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Construction of a Patent Value Index by measuring of indirect economic and technological value

Construção de um Índice de Valor de Patentes por meio da medição do valor econômico indireto e tecnológico

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Abstract

The present research intends to create an index of indirect economic (through patent family size and paid renewals) and technological value (forward citations), in order to identify possible innovations among inventions. The novelty of the research lies on the construction of equations reproducible by any field of knowledge, due to their intelligibility. In addition, it details the different steps to create the search database, which comprises free resources, trial versions and personal effort. After the construction of the index and its application, the patent population was divided into quartiles. Quartile 1 possibly houses innovation patents, as it was found that the value indicators assessed go together and relate to each other. Their behavior was shown to be such that, when one is present, there is a higher chance of the others appearing as well. The logical justification for this is that, if an invention has broad market potential, depositors will also protect the patent outside their own country; the most practical way of doing so is the Patent Cooperation Treaty application. Thus, the higher the number of countries where a patent is published and translated, the more likely it is to be cited. And if by then patents prove somehow profitable for their holders, they will continue to pay for renewals on time. This index is configured as a decision-supporting tool that seeks to rely on qualitative and strategic information.

Keywords: Bibliometric indicators.Bibliometric techniques. Patents. Technological innovation.

Resumo

A pesquisa objetiva criar um índice de valor econômico indireto (por meio do tamanho da família de patentes e renovações pagas) e tecnológico (citações recebidas) das patentes com o intuito de *identificar possíveis inovações dentre as invenções. O ineditismo da pesquisa recai sobre a construção dos cálculos, os quais qualquer área do conhecimento conseguirá reproduzir, devido a sua inteligibilidade. Além de detalhar as diferentes etapas para criar o banco de dados de pesquisa, o qual foi constituído com recursos disponibilizados de forma gratuita, versão de teste e esforço pessoal. Após a construção do Índice e sua aplicação, a população de patentes foi dividida em quartis. O Quartil 1 possivelmente abriga as patentes de inovação, pois foi constatado que os indicadores de valor avaliados andam junto e se relacionam. Eles exibem um comportamento em que quando um está presente, maiores as chances dos demais também aparecerem. A justifica lógica para tal é que, se uma invenção possui potencial de mercado amplo, o depositante também protegerá a patente fora do país, para isso, a forma mais prática, é a solicitação do Tratado de Cooperação de Patentes. E após, quanto mais países a patente for publicada e traduzida, mais chances ela terá de ser citada. E se até então a patente se mostrar lucrativa em algum aspecto para seu titular, ele permanecerá pagando as anuidades em dia. O uso do Índice se configura como ferramenta para embasar as decisões que buscam apoiar-se em informações que tragam aspectos qualitativos e estratégicos.*

Palavras-chave: *Indicadores Bibliométricos. Técnicas Bibliométricas. Patentes. Inovação tecnológica.*

Introduction

The literature on patent value has sought to develop methodologies that show the performance of technological inventions. The simple count of patents applied for and granted is no longer sufficient to measure the innovative activity of a country or organization, as a large volume of inventions protected by patents is known to exist with no value for their owners or which hardly reach the market for consumer use.

For example, Stevens and Burley (1997) report that for one to three out of every 100 patents produced may bring significant financial returns, as the chances of any idea becoming economically successful are so low that many ideas are needed. In addition, the world patent count reflects the "inventiveness" and business orientation of countries, whereas quality-measuring indicators, due to their high selectivity, reflect the inventive "performance" of countries (Rassenfosse *et al.*, 2013). Therefore, innovation is more likely to be identified when performance is sought to be measured.

Some of the literature uses value indicators combined with patentometric studies to measure patent performance. Properly collecting and measuring data is certainly the biggest challenge for researchers. Patent databases do not always allow large volumes of value-indicating data to be exported; value indicators will also appear over time, favoring older patents.

In this context, the present research intends to build a Patent Value Index (PVI) that includes: (a) indirect economic value, measured by renewal payment rates and patent family size, and (b) technological value, measured by the number of forward citations that a given patent has received from other patents.

The PVI equations seek to contemplate the individuality of each patent concerning the full set. Thus, in the indicators relating to renewal and citations, the inventions' lifespan and the year of publication are taken into account, respectively. Regarding patent family, intensity features such as Patent Cooperation Treaty (PCT) application and triadic family are accommodated.

The novelty of the present research is demonstrated by detailing the different steps to create the research database, which was made up of free resources, trial versions and personal effort.

Index Value Dimensions Theory

Research on patent value points to different value dimensions for the indicators; after research in the fields, it was decided to base the kinds of value the PVI seeks to reveal on Lee (2009) and Neuhäusler and Frietsch (2013).

a) Indirect economic value — Family size — Lee (2009) argues that the direct economic value of a patent mainly refers to its high market value. If a patent is licensed and products that incorporate the patented technology sell well, its direct economic value may be high. Lee explains he does not have the patented products' sales data, but he will use data on whether or not the patent is transferred/licensed.

