0.015	0.006	0.000
Food chemistry	251	0.011	0.006	0.000
Biotechnology	248	0.011	0.007	0.000
Control	233	0.010	0.005	0.000
Organic fine chemistry	211	0.007	0.006	0.000
Surface technology, coating	205	0.010	0.004	0.000
Macromolecular chemistry, polymers	173	0.007	0.004	0.000
Computer technology	121	0.005	0.004	0.000
Telecommunications	110	0.004	0.004	0.000
Optics	98	0.004	0.003	0.000
Semiconductors	27	0.001	0.001	0.000
Digital communication	25	0.001	0.001	0.000
Basic communication processes	21	0.001	0.001	0.000
Micro-structural and nano-technology	14	0.000	0.001	0.000
IT methods for management	12	0.000	0.001	0.000

Source: INPI, author's elaboration

Table 13 – Average annual shares of patents issued to non-residents, by the INPI, by technological area (totals, averages annual shares, standard deviations of annual shares, and coefficients of variability (2000-2020))

Technological Area	Total	Average	Standard deviation	Coefficient of variantion
Basic materials chemistry	6,698	0.078	0.023	0.001
Organic fine chemistry	5,921	0.065	0.022	0.000
Medical technology	5,590	0.056	0.014	0.000
Transport	5,195	0.056	0.021	0.000
Macromolecular chemistry, polymers	5,131	0.057	0.013	0.000
Other special machines	5,034	0.054	0.011	0.000
Chemical engineering	4,758	0.050	0.012	0.000
Materials, metallurgy	4,648	0.055	0.015	0.000
Handling	4,647	0.053	0.018	0.000
Pharmaceuticals	4,615	0,038	0,023	0.000
Mechanical elements	4,607	0.051	0.024	0.001
Civil engineering	3,978	0.040	0.012	0.000
Textile and paper machines	3,413	0.043	0.012	0.000
Electrical machinery, apparatus, energy	3,175	0.028	0.012	0.000
Measurement	3,007	0.022	0.014	0.000
Machine tools	2,988	0.033	0.014	0.000
Engines, pumps, turbines	2,816	0.032	0.014	0.000
Digital communication	2,411	0.016	0.014	0.000
Surface technology, coating	2,191	0.025	0.005	0.000
Biotechnology	2,116	0.017	0.012	0.000
Other consumer goods	1,971	0.022	0.007	0.000
Food chemistry	1,747	0.017	0.014	0.000
Computer technology	1,552	0.011	0.007	0.000
Audio-visual technology	1,404	0.014	0.007	0.000
Thermal processes and apparatus	1,280	0.014	0.006	0.000
Telecommunications	1,124	0.011	0.008	0.000
Furniture, games	1,016	0.011	0.004	0.000
Optics	969	0.009	0.005	0.000
Environmental technology	896	0.010	0.003	0.000
Control	637	0.006	0.002	0.000
Basic communication processes	276	0.003	0.003	0.000
Semiconductors	189	0.001	0.001	0.000
IT methods for management	96	0.001	0.001	0.000
Micro-structural and nano-technology	8	0.000	0.000	0.000

Source: INPI, author's elaboration

Finally, Tables 11 and 12 list patent filings and grants by country of origin of the applicant.

Despite being the country with the most deposits (about 38% of the total), Brazil is not the country with the highest number of grants, a position occupied by the United States. Germany, Japan, and France complete the remainder of the top 5 in both rankings.

As shown in the list of main applicants, European countries are pretty relevant in the patenting market in Brazil. Of the top 20 countries with patent filings, 12 are European. As for the top 20 countries with granted patents, this number rises to 13. There is no representative from Africa or Latin America, except for Brazil itself, in both rankings.

The case of China stands out in this analysis. The country that filed less than 50 cases at the beginning of the millennium started to file more than 1,000 patents in the last two years of the sample (2019 and 2020). Surpassing countries like France and Switzerland, which are historically at the top of the list of major depositing countries.

Table 14 – Top 20 countries with patents granted in Brazil (2000 - 2020)

#	Country	Total	Average	Standard deviation	Coefficient of variation
1	United States	32,628	0.283	0.034	0.001
2	Brazil	20,968	0.196	0.032	0.001
3	Germany	13,403	0.122	0.015	0.000
4	Japan	7,984	0.058	0.018	0.000
5	France	7,879	0.064	0.008	0.000
6	Switzerland	5,450	0.046	0.010	0.000
7	Netherlands	4,314	0.037	0.007	0.000
8	Italy	4,026	0.033	0.004	0.000
9	Sweden	2,919	0.025	0.009	0.000
10	United Kingdom	2,901	0.026	0.005	0.000
11	Finland	1,338	0.011	0.003	0.000
12	South Korea	1,234	0.009	0.003	0.000
13	Belgium	1,227	0.009	0.002	0.000
14	Canada	1,162	0.010	0.003	0.000
15	China	1,027	0.004	0.003	0.000
16	Norway	1,026	0.008	0.002	0.000
17	Austria	966	0.008	0.002	0.000
18	Denmark	869	0.006	0.002	0.000
19	Australia	836	0.007	0.002	0.000
20	Spain	781	0.006	0.002	0.000

Source: INPI, author's elaboration

Table 15 – Top 20 countries with patents filings in Brazil (2000 - 2020)

#	Country	Total	Average	Standard deviation	Coefficient of variation
1	Brazil	166,867	0.381	0.077	0.006
2	United States	160,592	0.367	0.096	0.009
3	Germany	48,424	0.111	0.029	0.001
4	Japan	32,732	0.075	0.033	0.001
5	France	28,905	0.066	0.021	0.000
6	Switzerland	23,919	0.055	0.019	0.000
7	Netherlands	17,334	0.040	0.015	0.000
8	United Kingdom	13,387	0.031	0.008	0.000
9	Italy	12,209	0.028	0.008	0.000
10	Sweden	10,824	0.025	0.006	0.000
11	China	9,016	0.021	0.019	0.000
12	South Korea	6,855	0.016	0.007	0.000
13	Canada	5,135	0.012	0.004	0.000
14	Belgium	5,000	0.011	0.005	0.000
15	Spain	4,440	0.010	0.004	0.000
16	Finland	4,137	0.010	0.003	0.000
17	Denmark	4,019	0.009	0.004	0.000
18	Australia	3,707	0.008	0.003	0.000
19	Austria	3,291	0.008	0.003	0.000
20	Israel	3,287	0.008	0.003	0.000

Source: INPI, author's elaboration

3.2 Count Data Model

According to Cameron & Travedi (2005), in several economic contexts, the dependent variable of interest is a non-negative integer or a count that we want to explore or analyze in terms of a set of regressors. Unlike the classical regression model, the dependent variable is discrete, with a distribution that only places probability mass at non-negative integer values. Several models can be shown to be closely related to the count data regression model. Like other limited or discrete dependent variable models such as logit and probit, regression models for counts are nonlinear, with many properties and special features intimately connected to discreteness and nonlinearity.

Cameron & Travedi (2005) further report that the count is the ultimate variable of interest in some cases. In other cases, the leading variable of interest is continuous, but the best available data are counted. The sample is often concentrated on small discrete values, such as 0, 1, and 2. In addition, the data can be skewed to the right. Finally, the data are intrinsically heteroscedastic, with the variance increasing with the mean.

The Poisson Regression is the starting point for count data analysis. This occurs, according to Wooldridge (2009), since this regression is simple, often produces good results, and has a robustness property that will be discussed further below.

The basic count data regression models can be represented using the GLM framework (Nelder and Wedderburn, 1972). As pointed out by Zeileis, Kleiber and Jackman (2008), GLMs describes the dependence of a scalar variable y_i $(i = 1, ..., n)$ on a vector of regressors x_i. The conditional distribution of $y_i \mid x_i$ is a linear exponential family with probability density function

$$f(y; \lambda, \phi) = exp\left(\frac{y \cdot \lambda - b(\lambda)}{\phi} + c(y, \phi)\right), \tag{3.1}$$

where λ is the canonical parameter that depends on the regressors via a linear predictor and ϕ is a dispersion parameter that is often known. The functions $b(\cdot)$ and $c(\cdot)$ are known and determine which member of the family is used, e.g., the normal, binomial or Poisson distribution. Conditional mean and variance of y_i are given by $E[y_i \mid x_i] = \mu_i$ on the regressors x_i is specified via

$$g(\mu_i) = x_i^T \beta \tag{3.2}$$

where $g(\cdot)$ is a known link functional and β is the vector of regression coefficients which are typically estimated by maximum likelihood (ML) using the iterative weighted least squares (IWLS) algorithm.