According to Lee (2009), patents' direct economic value may be seen through commercialization and technology transfer processes and mechanisms. In the meantime, as it was impossible to find a source of data on sales value or technology transfer, the family size indicator was used as a marketing mechanism.

Neuhäusler and Frietsch (2013) explain that the economic value of patents is not determined only by the features of a single patent, but by various factors pertaining to a technology or company and their interactions with competitors and markets. Therefore, a patent application in a foreign country means that the applicant tries to secure that market to sell their invention and is willing to bear additional costs to protect their invention in that market. In this sense, patent holders are assumed to only deposit their patents abroad if the corresponding profit is expected from the sale of the protected technology. That is to say, a large patent family means greater market coverage, which is associated with preliminary and current expenses (Neuhäusler; Frietsch, 2013).

However, even if the family size indicator represents part of the marketing mechanism, it falls under indirect economic value, because it does not yield data that explain the sales/licensing of the products and processes of the inventions, rather the value that was invested by the owner for the protection of the patent.

b) Indirect economic value — Renewals — For Lee (2009), indirect economic value of the patent, as opposed to its market value, refers to the value generated by the possession of the patent right. It is assumed that the longer a patent remains protected, the more valuable it is. Even if a given patent is not sold in the market, it can generate economic value; this may occur when the owner of a technology occupies a technological position by holding an important patent, and rivals tend to avoid the technological path related to that patent. Thus indirect economic value is created. Lee (2009) takes a patent's lifespan — i.e. the duration of patent rights, and consequently the rate of paid renewals – to yield this value.

He also argues that parameter estimates related to patent renewal yield information on various features of the process of innovation, including the nature of the process by which the market for an innovation opens up, and the extent to which returns from a given innovation become obsolete over time (Lee, 2009).

c) Technological value – Forward citation – According to Lee (2009), technological value refers to a patent's position in a network of technological value, which can be captured by counting patent citations. The more often a patent is cited, the more technologically important it is, as it plays a significant role in the success of innovations.

It is worth noting that different authors list different value dimensions for each indicator. For example, family size indicators (Deng, 2007a, 2007b; Marco, Miller, 2019) and renewals (Marco, Miller, 2019; Deng, 2012; Bakker, 2017; van Zeebroeck, 2011) are also highlighted in the literature as strong indicators of private value, just as the citation indicator is said to be a strong predictor of economic value (van Zeebroeck, 2008; Lee; Sohn, 2017; Oda; Gemba; Matsushima, 2008).

PVI Data and Equations

This section presents how the data were collected and processed to arrive at the final calculation of the ranking.

Survey Population Selection and Data Collection

The chosen research population was the green patents filed in Brazil. The choice is because green patent application examinations are speedier, i.e., whether or not to grant the patent is made faster than for other patents. In addition, it is a strategic sector worldwide, in times that demand conscious use of natural resources, to allow the development of technological innovations that improve human quality of life while coexisting in harmony and balance with nature.

The main data source for the index was the Global Patent Index (GPI), because it offers the largest number of fields for exporting a large volume of data. The Derwent Innovation Index (DII) was used to collect the citations that patents received from other patents. The third source of information chosen to complement the data is the Brazilian IP office (INPI) database; it provides data on renewals paid by the holders and information relating to the patents' date of grant.

The search strategy used in the GPI was EVDE (event description) = "green patent"; the search, conducted in November 2019, recovered 631 patent family documents. Patents that did not contain the code "b27b" were removed from the population; this code indicated applications granted entry into the Green Patents Program and patents related to utility model. There remained 478 patent families.

PVI Value Indicator Calculation

Each of the three indicators is assigned a weight from 1 to 100; the final grade will be the sum of each indicators' score divided by three.

For this, the following calculations were made:

a) *Family size*: the number of countries where the patent applied for protection makes up 90% of the indicators' score; triadic family and PCT application make up 5% each. Patent families were thus divided because the literature on triadic patents – patents that have applied for protection in the main world markets: Europe, Japan and the United States – may be used as an indicator of "patent intensity", due to the importance of the three offices involved, in addition to being used to compile high-value inventions when comparing countries (Organisation for Economic Co-operation and Development, 2009). Martínez (2011) reinforces this idea by reporting that there are different indicators of internationalization and geography of inventions, based on data from patent families that seek to capture different effects, and triadic family is one of the most used. Researchers and statisticians use this indicator to assess a country's most valuable patents (Martínez, 2011).