As mentioned before, the simplest distribution used for modeling count data is the Poisson distribution. The probability density function of the Poisson distribution is given by (Zeileis, Kleber and Jackman, 2008):

$$f(y; \mu) = \frac{exp(-\mu) \cdot \mu^y}{y!}, \tag{3.3}$$

which is of type (3.1) and thus Poisson is a special case of the GLM framework. The canonical link is $g(\mu) = log(\mu)$ resulting in a log-linear relationship between mean and linear predictor. The variance in this model is identical to the mean, thus the dispersion is fixed at $\phi = 1$ and the variance function is $V(\mu) = \mu$. This shows the equidispersion (equality of mean and variance) property of the Poisson distribution.

According to Wooldridge (2009), the fact that $Var(y \mid \mathbf{x}) = E(y \mid \mathbf{x})$ is restrictive and it is possible to show that it is violated in many applications. Fortunately, the Poisson distribution has a very accurate robustness property: regardless of whether the Poisson distribution is valid, it is still possible to obtain consistent and asymptotically normal β_j estimators.

By introducing the observation subscript i, attached to both y and μ, the iid framework is extended to the regression case (Cameron & Travedi, 2005). The Poisson regression model is derived from the Poisson distribution by parameterizing the relation between the mean parameter μ and covariates (regressors) $\mathbf{x}$. The standard assumption is to use the exponential mean paraeterization (Cameron & Travedi, 2005),

$$\mu_i = exp(\mathbf{x}_i'\beta), i = 1, ..., N, \tag{3.4}$$

where by assumption there are K linearly independent covariates, usually including a constant. Because $V[y_i \mid \mathbf{x_i}] = exp(\mathbf{x}_i'\beta)$, the Poisson regression is intrinsically heteroskedastic.

Given (3.3) and (3.4) and the assumption that the observations $(y_i \mid \mathbf{x}_i')$ are independent, the most natural estimator is maximum likelihood. The log-likelihood function is (Cameron & Travedi, 2005):

$$lnL(\beta) = \sum_{i=1}^{N} \{y_i \mathbf{x}_i'\beta - exp(\mathbf{x}_i'\beta) - lny_i!\}. \tag{3.5}$$

The Poisson MLE, denoted by $\hat{\beta}_P$, is the solution to K nonlinear equations corresponding to the first-order conditional for maximum likelihood (Cameron & Travedi, 2005),

$$\sum_{i=1}^{N} (y_i - exp(\mathbf{x}'\beta))\mathbf{x}_i = \mathbf{0}. \tag{3.6}$$

If $\mathbf{x}_i$ includes a constant term then the residuals $y_i - exp(\mathbf{x}'\beta))$ sum to zero by (3.6). The log-likelihood function is globally concave; hence solving these equations by a Gauss-Newton or Newton-Raphson iterative algorithm yields unique parameters estimates.

For linear models, with $E[y \mid x] = \mathbf{x}'\beta$, the coefficients β are interpreted as the effect of a one-unit change in regressors on the conditional mean (Cameron & Travedi, 2005).

The Poisson model was used to explain the number of patents filed per applicant in this work, the dependent variable [3]. The independent variables used were: the technology field of the patent, the continent/region of the patent applicant, ownership structure of the patent applicant [4]. Patents were classified in their technological fields according to the first IPC in their filing. The list of IPCs and technological fields can be found in Annex A of this work. The cardholder region targeting comprises the following geographic regions: North America (the United States and Canada only); Latin America; Europe; Oceania; Asia (excluding the Middle East); Middle East; and Africa (excluding the Middle East) [5]. Finally, the ownership structure encompasses the same categories used in subsection 2.2: individuals, universities and research institutions, government agencies, state-owned firms, and privately-owned firms.

Table 16 below shows the results found for data on deposits and grants in Brazil from 2000 to 2020 using the Count Data model.

As can be seen from the results shown in the table, all technological fields presented positive and statistically significant results at a significance level of 5%. Among them, the field of electrical engineering is the one with the highest estimated value, 0.005, followed by the field of chemistry. Thus, holders whose patents belong to these two technological fields tend, on average, to file more patents than the others.

Regarding the applicant's region, all regions presented positive and statistically significant results at a significance level of 5%. Africa was chosen as the omitted variable. The region with the highest estimated value was North America, with 4,278, which is in line with expectations since the United States was the second country with the highest number of deposits in Brazil, only behind Brazil itself, in addition to several American companies to be among the main depositors in Brazil, as previously shown. North America was followed by Asia, with 4,159, a region that encompasses two other countries that deposited a lot in Brazil in the period: China and Japan. Oceania was the region that recorded the lowest estimated value, at 0.209.

Finally, when analyzing the ownership structure of the applicants, it can be seen that individuals are the only group to present a negative estimated value, -2,377, which is in line with expectations. Individuals do not usually file many patents, since, due to financial and physical limitations. The groups that reached the highest expected values were state-owned firms and universities, which, as seen before, are among the main patent applicants in Brazil. It is important to emphasize that the dummy that encompasses government agencies was chosen as an omitted variable and that all groups presented statistically significant results at a significance level of 5%.

[3] The model can also be estimated using panel data.
[4] The size of the company can be one of the independent variables of the model in future extensions of the work.
[5] The country classification by region can be found in Annex B

Table 16 – Count Data Model

	Dependent variable:
	Total
Electrical_engineering	0.005***
	(0.00001)
Instruments	0.002***
	(0.00000)
Chemistry	0.004***
	(0.00000)
Mechanical_engineering	0.003***
	(0.00000)
Other_fields	0.002***
	(0.00000)
North_America	4.278***
	(0.041)
Latin_America	3.505***
	(0.041)
Europe	3.984***
	(0.041)
Oceania	0.209***
	(0.045)
Asia	4.159***
	(0.041)
Middle_East	0.182***
	(0.050)
Caribbean	1.099***
	(0.049)
Privately-owned_firm	1.031***
	(0.012)
State-owned_firm	1.994***
	(0.012)
Individuals	−2.377***
	(0.013)
Universities	1.514***
	(0.012)
Constant	0.222***
	(0.043)
Observations	269,308
Log Likelihood	−17,325,643.000
Akaike Inf. Crit.	34,651,319.000
Note:	*p<0.1; **p<0.05; ***p<0.01

In this way, the Count Data model leads us to the conclusion that the most significant factor in the patent filing process in Brazil is the fact that the holders come from countries in North America and Asia, and belong to an organizational structure of a state-owned firm or universities and research institutions, and to file patents in the technological fields of electrical engineering and chemical engineering.

One of the factors that lead applicants to file patents in Brazil is the intensity of Research & Development in the sector in which the innovation to be patented was developed. To analyze this factor, it was necessary to estimate the R&D Intensity Index. According to Brigante (2018), the intensity index, when referring to the national economy, is estimated by the relationship between total expenditures on R&D and the Gross Domestic Product (GDP). For industrial sectors, this indicator can be estimated by the R&D/Net Sales Revenue ratio. This will be the definition used in this work. To calculate this relationship, data from the IBGE's Innovation Survey (PINTEC) were used, in its 2017 edition. [6]. As PINTEC data are estimated for national companies, it was necessary to segment the base used for the count data model to only consider Brazilian holders. The values found in PINTEC are segmented by Industry Activity, however, the INPI base segments patents by Technological Field, so there was a need to bring these two pieces of information together. Thus, it was considered as the R&D index of a given technological field, the average of the RD indexes of all the Industry Activities included in that field. Appendix C further explains this relationship.

It is important to emphasize that there is a lag between spending on R&D and the development of patents. To capture this effect, only patent deposits from 2018 were used, since PINTEC data refer to 2017.

Table 17 consolidates the estimated results for the count data model including the variables of R&D Intensity by Technological Field. As can be seen, all estimates for the intensity variables were statistically significant at a significance level of at least 10%. The only Technological Field that presented a positive result was Chemistry, a result influenced by the pharmaceutical sector, a sector of great relevance within the Brazilian patenting system, as already seen, and in which there is a strong intensity of spending on R&D, a time it presented the second highest intensity indicator, only behind the telecommunications sector.

[6] Data can be obtained from Table 1.1.7

Table 17 – Count Data Model for Brazilian Applicants - R&D Intensity

	Dependent variable:
	Total
R&D_Electrical_engineering	-5.048^{***}
	(0.917)
R&D_Mechanical_engineering	-1.897^{*}
	(1.128)
R&D_Instruments	-5.985^{***}
	(0.926)
R&D_Chemistry	$3.908\ ^{***}$
	(1.049)
Privately-owned_firm	-0.859^{***}
	(0.219)
State-owned_firm	0.278
	(0.232)
Individuals	-1.038^{***}
	(0.219)
Universities	-0.110^{***}
	(0.219)
Constant	1.281^{***}
	(0.219)
Observations	15,737
Log Likelihood	−25,469.380
Akaike Inf. Crit.	50,956.760
Note:	*p<0.1; **p<0.05; ***p<0.01

4 Database

To carry out this work, data from filings, grants, oppositions, agreements, and patent renewals provided by INPI were used. The time frame encompasses all patent filings, grants, and oppositions made at the INPI from January 2000 to December 2020. In addition, it was used WIPO's data on the designations of patent applications to Brazil via the Patent Cooperation Treaty (PCT). It is important to emphasize that it was necessary to cross all these bases to be able to collect the data and information required for this project.

The applications and grants database includes data about the type of patent, patent status, patent application number, IPC classification, application date, applicant, applicant's country, and grant date. All patent application registrations that had a grant date between 01/01/2000 and 12/31/2020 were considered grants. This database is static, so grants obtained after the specified period were not considered in the analysis.

From the columns originating from the database, other fundamental columns for the analysis were created. The first of these was a field adjusted for the applicant. Patent applicants are self-declared and do not follow a pattern. Thus, the same company can have its name written in different ways, such as "Petróleo Brasileiro S.A. - PETROBRÁS (BR/RJ)" and "PETROLEO BRASILEIRO S.A. (BR/RJ)" to indicate Petrobras. Therefore, it was necessary to adjust these names to standardize these differences in writing [1].

The second column created refers to the applicant's ownership structure, divided into five categories: individuals, universities and research institutions, government agencies, state-owned firms, and privately-owned firms.

Finally, the last field created concerns the Technological Field based on the IPC. Patents deposited in certain IPC classes were classified into a Technological Field according to the grouping defined by the INPI. The list of IPCs can be found in Appendix A.

The renewal database was obtained through the service codes related to the patent applications. In this way, forcing all the patent application data in which, during the analysis period, the renewal payment appears, were piled up in a base. [2].

Quantitative information on the base of deposits and concessions can be seen in the following table.

Regarding the renewals database, the following table provides the distribution of data by year.

[1] Thanks to Daniel Advogados for the grouping of applicants.

[2] The service codes for the renewals are: 223, 225, 227, 229, 230, 231, 232, 233, 234, 235, 236, 237, 238, 239, 240, 241, 242, 243, 244, 245, 246 and 247

Table 18 – Description of the application and grants database

Description	Quantity
Number of records	616,595
Number of applications (2000 a 2020)	587,564
Number of grants (2000 a 2020)	140,209
Average applications by year of application ($\overline{NPAT}$)	27,979
Average grants by year of grant	5,575
Number of applicants	157,079
First year of renewal	3
Last year of renewal	20 (invention) e 15 (utility model)
Estimated average rate of patents granted per patents filed	0.24
Number of applications by applicant	3.74
Number of grants by applicant	4.38

Source: INPI. Author's elaboration.

Table 19 – Renewals by year (2000 - 2020)

Year	Number of Records
2000	5
2001	3
2002	6
2003	995
2004	18,098
2005	101,576
2006	58,144
2007	114,748
2008	127,821
2009	130,199
2010	138,610
2011	155,039
2012	152,354
2013	179,615
2014	185,715
2015	189,486
2016	200,140
2017	201,761
2018	202,277
2019	195,395
2020	184,609

Source: INPI. Author's elaboration.

Table 3 presents the renewal amounts paid by period and type of service. The analyzed periods were divided according to the four price adjustments that took place during the analysis period (2000 to 2020): January/2000 to October/2003; November/2003 to December/2011; January/2012 to September/2019; and October/2019 to December/2020.

Table 20 – Amounts charged for renewals, in reais (R$), per period (2000 - 2020)

		Prince (in R$)			
Service	Description	Jan/00 to Oct/03	Nov/03 to Dec/11	Jan/12 to Sept/19	Oct/19 to Dec/20
Invention patent application renewal					
220	ordinary term	150	195	250	295
221	extraordinary term	225	290	500	295
Invention patent renewal in the ordinary term					
222	from 3rd to 6th year	390	505	660	780
224	from 7th to 10th year	607	790	1,030	1,220
226	from 11th to 15th year	820	1,065	1,390	1,645
228	from the 16th onwards	1,500	1,300	1,690	2,005
Invention patent renewal in the extraordinary term term					
223	from 3rd to 6th year	585	760	1,320	1,565
225	from 7th to 10th year	910	1,185	2,060	2,440
227	from 11th to 15th year	1,230	1,600	2,780	3,295
229	from the 16th onwards	1,500	1,950	3,380	4,005
Renewal of application for certificate of addition of invention					
230	ordinary term	50	65	90	105
231	extraordinary term	75	95	180	215
Renewal of certificate of addition of invention in the ordinary term					
232	from 3rd to 6th year	120	155	200	235
234	from 7th to 10th year	180	235	310	365
236	from 11th to 15th year	240	310	400	475
238	from the 16th onwards	300	390	510	605
Renewal of certificate of addition of invention in the extraordinary term					
233	from 3rd to 6th year	180	235	400	475
235	from 7th to 10th year	270	350	620	735
237	from 11th to 15th year	360	470	800	950
239	from the 16th onwards	450	585	1,020	1,210
Utility model order renewal					
240	ordinary term	100	130	170	200
241	extraordinary term	150	195	340	405
Utility model patent renewal in the ordinary term					
242	from 3rd to 6th year	200	260	340	405
244	from 7th to 10th year	400	520	680	805
246	from the 11th onwards	600	780	1,020	1,210
Utility model patent renewal in the extraordinary term					
243	from 3rd to 6th year	300	390	680	805
245	from 7th to 10th year	600	780	1,360	1,610
247	from the 11th onwards	900	1,170	2,040	2,415

Source: INPI. Author's elaboration.

Finally, the WIPO PCTs filing and designation base was used to estimate the size of patent families, since this information is based on the number of patent offices in which the patent was designated.

5 Weighted Patent Counts Model

Measures of the outcome of the innovation process help to analyze a range of political and descriptive issues related to the causes and effects of technological change. Simple patent counting has been used extensively for this purpose. However, patents protect innovations of widely varying value, so measuring patent counts is often tricky. According to Lanjouw, Pakes & Putnam (1998), the simple count of patents generates two measurement problems. First, there must be differences in the average value of innovations protected by different groups of patents, which makes comparisons of counts a biased measure of differences in the value of the innovations being counted, both in terms of social value and which refers to a private value. Second, even within groups with similar mean values, distorted relationships between patent counts and their value make it challenging to use counts to study the causes and consequences of inter-group variation in innovation value.

Recent studies have used additional information about the patent system to refine patent count measures. Some studies, such as Pakes (1986), use the fact that holders need to renew their patents annually to approximate their value. Others point to family size as another way to approximate the value of a patent. As presented in the previous section, there are five traditional indicators for the value of patents. It will be from these indicators that the weighted patent counting model will be constructed.

As already pointed out, the simple count of patents leads to wrong results despite being used extensively. An example of this, as pointed out by Lanjouw, Pakes & Putnam (1998), is in the study by Schankerman and Pakes (1986), which leads to the result of the decline, at an accelerated rate, of the patent/RD ratio in several Western countries. This observation led to the idea that the Western world had entered a period of 'technological exhaustion,' in which the potential for future productivity growth was small, as Evenson (1984).

Schankerman and Pakes (1986) compared aggregate patent count indices with their estimated patent value indices for the United Kingdom, France, and Germany from 1955 to 1975. The authors concluded that changes in the number of patents could not be inferred, as there have been significant changes in the quality of patents. Pakes and Simpson (1989) reached a similar conclusion after applying non-parametric tests to aggregate patent renewal data in Finland and Norway.

Economists' interest in patent renewal data dates back at least to Nordhaus' (1969) thesis. Pakes and Schankerman (1984) evolved the idea by showing how to use this data to discover features of patent protection value. In turn, Pakes (1986) added the possibility that the patent holder may not be sure about the sequence of returns that would be gained if the patent were kept in force. The shift to a stochastic model of returns allows for the fact that inventors often apply for patents at an early stage of the innovative process. In this way, the benefits of protection can increase as the holder becomes aware of the characteristics of the invention and the market. In this model, as there is a possibility that returns will increase, patent holders may infer that it is worth renewing, even if current returns are lower than the renewal rate, to preserve the protection option in the future (Lanjouw, Pakes Putnam, 1998).

Putnam's (1996) work, as Lanjouw, Pakes Putnam, (1998) point out, expands the utility of patent data in several ways. First, it shows how to calculate estimates of the distribution of the overall value of patent protection for inventions. Second, it allows for studying the international flow of patent protection returns. Third, it makes it possible to estimate differences in application cost as a function of both country of origin and country of application. Fourth, it extended the ability to use weights with the size of the patent family beyond the renewal years. Finally, the study points to combining application and renewal data for a scheme involving weighted patent counting, which becomes more accurate than just using renewal data.