Counting patent families was conducted according to the number of countries in which the depositor sought protection, i.e., geographical scope size (GS). To make a fair calculation, considering the chosen population, patents were leveled by the largest number of components presented by a given invention within the population. In this case, the rule of three is performed; the invention that presented the largest number of protection requests in different countries was BR 112014000125, with 35. Therefore, the equation is:

$$GS = \frac{\text{number of countries in which the patent was filed} \times 90}{35}$$

After calculating the GS, 5 is added for patents with a triadic family and 5 more for those with a PCT request.

b) Renewals: payment of maintenance fees begins 24 months after the application date. Fees increase over the years, so it is necessary to calculate two items: whether the patent is being paid and its current stage of payment (CSP).

To calculate whether the patent is active or when it was active, the number of renewals that the depositor should have paid (PR) is initially ascertained, and then compared with the fees paid, thus patent life percentage (PL) is identified. This is done using the following equation:

$$DY = 2019 - \text{Deposit year}$$

$$PL = \frac{\text{Number of paid renewals x 100}}{PR}$$

The use of the year 2019 to calculate the number of renewals that should have been paid (instead of 2020) is justified by the fact that, in the Brazilian IP office, applicants have three months to pay patent fees in the normal mode and another six months in the extraordinary mode. Due to this payment period and the margin of tolerance as adopted here to avoid injustice, there are cases when depositors who have paid fees on time can exceed the PL by more than 100%; these values will be corrected back to 100%.

The second renewal indicator equation intends to assess the stage of payment. It is necessary to locate the largest number of renewals that a patent within the Brazilian green patent population has, i.e. 16 paid renewals (which are actually 14, due to the first two unpaid years). It should be remembered that an invention patent may remain active for up to 20 years, if its fees are paid on time. Therefore, 100 was divided by 14 (= 7.14), so a patent scores higher for each renewal paid.

After this, for the final equation of the calculation of renewals (RC), we add the two results – PL percentage and CSP – and divide by two:

$$\frac{RC = PL + CSP}{2}$$

c) *Number of forward citations*: First of all, it is important to know how many citations the patent received per year (CPY), taking into account the years in which the invention became publicly accessible, i.e. the year of publication (YP) is taken into account. The equation is the following:

$$CPY = \frac{\text{Number of forward citations}}{2020 - YP}$$

The second step is leveling patents according to the highest-scoring patent from the research population, i.e. the patent with the highest CPY percentage based on the maximum registered value (PCPY-MV). In this case, the highest-scoring patents were BR PI0913013 and BR 112014028704, which reached the maximum CPY score, with 24 citations per year. Therefore, the final equation for citation calculation is:

$$PCPY\text{-}MV = \frac{CPY \times 100}{24}$$

See Figure 1 for the equations that make up the PVI:

The general PVI equation may be consulted in Appendix A: Final PVI (Cativelli, 2022) equation.

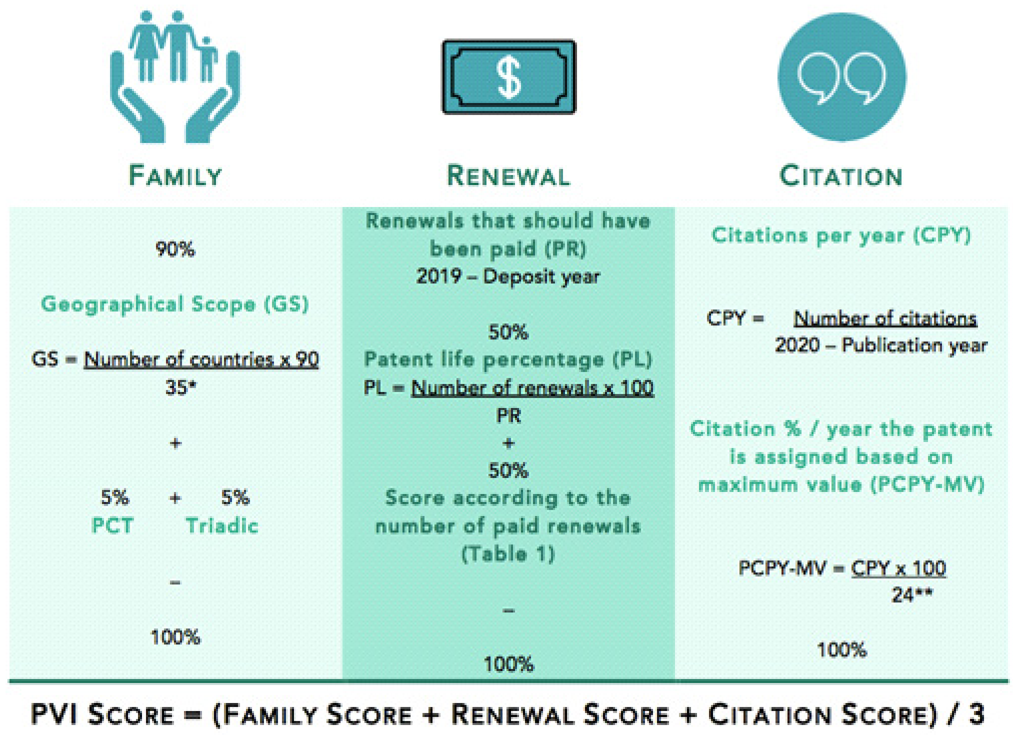

Figure 1 – PVI indicator equations.