Keeping in mind the problems that the simple counting index can bring to inferences about the patent system, Lanjouw, Pakes & Putnam (1998) developed a weighted patent counting measure that mitigates these problems. The idea is as follows. Instead of simply counting the number of patents, one can divide them into cohorts (J cohorts, for example) by the age at which the patent was allowed to expire, i.e., at which the renewal fee was not paid, and by the set of countries in which the patent applications were filed. It is then possible to construct an index of the value of the patent, called VI by the authors, as follows:

$$VI = \sum_{j=i}^{J} w_j N_j \tag{5.1}$$

where N_j is the number of patents in group 'j' and w_j is the weight associated with that group. To construct this index, it is necessary to define the set of weights, $\{w_j\}$.

There are several ways to determine these weights [1]. One is to regress a measure of the innovation's value (private or social) on the N_j and let the data estimate the $\{w_j\}$. The choice of the dependent variable will determine the interpretation of the weights. The dependent variables used in this work will be one of the traditional indicators of patent value, which will be better presented in the next chapter.

In this work, the cohorts will be divided according to the age at which patents were allowed to expire, i.e., how many years patent renewal fees were paid. Pakes (1986) points

[1] One of these ways is a Dynamic Single-Agent Model, which can be seen in Pakes (1986).

to the relevance of using renewal data. According to him, assuming that renewal decisions are based on economic criteria, agents will only renew their patents if the value of holding those patents over an additional year exceeds the cost of the renewal. The analysis of the proportions of different cohorts of patents renewed at alternative ages, together with the values of renewal rates, provides information on the distribution of patent values for the holders and on the evolution of this distribution function over the useful life of patents.

The econometric problems encountered in using regression techniques to obtain accurate estimates of required weights are similar to those that arise in estimating distributed lag. Notwithstanding, the situation here seems calmer. First, there is, at least potentially, a wealth of patent data. Moreover, if there is supposed to be some connection between the value of patent protection and the value of patented ideas, there is substantial prior information about the structure of weights that will be favorable to their estimation (Lanjouw, Pakes & Putnam, 1998).

As pointed out by Lanjouw, Pakes & Putnam (1998), a starting point is to assume that the average value of the ideas present in the patents of a given group is proportional to the value of the patent protection in that group. Suppose it is assumed that the distribution of the importance of patent protection is estimated correctly by the renewal model. In that case, one can obtain the necessary weights for the VI equation up to a proportionality factor from the work of the implications of the estimates of the parameters. The present work considers this assumption.

It is noteworthy, as the authors Lanjouw, Pakes & Putnam (1998) did, that the parameter estimates derived from the model based on renewal are informative about specific characteristics of the innovative process. The rate of obsolescence of the private returns of innovations was one of the first interests in estimating models of renovation decisions. This can be seen in Griliches (1979) or Pakes and Schankerman (1984). This obsolescence rate is necessary for weighting R&D investments in building "stocks" of knowledge, just as there are stocks for physical capital. The first deterministic renewal models find obsolescence rates in the private value of patents significantly higher than the depreciation rates usually used to construct material capital stocks.

6 Probability Model of an Innovation

This chapter aims to analyze which traditional indicators of patent value can be used as indicators of innovation in the Schumpeterian sense, that is, the introduction of an innovation in the market, and present the probability model of an innovation, which is based on these indicators. This chapter is based on the model developed by Svensson (2022).

As van Zeebroeck (2011) points out, the literature on the value of patents can be broadly organized into three main categories. The first category is focused on estimating the economic value of patents based on different information within patent databases or through field research. The former approach includes patent families (see Grefermann et al., 1974; Schmoch et al., 1988; Putnam, 1996; Harhoff et al., 1999) and renewals (see Pakes and Schankerman, 1984), and the latter varies between inventor research (Harhoff, Scherer, and Vopel, 2003; Brusoni et al., 2006; Gambardella, Harhoff, and Verspagen, 2006) and expert research (Reitzig, 2003). The main common observation of this category of literature is a severe asymmetry in the value distributions of patents, with a very long right tail and most patents associated with no or little value (see Scherer, 1965; Griliches, 1990; Lanjouw, 1993).

The second category of literature uses weighted patent counting to analyze the impact of innovation and intellectual property rights on company value or performance. For this purpose, researchers in the field evaluate the correlation of different characteristics of patents with the value of the company, with the introduction of new products, the creation of new companies (Shane, 2001), or with monetary evaluation researched by inventors. Patent characteristics considered in this regard include citations received from subsequent patent filings, legal disputes such as patent opposition (Harhoff, Scherer, and Vopel 2002; Graham et al., 2003), litigation (Lanjouw and Schankerman, 1997), and claims count (Lanjouw and Schankerman, 2004). As can be seen, this category encompasses the way to visualize the value of patents from the Weighted Patent Count Model presented in the previous chapter.

The third category, points out van Zeebroeck (2011), is based on the previous ones, taking the proposed indicators and correlating them, exploring them to investigate different determinants and patterns about the value of the patent. One of the models that emerged from this third category is the Probability Model of an Innovation (Svensson, 2022), which will be presented in this chapter.

6.1 Traditional Indicators of Patent Value

According to van Zeebroeck (2011), five indicators are pointed out as the traditional indicators of the value of the patent: citations received, grant, family size, renewals, and oppositions. Each of them will be explained further in this subsection.

It is important to emphasize that in this work, it is considered that there is a market for the patented invention. The idea behind this idea, as pointed out by van Zeebroeck (2011), is that it seems to be the most actionable information that one can expect to find in patent characteristics and the common denominator of most value measures and correlates proposed in the literature.

1. Citations

The forward citations, that is, when other technologies use the patent in their development (Marques et al., 2015), have often been used as a measure of patent value despite skepticism about whether these citations measure the private value of patents or spillover effects, as elucidated by Hall et al., 2007 (apud SVENSSON, 2022). Van Zeebroeck (2011) points out that citations indicate the existence of research efforts and a potential market for a patent. Trajtenberg (1990) argues that later citations measure the social value of patents. For a specific patent, a higher frequency of citations is associated with more significant spillover effects and, consequently, greater social value.

2. Grant Decisions

Guellec and van Pottelsberghe de la Potterie (2000, 2002) show that when a patent application results in a grant or not, this can be used as an insight into a potential patent value. Undoubtedly, patents that have not been granted have, by nature, limited private value for their holder since they can hardly be, and the costs of examination, and translation, among others, are still incurred in these applications (van Zeebroeck, 2011).

3. Family Sizes

The size of patent families, represented by the number of countries in which protection is sought for the same invention (van Zeebroeck, 2011), was examined by Schmoch et al. (1988), Lanjouw and Shankerman (2001) and Harhoff, Scherer, and Vopel (2002), that found a positive correlation between the indicator and the value of the patent or firm. As van Zeebroeck (2011) points out, given the costs required to file and enforce patents in many countries, only those with the expected value for their holders will be extended abroad, which denotes an expected market for the patented technology.

4. Renewals

In several countries, including Brazil, patent holders must pay an annual renewal fee to keep their patents in effect. The patent is permanently canceled if the renewal fee (annuity) is not paid within a single year. Assuming that renewal decisions are based on economic criteria, agents will only renew their patents if, in each period, the value of holding these patents for an additional year exceeds the cost of the annuity (Pakes, 1986).

5. Oppositions

According to WIPO (2022), the opposition is a mechanism offered by patent offices that allows third parties to oppose a patent grant. The opponent must allege at least one of the grounds for opposition among those prescribed in the applicable law. An opposition may be requested soon before the grant of a patent (pre-grant opposition) or after the grant (post-grant opposition).

Third-party oppositions signal the potential value of a patent in a given market. Thus, oppositions indicate a potential market for the patent and that the patent is sufficiently essential to justify the costs and risks associated with a dispute (Lanjouw Schankerman, 1997).

After presenting the indicators, van Zeebroeck (2011) points out that these five measures can be seen as informative about the economic importance of each patented invention. However, it is essential to remember that not all measures can be used to infer the economic value of patents.

6.2 Technology Agreements

In his article, Svensson (2022) uses commercialization as the dependent variable of his model. Commercialization indicates that a product or process innovation based on a patent has been introduced in the market. To obtain this variable, Svensson (2022) based on a survey carried out by the government of Sweden, between 2003 and 2004, with small and medium-sized companies, in which all 1,082 Swedish patents were granted in 1998 to small and medium-sized companies, and individuals were included. In this research, the patent holders indicated whether or not their patents had been commercialized. There is no similar survey for Brazil, so a proxy for this variable will be used. The proxy consists of whether or not the patent has been submitted to an agreement. A patent holder may use the patent himself, subject it to a contract, or not use the patent. In this work, only one of these cases is considered.

As presented by INPI (2020b), in addition to protecting their assets, the patent holder may want to license them to a company, or he may prefer to acquire knowledge not supported by industrial property rights. For these transactions to be secure and to allow the payment to be made abroad, some agreements must be endorsed and registered with the INPI.

The agreements registered with the INPI are Licenses for the Commercial Exploitation of Patents, Assignment of Patents, and Compulsory Patent Licenses.

The License for Commercial Exploitation of Patents is defined as an agreement that aims at the license to commercially exploit the patent or patent application filed with INPI by the patentee or the applicant. It shall comply with Articles 61, 62, and 63 of Law No. 9,279/96 (LPI) (INPI, 2020b).

In turn, the Assignment of a Patent is an agreement that aims at the assignment of a patent or patent application filed with INPI, entailing the change in ownership. It shall comply with Articles 58 to 59 of Law No. 9,279/96 (LPI) (INPI, 2020b).

Finally, a Compulsory Patent License is the effective commercial exploitation, by third parties, of the object of patent duly granted by INPI, identifying the industrial property right, and shall comply with the provisions in articles 68 to 74 of Law No. 9,279/1996 (LPI), in addition to Decree No. 3,201 of October 6, 1999, and Decree No. 4,830 of September 4, 2003. (INPI, 2020b).

6.3 Model Estimation

In parallel to Sversson's (2022) model, the dependent variable Agr_i represents whether patent i has been submitted to an agreement. It takes the value of 1 if the patent has been submitted to an agreement and 0 otherwise. Hence, a standard probit model [1] based on the cumulative normal distribution function is used to predict variation in the dependent variable.

Before presenting the model to the reader, a brief explanation of the probit models is necessary. According to Wooldridge (2009), the probit model fits into a category of binary response models, in which the interest lies mainly in the probability of response. Thus,

$$P(y = 1 \mid \mathbf{x}) = P(y = 1 \mid x_1, x_2, ..., x_k), \tag{6.1}$$

where $\mathbf{x}$ represents the complete set of explanatory variables. One way to ensure that the estimated value for y is between zero and one is to assume that:

$$P(y = 1 \mid \mathbf{x}) = G(\beta_0 + \beta_1 x_1 + ... + \beta_k x_k) = G(\beta_0 + \mathbf{x}\beta). \tag{6.2}$$

where G is a function taking values strictly between zero and one, for all real z numbers. This ensures that the estimated probabilities of responses are strictly between

1 The model can also be estimated using Panel Data.

zero and one. In the probit model, G is the standard normal cumulative distribution function, which is expressed as an integral:

$$G(z) = \Phi(z) = \int_{-\infty}^{z} \phi(v)dv \tag{6.3}$$

where $\phi(z)$ is the standard normal density

$$\phi(z) = (2\pi)^{-1/2} exp{-z^2}/2. \tag{6.4}$$

Thus, the Probability Model of an Innovation can be written as follows:

$$\begin{aligned} a_i^* &= X_i\beta + \nu, \\ a_i &= 1 \text{ if } a_i^* > 0 \text{ and } 0, \text{ otherwise} \end{aligned} \tag{6.5}$$

where a_i^* is a latent index, a_i is the selection variable indicating whether the patent has been submitted to an agreement, X_i is a vector of explanatory variables that influence the probability that the patent will be submitted to an agreement, β is a vector of parameters to be estimated and $\nu_i \sim N(0, 1)$.

As explanatory variables, the traditional indicators of patent value already presented were used. Unfortunately, a database with all the citations of patents deposited and granted in Brazil between 2000 and 2020 was not found, so this variable will not be used in this work. In addition, this variable is of lesser relevance for analyzing the Brazilian case since many patent deposits in Brazil are part of patent families, that is, that were also deposited in other patent offices so that the Citations will often refer to the parent patent (the original patent), which is traditionally filed in the holder's home country. Svensson (2022) did not find statistical relevance for the variable in his work.

The patent family size is represented by the variable $family\_size$, which measures the total number of countries in which protection was sought for the same invention. Another variable was included to indicate whether the patent belongs to a triadic family, that is, it was filed in the three main patent offices in the world, namely: the USPTO (the United States Patent and Trademark Office); the EPO (European Patent Office); and the JPO (Japan Patent Office).

Grants were encompassed by the variable *Grant*, which is a *dummy*, taking the value equals 1 if the patent was granted (until December 2020) and 0 otherwise.

In turn, patent renewals are represented by *Age*, which measures the age of the patent, i.e., the number of years the patent was in force before it expired. It is important to remember that the applicant only needs to start paying the annuities from the third year after the application. Dummies for different ages are used, then, for example, *Age5* equals 1 if the last year that the patent was in force was the fifth, *Age6* equals 1 if the last year that the patent was in force was the sixth, etc.

Finally, oppositions were captured by the variable *oppositions*, which is also a *dummy* and considers whether or not the patent has been opposed.

Control variables were also used in the model in order to incorporate the region of the patent applicant, the ownership structure of the applicant, and the field of technology of the patent, based on the first IPC of the patent registration. The complete list of fields of technology can be seen in Annex A.

The results of this model can be found in the results section.

7 Results

This section aims to present the results of the Weighted Patent Counts Model and Probability model of an Innovation.

7.1 Weighted Patent Counts Model

Table 21 shows the average weights found for each patent age cohort. Notably, the obligation to pay an annuity starts only from the 3rd year, which explains the lack of results for cohorts aged 1, 2, and 3. There were also no results found for the cohort aged 4. The table also contains the number of patents by age.

Weights were estimated as having the traditional indicator of Opposition patents as the dependent variable. This choice was based on the fact that this is the only indicator compatible with this estimation. The Family Size indicator is not statistically significant for Brazil, and the Grant indicator, being a dummy, does not correctly capture the weights by age since if the patent was not granted, it would be in age cohort 0, and if granted, it will have a value of 1 for all other age cohorts. Control variables of the applicant's region, ownership structure, and the patent's technological field were included.

When analyzing the weights estimated from the Opposition dependent variable, it is essential to remember the idea, explained in Lanjouw and Schankerman (1997), that patents that suffer more opposition tend to have more significant market potential and, consequently, are more valuable.

Given this, and returning the analysis to table 21, it is interesting to note that patents belonging to cohorts aged 6 to 9 years and patents aged 13 years have the same weight, 0.001, and are statistically significant. These patent groups are followed by the patents of the 11-year-old cohort, which have twice the value of patents in the previous groups: 0.002.

Next come the 0-year age cohort patents, weighing 0.003. A possible explanation for this phenomenon is that the opponents were successful with the opposition, so the holders of these patents lost their right to them and could not extend their age. This cohort also included patents that were not granted, patents where the holders did not have to pay annuities.

Finally, the patents of the 18 and 20-year-old cohorts obtained the highest weights, 0.006, twice as many patents with an age of 0, and three times as many patents with an age of 11 years. Except for the 17-year-old cohort, which obtained a negative result, the other cohorts did not get statistically significant results at any level of significance considered.

Table 21 – Average Weight for Patent Cohort

	Dependent variable:	
	Oppositions	Number of Patents
Age1	0.003***	136,704
	(0.0002)	
Age5	0.001**	63,338
	(0.0003)	
Age6	0.001**	53,602
	(0.0003)	
Age7	0.001**	46,944
	(0.0003)	
Age8	0.001*	41,004
	(0.0003)	
Age9	0.001*	34,969
	(0.0004)	
Age10	0.0002	29,628
	(0.0004)	
Age11	0.002***	25,822
	(0.0004)	
Age12	0.0003	20,566
	(0.0005)	
Age13	0.001**	16,472
	(0.001)	
Age14	0.001	13,283
	(0.001)	
Age15	0.001	10,189
	(0.001)	
Age16	0.001	7,955
	(0.001)	
Age17	−0.001*	7,665
	(0.001)	
Age18	0.006***	4, 806
	(0.001)	
Age19	0.001	2,317
	(0.001)	
Age20	0.006**	453
	(0.003)	
Observations	615,171	
R^2	0.007	
Adjusted R^2	0.007	
Residual Std. Error	0.050 (df = 615138)	
F Statistic	136.420*** (df = 32; 615138)	
Note:	*p<0.1; **p<0.05; ***p<0.01	

Based on the weights and number of registrations per cohort, it is possible to estimate the patent value index presented by Lanjouw, Pakes & Putnam (1998). Thus, we find the following result for Brazilian data from 2000 to 2020.

$$VI = \sum_{j=i}^{J} w_j N_j = 773.401 \tag{7.1}$$

In comparative terms, Lanjouw, Pakes Putnam (1998) found 449, 277, 201, and 172 for the US, Germany, France, and the UK, respectively, for the cohorts of patents filed in 1974.