Note: *Within the Brazilian green patent population, the highest number of applications for protection in different countries was 35; ** Within the Brazilian green patent population, the highest number of citations per year an invention received was 24.
Source: Elaborated by the authors (2021).

Results

The analyzes of the results found from the IVP will be presented below.

Descriptive Statistics

To determine how the patent population was distributed in the PVI, the population of 478 patents was divided into four parts. Quartile 1 (Q1) comprises 25.1% (120) of Brazilian green patents – the highest-scoring patents, between 80.3 and 28.6. Quartile 2 (Q2) comprises 24.9% (119) of the patent population, with scores between 28.4 and 21.3. Quartile 3 (Q3) comprises 25.3% (121), with patents scoring from 21.2 to 14. Quartile 4 (Q4) comprises the remaining 24.7% (118) patents, with scores between 13.8 and 0. Table 1 details the quartiles' descriptive statistics.

Table 1 shows that family and citation indicators are concentrated in Q1, reaching much higher mean and median than other quartiles. In addition, Q1 also stands out regarding data discrepancy, with a high standard deviation, especially in the citation indicator. This may demonstrate the existence of patents that display a much higher volume of the indicators evaluated than other patents in the group. This determinant may also be seen in the maximum and minimum scores each patent received in each quartile, with Q1 scores ranging from 80.3 to 28.6 – the highest span among the four groups.

As expected, numbers significantly plummet at each quartile, and the renewal indicator is the one that guarantees patent scores. In addition, among the indicators assessed, renewal is balanced among quartiles, with the following means: 6.4 (Q1), 4.3 (Q2), 1.5 (Q3) and 0.5 (Q1).

Table 1 – PVI descriptive statistics per quartile.

Indicators of patent value	Mean	Median	Standard deviation
	Q1 (120)		
Family	11.7	12	6
Renewal	6.4	7	2.9
Citation	13.3	5	22.3
Overall Score	40.2	36.9	10.3
	Q2 (119)		
Family	2.2	0	3
Renewal	4.3	5	1.8
Citation	0.7	0	1.9
Overall Score	24.2	23.8	2.1
	Q3 (121)		
Family	0.9	0	2.1
Renewal	1.5	1	1.4
Citation	0.2	0	0.8
Overall Score	17.9	17.8	1.7
	Q4 (118)		
Family	0.4	0	1
Renewal	0.5	0	0.9
Citation	0.1	0	0.4
Overall Score	3.5	0	4.5

Source: Elaborated by the authors (2021).

On the other hand, the citation indicator presents the highest score difference among quartiles, with the following means: 13.3 (Q1), 0.7 (Q2), 0.2 (Q3) and 0.1 (Q4). The highest concentration of cited patents is in Q1; the other quartiles display far lowers numbers.

Behavior of PVI Quartiles

In order to disclose the data behavior that justifies the inclusion of inventions within a given quartile, an analysis of the proportions of the value indicators present in each quartile was conducted. Features related to depositor profile, year of deposit and IPC area were also analyzed.

Patent Value Indicators Present in the Four Quartiles

The first step was to assess the presence of the value indicators – family, PCT, triadic, renewals and citation – in each quartile. This may initially sound biased, as it is already expected that Q1, the highest-scoring group, will present higher numbers. However, this is not an assessment of quantity, but of whether or not the indicator is present; in the case of the renewal indicator, it will be also ascertained whether the patent remains active (whether holders are keeping up with payments). Results may be seen in Figure 2 below.

As expected, Q1 (120) scores higher across all value indicators. Almost all the patents in this group were shown to have PCT (111) and family (116), which indicators are usually seen in conjunction, as it will be more advantageous for holders to file a PCT application when they wish protect their patents in several countries.

The same phenomenon occurs in Q2 (119), Q3 (121) and Q4 (118): Q2 has 52 patents with PCT application and 58 with family; Q3 shows 22 patents with PCT application and 29 with family; Q4 has 16 patents with PCT application and 19 with family.