When analyzing the patent value index by field of technology, we found the results that can be seen in table 22. It is possible to notice that the fields with the highest index are Pharmaceuticals, Medical Technology, Transport, and Civil engineering, respectively. In contrast, the ones with the lowest index are those of Micro-structural and nano-technology, Basic communication processes, and Semiconductors.

Table 22 – Patent Value Index by Field of technology

Field of technology	VI
Pharmaceuticals	44.022
Medical technology	39.475
Transport	39.053
Civil engineering	35.227
Other special machines	35.149
Organic fine chemistry	33.537
Handling	32.594
Basic materials chemistry	29.276
Furniture, games	28.634
Electrical machinery, apparatus, energy	25.906
Other consumer goods	24.443
Mechanical elements	22.123
Chemical engineering	22.050
Biotechnology	21.801
Measurement	21.379
Macromolecular chemistry, polymers	19.056
Engines, pumps, turbines	18.427
Digital communication	17.791
Computer technology	16.113
Materials, metallurgy	15.962
Machine tools	15.756
Audio-visual technology	14.733
Food chemistry	13.974
Textile and paper machines	13.666
Control	10.101
Telecommunications	10.098
Surface technology, coating	9.928
Thermal processes and apparatus, coating	9.697
Environmental technology	7.959
Optics	6.447
IT methods for management	4.856
Semiconductors	1.875
Basic communication processes	1.619
Micro-structural and nano-technology	0.216

Finally, table 23 depicts Brazil's top 20 patent applicants, from 2000 to 2020, by patent value index. It is interesting to note the significant presence of American applicants in this list since 10 of the 20 applicants are Americans. Companies from Germany, Netherlands, Sweden, Japan, China, and France complete the list. The top 20 list does not contain any Brazilian holders. The Brazilian applicant with the highest index was Unicamp, in position 47, followed by Petrobras, in position 50. Thus, as can be seen in the table, of the twenty patent applicants with the highest index, five belong to the Biotech & Pharma segment, such as Bayer and Roche, which is by the information shown in table 23, in that the technological field of Pharmaceuticals appears first. The Chemicals, Machinery, and Consumer Products segments have two representatives on the listing. There is also the presence of companies linked to the technology sector, belonging to the industries of Semiconductors, Hardware, and Technology Hardware & Semiconductors, represented by companies such as Qualcomm, Sony, and Huawei.

Table 23 – Patent Value Index by Applicant

	Applicant	Country	Industry[1]	VI
1	BASF	Germany	Chemicals	6.497
2	QUALCOMM	United States	Semiconductors	6.476
3	PROCTER AND GAMBLE	United States	Consumer Products	5.617
4	BAYER	Germany	Biotech & Pharma	5.429
5	DOW	United States	Chemicals	5.048
6	PFIZER	United States	Biotech & Pharma	4.200
7	PHILIPS	Netherlands	Home Construction	3.847
8	GENERAL ELECTRIC	United States	Electrical Equipment	3.639
9	UNILEVER	Netherlands	Consumer Products	3.217
10	3M	United States	Diversified Industrials	2.793
11	ROCHE	United States	Biotech & Pharma	2.756
12	ERICSSON	Sweden	Hardware	2.631
13	DEERE & CO	United States	Machinery	2.629
14	BOSCH	Germany	Automotive	2.613
15	HALLIBURTON	United States	Oil & Gas Services & Equip	2.555
16	SONY	Japan	Technology Hardware	2.395
17	HUAWEI	China	Tech Hardware & Semiconductors	2.334
18	SIEMENS	Germany	Machinery	2.266
19	JOHNSON & JOHNSON	United States	Biotech & Pharma	2.224
20	SANOFI	France	Biotech & Pharma	2.218

[1]Based on Bloomberg's Sub-Industry

7.2 Probability Model of an Innovation

Table 24 compiles the results of the probability model of innovation without age dummies so that age becomes a discrete variable. It is important to remember that the dependent variable is *Agreement*, which indicates whether a patent was submitted to an agreement endorsed by the INPI. The independent variables are the traditional indicators of patents. Control variables were added, including the field of technology, in which the field Enviromental Technology was used as an omitted variable; the applicant's region, in which the variable that captures African countries was used as the omitted variable; and the applicant's ownership structure, in which the variable Government Agencies was omitted.

Table 24 – Probability Model of an Innovation

	Dependent variable:
	Agreement
Age	-0.009^{***}
	(0.003)
Family_size	-0.006
	(0.019)

Triadic_Family	0.061
	(0.162)
Oppositons	0.460***
	(0.112)
Grant	0.799***
	(0.035)
Civil_Engineering	2.798
	(34.503)
Control	2.547
	(34.503)
Electrical_Machinery	2.443
	(34.503)
Handling	2.703
	(34.503)
Chemical_Engineering	2.489
	(34.503)
Transport	3.027
	(34.503)
Pharmaceuticals	1.944
	(34.503)
Materials	2.528
	(34.503)
Surface_technology	2.488
	(34.503)
Other_machines	2.701
	(34.503)
Basic_materials	2.591
	(34.503)
Measurement	2.613
	(34.503)
Machine_tools	2.508
	(34.503)
Audio-visual	2.035
	(34.503)
Other_consumer	2.469
	(34.503)
Organic_chemistry	2.146
	(34.503)
Macromolecular_chemistry	2.928
	(34.503)
Medical_technology	2.003
	(34.503)
Mechanical_elements	2.864
	(34.503)
Thermal_process	2.473
	(34.503)
Computer_technology	2.052

	(34.503)
Furniture	2.733
	(34.503)
Food_chemistry	2.333
	(34.503)
Basic_Communication	2.633
	(34.503)
Semiconductors	−0.701
	(145.038)
Textile	2.363
	(34.503)
Telecom	−0.698
	(72.339)
Environmental	3.054
	(34.503)
Engines	2.813
	(34.503)
IT	−0.442
	(99.698)
Optics	2.676
	(34.503)
Biotechnology	2.436
	(34.503)
Digital_communication	1.921
	(34.503)
North_america	3.360
	(178.441)
Latin_america	2.977
	(178.441)
Europe	3.455
	(178.441)
Oceania	2.827
	(178.442)
Asia	3.570
	(178.441)
Middle_East	3.238
	(178.441)
Caribbean	0.019
	(221.230)
Privately-owned_firm	3.128
	(339.833)
State-owned_firm	−0.104
	(374.209)
Universities	2.861
	(339.833)
Individual	2.841
	(339.833)

Constant	−12.477
	(385.380)
Observations	615,171
Log Likelihood	−4,460.905
Akaike Inf. Crit.	9,011.811
Note:	*p<0.1; **p<0.05; ***p<0.01

As can be seen, of the four traditional patent indicators analyzed in this work, only the patent family size did not show statistical significance at any significance level considered (at 1%, 5%, and 10%). The triadic family variable, which indicates whether the patent was filed in the American, Japanese and European offices, was also not statistically significant. Age presented negative estimate, of 0.009. On the other hand, Opposition and Grant registered positive estimates of 0.460 and 0.799, respectively. This effect can be explained by the dependent variable used, that is, the fact that the patent was subject to an agreement. It is expected that very valuable patents, that is, patents with a significant degree of innovation, will be protected by their holders so that they do not wish to enter into agreements with third parties and exclusively exploit their invention. As can be seen in Pakes (1986), agents only pay patent renewal fees in periods when the value of maintaining the patent exceeds the costs. That is, *coeteris paribus*, the higher the age of the patent, the more times the holder concluded that the value of the patent was greater than its cost. Thus, it makes sense the higher the age of the patent, the lower the willingness of the holder to submit that patent to an agreement.

On the other hand, patents that have been opposed are patents in which the interest of third parties can be noted. On these occasions, there are conflicts regarding the ownership of the invention. Consequently, to avoid future legal conflicts, the holder may become more likely to enter into agreements with third parties, which justifies the positive estimate found by the model. This notion of conflict corroborates the idea of patent value for innovation since if the patent were not valuable to be introduced in the market, the definition of innovation for Schumpeter (Svensson, 2022), there would be no interest from third parties to oppose it (Lanjouw Schankerman, 1997).

Granted patents are patents that have already passed the examination stages and were approved by the INPI, which attests to the inventiveness and novelty of these patents. In this way, they are patents whose value may be different, but it can be affirmed that the holder has the exclusive right to exploit them. Because of this right, the holder becomes more likely to sign agreements on top of their patents, earning royalties or other returns in exchange, which justifies the positive estimate for this variable.