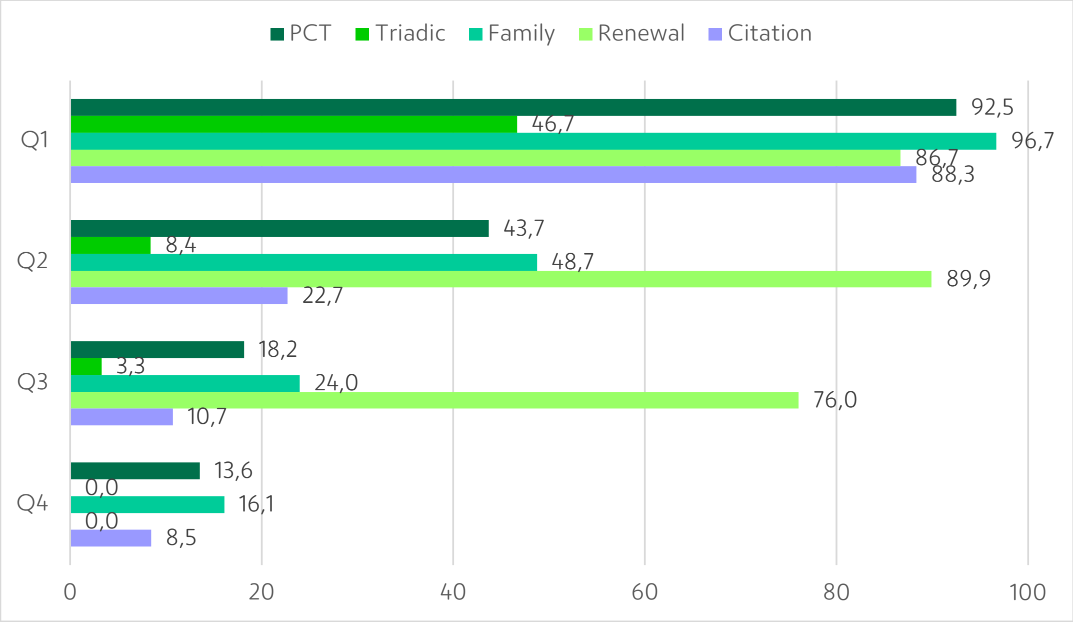

Figure 2 – Patent value indicators present in quartiles.
Source: Elaborated by the authors (2021).

It also calls attention that, in Q1, there is a large number of patents with citations: 106; this means only 14 patents in this group are not cited. This indicator drops drastically in the other groups: Q2 has 27 cited patents, Q3 has 13 and Q4 has 10.

As previously mentioned, the renewal indicator shows the most balanced scores among quartiles; however, here it was assessed whether renewal payments are up-to-date. None of the patent renewals in Q4 were up-to-date.

Therefore, patents were found to have a somewhat predictable behavior according to the quartile to which they belong: the better positioned in the PVI, the higher their chances of presenting the indicators here assessed. And, as proved in Q1, the major finding of the present research is that the evaluated indicators go together and relate, i.e. these value indicators are not scattered among quartiles; their behavior is such that, when one indicator is present, chances of the others being present as well are higher. The logical justification for this is that, if an invention has broad market potential, depositors will also protect the patent outside their own country; the most practical way of doing so is filing a PCT application. Thus, the higher the number of countries where a patent is published and translated, the more likely it is to be cited. And if patents prove profitable for their holders by then, they will continue to pay for renewals on time.

Depositor Profile and Grant of Patents

The next features to be assess are depositors' profiles – whether or not they are foreign – and to what type of organization they belong. When ownership was mixed, only the first holder was taken into account. In addition, it was verified whether inventions were granted in Brazil. These numbers are shown in Figure 3.

The most prominent feature in Figure 3 is the high number of patents from foreign companies in Q1: 106 companies, 98 of which are foreign. Q2 also presents significant numbers, with 57 patents

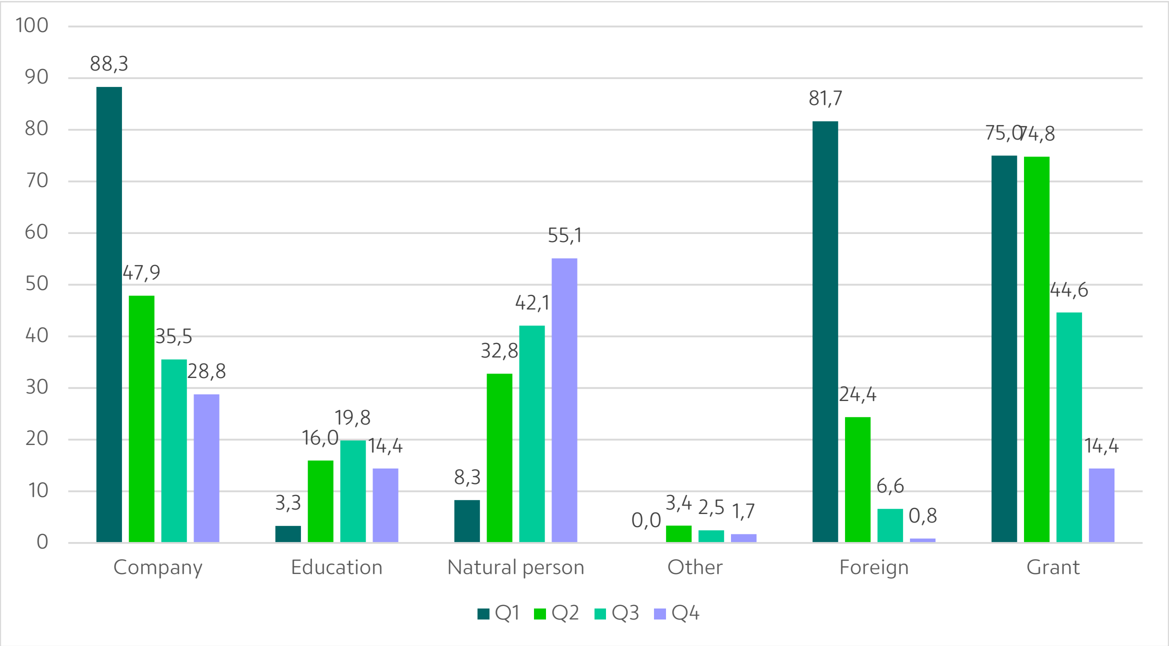

Figure 3 – Depositors profile and grant of patents by quartile.
Source: Elaborated by the authors (2021).

belonging to companies, 29 foreign ones. In Q3, there is a balance between patents belonging to companies (43) and natural persons (51); only 8 foreign holders are in this quartile. In Q4, the number of natural-person depositors is higher (65); only one is foreign.

About patent grants, Q1 and Q2 are practically identical, with 90 and 89, respectively; in Q3, 54 patents were granted; in Q4, only 17.

It is also possible to notice the following behavior: highest-scoring quartiles have the most expressive numbers of foreign company holders with granted patent, whereas the lowest-scoring ones show higher concentrations of natural person holders, who are Brazilian and have less chances of being granted the patent.

Patent Filing Year Among Quartiles

Data on the year of filing a patent application is thought relevant for assessing whether the most recent patents are in the lower quartiles. This is because newer patents are at a disadvantage regarding citations and grant, in addition to other aspects to be addressed later. Results may be seen in Figure 4.

It is observed that Q1 has the oldest patents; it peaks in the 2010, with 21 records, as indicated by the blue line. Another curious fact is that Q1 has more patents filed before the Green Patents Program (PPV) was launched (2012) than after: 68 patents from 2004 to 2011 and 52 from 2012 to 2018.

In the other quartiles, the number of patents filed before the PPV is low, and decreases according to the quartile to which they belong: Q2 has 23 patent filings, Q3 has 13 and Q4 has 5.

The data in Figure 4 clearly shows that the PVI's highest-scoring patents are concentrated in the years before 2014, as the blue and orange lines – representing Q1 and Q2, respectively – show significant numbers in this period.