Table 25 compiles the model results by dividing the Age variable into several dummies. As previously mentioned, the payment of annuities only becomes mandatory from the 3rd year of the patent, counted from the filing date. Ages that do not appear in the table are ages for which data are unavailable. Here, as in the estimation in which age is a discrete variable, the patent family size and the triadic family were not statically significant at any significance level considered (at 1%, 5%, and 10%). The opposition and grant variables maintained positive and statistically significant results in the previous estimation.

Analyzing the age dummies, only the variables of Age6, Age7, Age8, Age9, Age10, Age12 and Age13 showed statistically significant results at the considered significance levels. This is probably due to the higher incidence of patents at these ages. In this situation, it is interesting to note that up to age 9, the results are positive. However, from age 10, all significant results are negative. This observation corroborates the explanation given for the previous estimation: older patents are more valuable, and the holder's willingness to submit them to a contract is lower.

Table 25 – Probability Model of an Innovation

	Dependent variable:
	Contrato
Family_size	−0.010
	(0.019)
Triadic_Family	0.053
	(0.162)
Oppositions	0.568***
	(0.116)
Grant	0.780***
	(0.033)
Age1	2.611
	(25.029)
Age5	−0.093
	(0.240)
Age6	0.581***
	(0.196)
Age7	0.337***
	(0.078)
Age8	0.102*
	(0.054)
Age9	0.162***
	(0.045)
Age10	−0.087**
	(0.042)
Age11	−0.073
	(0.045)
Age12	−0.373***
	(0.063)
Age13	−0.610***
	(0.141)
Age14	0.113
	(0.174)
Age15	−3.144
	(93.041)
Age16	2.739
	(93.041)
Age17	0.314
	(0.288)
Age18	−0.199
	(0.310)
Age19	−2.910
	(216.696)
Age20	−0.028
	(535.642)

Chemistry	-3.427
	(548.567)
Instruments	0.078
	(0.125)
Electrical_engineering	-0.597^{***}
	(0.207)
Mechanical_engineering	0.217^{***}
	(0.063)
North_america	3.580
	(276.510)
Latin_america	3.256
	(276.510)
Europe	3.676
	(276.526)
Oceania	3.025
	(276.526)
Asia	3.741
	(276.526)
Middle_East	3.352
	(276.526)
Caribbean	0.019
	(346.230)
Individual	3.209
	(521.650)
Universities	2.951
	(521.650)
State-owned_firm	0.016
	(571.192)
Privately-owned_firm	3.397
	(521.650)
Constant	-13.700
	(590.941)
Observations	615,171
Log Likelihood	$-4,218.050$
Akaike Inf. Crit.	8,508.100
Note:	*p<0.1; **p<0.05; ***p<0.01

Table 26 consolidates the marginal effects of the previously estimated probit model. As can be seen, only the Grant variable has a marginal effect that is statistically different from zero. This result is in line with expectations. As explained earlier, granted patents are exclusive to the holder, which makes them more likely to be subject to a contract.

Table 26 – Probability Model of an Innovation - Marginal Effects

Variable	dF/dx	Std. Err.	z	P>|z|
Age	-0.0000*	0.0000	-2.0466	0.0407
Family_size	-0.0001	0.0001	-1.5639	0.1178
Triadic_Family	0.0015	0.0011	1.3307	0.1833
Oppositions	0.0009	0.0006	1.4042	0.1603
Grant	0.0042***	0.0003	16.3255	0.0000
Note:		*p<0.1; **p<0.05; ***p<0.01		

8 Conclusion

Due to what was presented, it was possible to understand some particularities of the Brazilian patent system. Despite being a country with strong characteristics of technological dependence on developed countries, Brazil proved to be relevant in the patent system by reaching the 11th position among patent offices around the world in 2020 by the number of applications, according to the WIPO Yearbook. However, this number of applications brings with it a series of characteristics of the Brazilian patent system, which still maintains characteristics observed in the 1980s and 1990s, by the study by Albuquerque (2000).

. As shown, between 2000 and 2020, only 38% of patents filed in the country were resident applicants. The percentage was very close to the American applicants in Brazil, which represented 37% of total applications in the period. Countries such as Germany, Japan, France, Sweden, the Netherlands, and the United Kingdom also have a strong presence among patent applicants.

In addition, about 48% of applications are made by individuals, universities, and research institutions, a higher percentage than that represented by private firms. Analyzing only resident deposits, the percentage of total patents filed by these groups is much higher, reaching 73%, almost triple the percentage of private firms. This strong presence of universities and individuals compared to companies can also be seen in the top 20 applicants that most filed patents in Brazil from 2000 to 2020, in which 13 of the 20 were universities.

In turn, the estimation of the count data model presented in the work showed that the factors that are most significant in the patent filing process in Brazil are: the fact that the holders come from countries in North America and Asia, belongs to an organizational structure of a state-owned firm or universities and research institutions, and to file patents in the technological fields of electrical engineering and chemical engineering.

By analyzing the results, the Weighted Patent Counts Model resulted in higher and statistically significant weights for patents belonging to 18- and 20-year-old cohorts, followed by patents in the 11-year-old cohort. The model also generated the patent value index for Brazil, between 2000 and 2020, of 773.4, and showed that the patents with the highest value index belong to the technological fields of pharmaceuticals, medical technology, and transport. In addition, it was also possible to observe that the holders who filed patents of more significant value over that time were BASF, Qualcomm, Procter & Gamble, and Bayer, all private and foreign companies, which corroborates the idea of a strong presence of foreign companies in the Brazilian patenting process.

Finally, using the main indicators of patent value, grant decisions, patent family size, renewals, and oppositions, as independent variables to estimate the probability of an innovation, defined here as the fact that the patent has been submitted to an agreement, the Probability Model of an Innovation showed that only renewals (or, equivalently, patent age), oppositions and grants are statistically significant when using the database of deposits and concessions that took place in Brazil between 2000 and 2020. From the results presented, age has a negative relationship with whether a patent is subject to a contract, which makes sense as valuable patents are renewed more often, and holders are less willing to subject valuable patents to a contract. On the other hand, patents that have been opposed have a positive and significant probability of being subject to contracts, which also meets the general idea that these patents are already undergoing a dispute, and an agreement is a great way to resolve this kind of situation. And granted patents belong exclusively to the holder, which facilitates the submission of these patents to agreements.

As limitations of the work, it is highlighted the non-use of a dependent variable that directly indicates the introduction of a patent in the market for the estimation of the Probability of Innovation Model, as did Svensson (2022), in addition to the non-use of the independent variable of citations in the same template. If available, these variables can be used in future work expansions. It is also worth mentioning the possibility of using time series models to estimate the Probability of the Innovation Model, which followed the cross-section formulation developed by Svensson in future work extensions. The development of the patent signaling idea, in which holders only deposit patents to signal to other competitors and to the market that is innovating, a fact that cannot necessarily be reflected in the value of their patents, and that certainly influences the patent count by the applicant, is a possible extension of the work. Finally, breaking down the types of contracts executed by the INPI is another addition that can be made to the work.