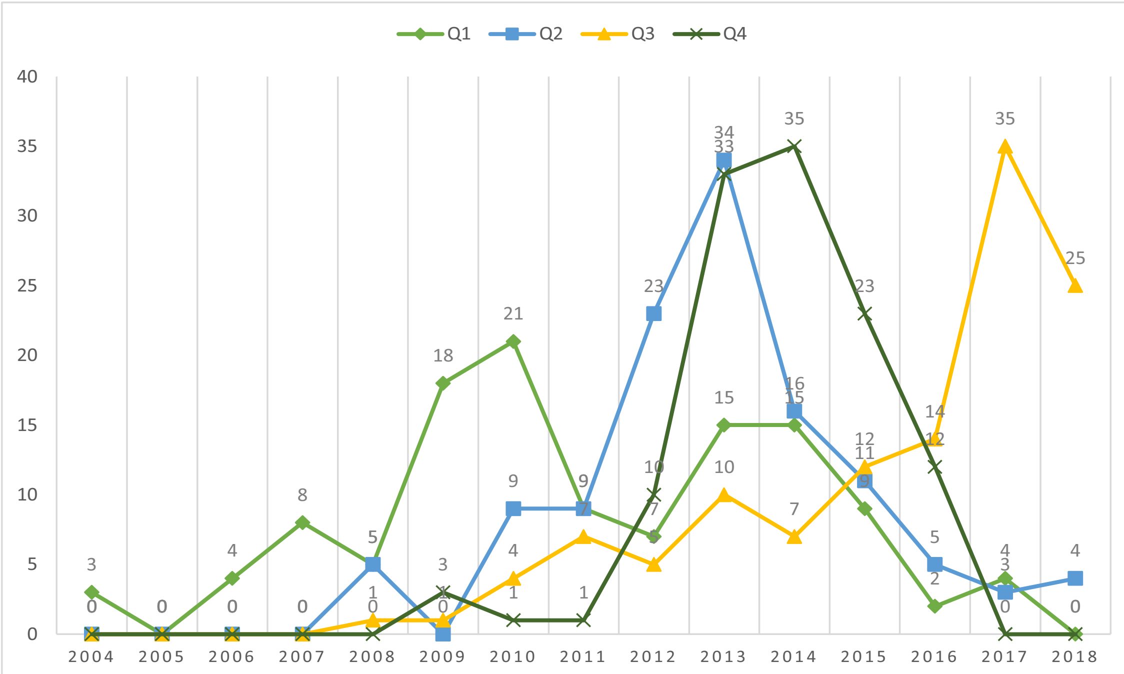

Figure 4 – PVI year of deposit per quartile.
Source: Elaborated by the authors (2021).

About Q3 and Q4, the opposite occurs: they begin to register more deposits as of 2013. Two explanations may be found for this phenomenon. The first and most obvious is that the older a patent is, the more chances it has to prove its value, as it will be more cited, in addition to patent holders already having a more defined marketing strategy, and, if necessary, having already applied for protection in the countries of their possible competitors.

The second explanation is that, during the last decades, the Brazilian IP office and technological innovation centers have promoted and encouraged applications, stimulating inventors to patent their inventions.

According to the Organization for Economic Cooperation and Development (Organisation for Economic Co-operation and Development, 2011), there was a drop in patent quality by approximately 20% between 1990 and 2000 in almost all countries studied. The reason for this is that the rush to protect small improvements in products or services may burden patent offices, which causes true innovations to take longer to reach the market, and reduces the potential for revolutionary inventions.

The Top Ten PVI Patents

Regarding the overall ranking, Brazil in not among the ten highest-scoring patents. This list may comprise patents of international owners of green inventions protected in Brazil. Table 2 shows how scores were achieved.

The ten best-evaluated patents have PCT application, six of them have triadic families and the invention was protected in 12 to 26 different countries. Regarding paid renewals and their percentage, it is also necessary to see Table 3 below; these patents were filed between 2007 and 2013, and only one is inactive. These inventions received 16 to 164 citations over the years;

Table 2 – Value indicators of the top ten patents in the PVI.

Patent Number	PCT	Triadic	Family (number)	Family (%)	Renewals (number)	Renewals (%)	Citations (number)	Citations (%)	Total
BR PI0913013	Yes	No	21	59.00	9	82.0	48	100.00	80.3
BR PI0718314	Yes	Yes	17	53.70	9	77.0	164	97.62	76.1
BR 112014028704	Yes	Yes	14	46.00	5	68.0	96	100.00	71.3
BR PI0913059	Yes	No	16	46.10	9	82.0	46	63.89	64.0
BR 112014014000	Yes	Yes	15	48.60	5	68.0	36	75.00	63.9
BR PI0911588	Yes	No	17	48.70	9	82.0	53	55.21	62.0
BR PI0916189	Yes	No	20	56.40	9	82.0	28	38.89	59.1
BR PI10085655	Yes	Yes	24	71.70	8	78.5	23	19.17	56.5
BR PI1013007	Yes	Yes	26	76.90	8	78.5	16	13.33	56.2
BR PI0820556	Yes	Yes	12	40.90	10	86.0	57	39.58	55.5

Source: Elaborated by the authors (2021).

the lowest citation record per year (counted from the date of publication) was that of patent BR PI1013007 with 3.2, and the largest were those of patents BR PI0913013 and BR 112014028704, with 24 citations per year.

As for other features of these patents, two were not granted in Brazil; the holders are all foreign, with a predominance of companies from the United States, especially Xyleco, with inventions involving biomass processing. Further details on patent features may be seen in Table 3 below.

As Table 3 shows, six patents belong to *Xyleco* – the holder with the highest number of green patent applications of the research population, totaling 24. It is a private scientific research and manufacturing company that develops processes to convert biomass into useful products (Xyleco, 2020). *Xyleco* may have seen Brazil as a true competitor in this industrial branch, as its immense national territory, almost entirely located in tropical and rainy regions, offers excellent conditions for

Table 3 – Other features of the PVI top ten patents.

Patent Number	Application year	Active patent	Grant	Applicant country	Applicant name	Patent title
BR PI0913013	2009	Yes	Yes	United States	Xyleco	Processing Biomass
BR PI0718314	2007	No	No	United States	Medoff Marshall	Processing Biomass
BR 112014028704	2013	Yes	Yes	United Kingdom	Isis Innovation Limited	Optoelectronic devices with organometal perovskites with mixed anions
BR PI0913059	2009	Yes	No	United States	Xyleco	Method of fermenting low-molecular weight sugar to ethanol
BR 112014014000	2012	Yes	Yes	United States	Monsanto Technology	Plant growth-promoting microbes and uses therefor
BR PI0911588	2009	Yes	Yes	United States	Xyleco	Method for obtaining animal feed by processing of biomass
BR PI0916189	2009	Yes	Yes	United States	Xyleco	Lignocellulose biomass material fermentation method
BR PI1008565	2010	Yes	Yes	United States	Xyleco	Method for reducing the recalcitrance of a biomass feedstock and a method for producing a product
BR PI1013007	2010	Yes	Yes	United States	Xyleco	Processing Biomass
BR PI0820556	2008	Yes	Yes	New Zealand	Lanzatech New Zealand	Novel bacteria and methods of use thereof

Source: Elaborated by the authors (2021).

large-scale biomass production and energy use. In addition to the production of alcohol, burning in furnaces and boilers, and other non-commercial uses, biomass has great potential in the electricity sector (Agência Nacional de Energia Elétrica, 2005).

In addition, the patent that appears in the GPI database as owned by Marshall Medoff (PI0718314), in the INPI database is registered by *Xyleco*: in fact, there are seven patents belonging to this company, as they were invented by the company's founder – Marshall Medoff himself.

Patent BR PI0718314 – which holds the second highest PVI score – was not granted in Brazil nor have its renewals been kept up-to-date, therefore, it may be used in Brazil for free. In this sense, the PVI shows high usability.

The story of Marshall Medoff is fascinating; he has no scientific background, and spent15 years recluse in a garage trying to find answers to his questions; he believes people were failing because they were trying to overcome nature, instead of working with it (Stahl, 2019). His breakthrough was being aware that there is a lot of energy in plant life, stored in the form of sugar molecules that, once accessed, can be converted into transport fuel. This sugar is almost impossible to extract inexpensively and cleanly, as it is firmly trapped inside the plant pulp. It should be noted that cellulose is rich in sugar and is the most abundant biological material on the planet (Stahl, 2019). With the visibility of his discoveries, Medoff began to attract investors and hire scientists to help him. He is even believed to be able to expand enough as to compete with the oil industry (Stahl, 2019).

The company that ranks third is from the United Kingdom: *Isis Innovation Limited*, a private technology and research company from the University of Oxford; in 2016, it was renamed Oxford University Innovation (Oxford University Innovation, 2020). It procures the university's advantage, by working with staff members and students to apply their knowledge and research; its vision is to create a worldwide leading innovation ecosystem, having the University of Oxford at its center (Oxford University Innovation, 2020).

The United-Statesian *Monsanto Technology*, which has Monsanto as its parent organization, ranks fifth. Monsanto provides agricultural products including special seeds, agricultural chemicals, plant varieties and agricultural productivity solutions to farmers worldwide (Monsanto, 2020). The company does not have a good reputation in terms of sustainability: it is a world leader in producing the herbicide glyphosate and genetically modified seeds.

The lesson here is that even if a given institution develops green patents, that does not necessarily mean it is concerned about the environment. Many companies may be seeking to improve their image by featuring sustainable patents in their portfolios; this practice is known as greenwashing. As Paviani (2019) explains, environmental protection gains space in business policies, especially, to gain credibility with consumers, but the extent to which green marketing agrees with the effective practices of corporations should be called into question.

Closing the top ten, one New Zealander holder is Lanzatech New Zealand. It claims to be turning the global carbon crisis into a raw material opportunity, by recycling carbon from industrial gases, synthesizing gas from any biomass resource and reformed biogas (Lanzatech, 2020).

Final Remarks

In general, the PVI identified patents with indirect and technological value to display the following features: having a family, PCT application, citations and a significant number of renewals being paid on time. In addition, they belong to foreign companies and have been granted.

The equations found to measure each indicator were an important achievement of the present research. It is believed that each one seeks to measure the particularities, both of the research population as a whole and of the different value indicators, from the perspective of individuality to the whole.

In the case of Brazilian green patents, applying the PVI has yielded knowledge of this field's best-performing inventions and holders. Delving into the history of successful cases may motivate entrepreneurs to follow a similar path in which development does not conflict with the environment. As Marshall Medoff said: it is necessary to work with nature, not against it (Stahl, 2019).

The issue of the environment around the world is latent; as our lives become more comfortable and daily tasks are handled more quickly, the technological devices used to sustain such comfort require depletion of natural resources. Any current enterprise that does not contemplate sustainability is out of keeping with reality. It is necessary to recreate and reinvent the world where we live; this is the challenge entrepreneurs currently face: minimizing consumption and its impact on nature.

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