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Annex

ANNEX A – List of Technology Field by IPC

Field of technology		IPC
Electrical engineering	Electrical machinery, apparatus, energy	F21B, F21C, F21H, F21K, F21L, F21M, F21P, F21Q, F21S, F21V, F21W, F21Y,H01B,H01C,H01F, H01G, H01H, H01J, H01K, H01M, H01N, H01R, H01T, H02B, H02G, H02H, H02J, H02K, H02M, H02N, H02P, H02R, H02S, H05B, H05C, H05F, H99Z
	Audio-visual technology	G09F, G09G, G09J, G11B, H04N, H04R, H04S, H05K
	Telecommunications	G08C, H01P, H01Q, H04B, H04H, H04J, H04K, H04M, H04Q
	Digital communication	H04L, H04W
	Basic communication processes	H03B, H03C, H03D, H03F, H03G, H03H, H03J, H03K, H03L, H03M
	Computer technology	G06C, G06D, G06E, G06F, G06G, G06J, G06K, G06M, G06N, G06T, G10L, G11C, G16B, G16C, G16Z
	IT methods for management	G06Q
	Semiconductors	H01L
Instruments	Optics	G02B, G02C, G02F, G03B, G03C, G03D, G03F, G03G, G03H, H01S
	Measurement	G01B, G01C, G01D, G01F, G01G, G01H, G01J, G01K, G01L, G01M, G01N, G01P, G01Q, G01R, G01S, G01V, G01W, G04B, G04C, G04D, G04F, G04G, G04H, G04M, G04R, G12B, G99Z
	Control	G05B, G05D, G05F, G07B, G07C, G07D, G07F, G07G, G08B, G08G, G09B, G09C, G09D
	Medical technology	A61B, A61C, A61D, A61F, A61G, A61H, A61J, A61L, A61M, A61N, G16H, G16Y, H05G
Chemistry	Organic fine chemistry	A61Q, C07B, C07C, C07D, C07F, C07H, C07J, C40B
	Biotechnology	C07G, C07K, C12M, C12N, C12P, C12Q, C12R, C12S
	Pharmaceuticals	A61K, A61P
	Macromolecular chemistry, polymers	C086, C08B, C08C, C08F, C08G, C08H, C08K, C08L
	Food chemistry	A01H, A21D, A23B, A23C, A23D, A23F, A23G, A23J, A23K, A23L, A23M, C12B, C12C, C12D, C12F, C12G, C12H, C12J, C12K, C13B, C13D, C13F, C13J, C13K, C13L
	Basic materials chemistry	A01N, A01P, C05B, C05C, C05D, C05F, C05G, C06B, C06C, C06D, C06F, C06K, C09B, C09C, C09D, C09F, C09G, C09H, C09J,C09K, C10B, C10C, C10F, C10G, C10H, C10J, C10K, C10L, C10M,C10N, C11B, C11C, C11D, C99Z
	Materials, metallurgy	B22C, B22D, B22F, C01B, C01C, C01D, C01F, C01G, C03C, C04B, C21B, C21C, C21D, C22B, C22C, C22F
	Surface technology, coating	B05C, B05D, B32B, C23C, C23D, C23F, C23G, C25B, C25C, C25D, C25F, C30B
	Micro-structural and nano-technology	B81B, B81C, B82B, B82Y
	Chemical engineering	B01B, B01D, B01F, B01J, B01K, B01L, B02C, B03B, B03C, B03D, B04B, B04C, B05B, B06B, B07B, B07C, B08B, C14C, D06B, D06C, D06L, F25J, F26B, F26F, H05H
	Environmental technology	A62C, B09B, B09C, B65F, C02B, C02C, C02F, F01N, F23G, F23J, G01T
Mechanical engineering	Handling	F01B, F01C, F01D, F01K, F01L, F01M, F01P, F02B, F02C, F02D, F02F, F02G, F02H, F02K, F02M, F02N, F02P, F03B, F03C, F03D, F03G, F03H, F04B, F04C, F04D, F04F, F04G, F04L, F04M, F23R, F99Z, G21B, G21C, G21D, G21F, G21G, G21H, G21J, G21K
	Machine tools	A62D, B21B, B21C, B21D, B21F, B21G, B21H, B21J, B21K, B21L, B23A, B23B, B23C, B23D, B23F, B23G, B23H, B23K, B23P, B23Q, B24B, B24C, B24D, B25B, B25C, B25D, B25F, B25G, B25H, B26B, B26D, B26F, B27B, B27C, B27D, B27F, B27G, B27H, B27J, B27K, B27L, B27M, B27N, B30B
	Engines, pumps, turbines	F01B, F01C, F01D, F01K, F01L, F01M, F01P, F02B, F02C, F02D, F02F, F02G, F02H, F02K, F02M, F02N, F02P, F03B, F03C, F03D, F03G, F03H, F04B, F04C, F04D, F04F, F04G, F04L, F04M, F23R, F99Z, G21B, G21C, G21D, G21F, G21G, G21H, G21J, G21K
	Textile and paper machines	A41H, A43D, A43H, A46D, B31B, B31C, B31D, B31F, B41B, B41C, B41D, B41F, B41G, B41J, B41K, B41L, B41M, B41N, C14B, D01B, D01C, D01D, D01F, D01G, D01H, D02G, D02H, D02J, D03C, D03D, D03J, D04B, D04C, D04G, D04H, D05B, D05C, D06G, D06H, D06J, D06M, D06P, D06Q, D21B, D21C, D21D, D21F, D21G, D21H, D21J, D99Z
	Other special machines	A01B, A01C, A01D, A01F, A01G, A01J, A01K, A01L, A01M, A21B, A21C, A22B, A22C, A22G, A23N, A23P, A23R, B02B, B28B, B28C, B28D, B29B, B29C, B29D, B29F, B29G, B29H, B29J, B29K, B29L, B33Y, B99Z, C03B, C08J, C12L, C13C, C13G, C13H, F41A, F41B, F41C, F41D, F41F, F41G, F41H, F41J, F41L, F42B, F42C, F42D
	Thermal processes and apparatus	F22B, F22D, F22G, F23B, F23C, F23D, F23H, F23K, F23L, F23M, F23N, F23Q, F24B, F24C, F24D, F24F, F24H, F24J, F24S, F24T, F24V, F25B, F25C, F27B, F27D, F28B, F28C, F28D, F28F, F28G
	Mechanical elements	F15B, F15C, F15D, F16B, F16C, F16D, F16F, F16G, F16H, F16J, F16K, F16L, F16M, F16N, F16P, F16S, F16T, F17B, F17C, F17D, G05G
	Transport	B60B, B60C, B60D, B60F, B60G, B60H, B60J, B60K, B60L, B60M, B60N, B60P, B60Q, B60R, B60S, B60T, B60V, B60W, B61B, B61C, B61D, B61F, B61G, B61H, B61J, B61K, B61L, B62B, B62C, B62D, B62H, B62J, B62K, B62L, B62M, B62R, B63B, B63C, B63D, B63F, B63H, B63J, B63M, B64B, B64C, B64D, B64F, B64G
Other fields	Furniture, games	A47B, A47C, A47D, A47F, A47G, A47H, A47J, A47K, A47L, A47S, A63A, A63B, A63C, A63D, A63F, A63G, A63H, A63J, A63K, F12V
	Other consumer goods	A24B, A24C, A24D, A24F, A41B, A41C, A41D, A41F, A41G, A42B, A42C, A42J, A42L, A43B, A43C, A44B, A44C, A45B, A45C, A45D, A46B, A62B, A99Z, B42B, B42C, B42D, B42F, B43K, B43L, B43M, B44B, B44C, B44D, B44F, B47F, B68B, B68C, B68F, B68G, D04D, D06F, D06N, D07B, F25D, G10B, G10C, G10D, G10F, G10G, G10H, G10K
	Civil engineering	E01B, E01C, E01D, E01F, E01H, E02B, E02C, E02D, E02F, E02M, E03B, E03C, E03D, E03F, E03G, E04B, E04C, E04D, E04F, E04G, E04H, E05B, E05C, E05D, E05F, E05G, E06B, E06C, E06D, E09B, E21B, E21C, E21D, E21F, E99Z

Source: INPI, author's elaboration

ANNEX B – List of Country by Region

Region	Countries
Africa	South Africa, Morocco, Mauritania, Mauritius, Madagascar, Central African Republic, Seychelles, Egypt, Sierra Leone, Réunion.
Asia	Bangladesh, China, Hong Kong, India, Indonesia, Japan, Kazakhstan, Malaysia, North Korea, Philippines, Singapore, South Korea, Taiwan, Thailand, Turkey, Turkmenistan, Vietnam.
Caribbean	Anguilla, Barbados, Bermuda, British Virgin Islands, Cayman Island, Dominica, Martinique, Saint Kitts and Nevis, Saint Vincent and the Grenadines, Turks And Caicos Islands, US Virgin Islands.
Europe	Albania, Andorra, Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Czechoslovakia, Denmark, Estonia, Faroe Islands, Finland, France, Germany, Gibraltar, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Luxemburg, Malta, Monaco, Netherlands, Norway, Oriental Germany, Poland, Portugal, Romania, Russia, San Marino, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom.
Latin America	Antigua and Barbuda, Argentina, Bahamas, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Curacao, Dominican Republic, Ecuador, El Salvador, Mexico, Netherlands Antilles, Panama, Paraguay, Peru, Puerto Rico, Trinidad and Tobago, Uruguay, Venezuela.
Middle East	Afghanistan, Bahrain, Israel, Qatar, Saudi Arabia, United Arab Emirates.
North America	Canada, United States.
Oceania	Australia, Cook Islands, New Caledonia, New Zeland, Papua New Guinea, Samoa.

ANNEX C – List of Industry Activity by Field of Technology

Field of Technology	Industry Activity
Electrical engineering	Manufacture of communication equipment Manufacture of machines, appliances and electrical materials Editing and recording and editing music Telecommunications Information technology services activities
Instruments	Manufacture of computer equipment, electronic and optical products Manufacture of instruments and materials for medical use
Chemistry	Food products manufacturing Beverage manufacturing Organic chemical manufacturing Pesticides and household disinfectants Manufacture of pharmochemicals and pharmaceuticals Metallurgy
Mechanical engineering	Manufacture of textile products Manufacture of machinery and equipment Motors, pumps, compressors and transmission equipment Manufacture of motor vehicles, trailers and bodies Maintenance, repair and installation of machinery and equipment
Other fields	Furniture manufacturing Architectural and engineering services, testing and technical analysis