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ANÁLISE MULTICRITÉRIO DE ECOSSISTEMAS DE INOVAÇÃO E O IMPACTO DO CAPITAL HUMANO NAS INDÚSTRIAS BRASILEIRAS

MULTICRITERIA ANALYSIS OF INNOVATION ECOSYSTEMS AND THE IMPACT OF HUMAN CAPITAL ON BRAZILIAN INDUSTRIES

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Comunicação:
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ANÁLISE MULTICRITÉRIO DE ECOSSISTEMAS DE INOVAÇÃO E O IMPACTO DO CAPITAL HUMANO NAS INDÚSTRIAS BRASILEIRAS

Objetivo do estudo
Investigar à luz da análise multicritério como dez setores da economia brasileira performam durante duas séries históricas (2011-2014 e 2014-2017) em um ranking a partir de cinco critérios atrelados ao processo de inovação com base em dados da PINTEC.

Relevância/originalidade
Mensurar o potencial de inovação dos setores da indústria e de serviços, visto que o melhor aproveitamento da mão de obra e dos dispêndios financeiros com inovação permitem a obtenção de melhores receitas e mais produtos inovadores ou substancialmente aprimorados.

Metodologia/abordagem
Metodologia quantitativa, com uso do PROMETHEE II. Foram utilizados dados da PINTEC publicados em 2014 e 2017. Embora os dados utilizados tenham sido publicados nestes dois anos, estes são referentes à duas séries históricas (2011 à 2014) e (2014 à 2017).

Principais resultados
Despesas em Inovação revelou-se crucial para mensurar o comprometimento financeiro das empresas com a inovação. Além disso, a Porcentagem de Pós-Graduados e Graduados emergiram como indicadores de destaque, apontando que setores com uma força de trabalho qualificada têm maior propensão à inovação.

Contribuições teóricas/metodológicas
A contribuição do estudo reside no preenchimento da lacuna literária, visto que não há estudos que utilizem o PROMETHEE II para a análise multicritério à fim de medir indicadores de inovação na economia brasileira.

Contribuições sociais/para a gestão
Este artigo propõe-se a auxiliar órgãos governamentais a formarem políticas públicas de incentivo aos setores analisados. Ademais, esta pesquisa também consegue oferecer aos empresários uma análise sumária a partir de um ranking de quais setores conseguiram melhor desempenho a partir dos critérios.

Palavras-chave: Inovação, Análise de Decisão Multicritério (MCDA), PINTEC, Capital Humano Qualificado, PROMETHEE II

MULTICRITERIA ANALYSIS OF INNOVATION ECOSYSTEMS AND THE IMPACT OF HUMAN CAPITAL ON BRAZILIAN INDUSTRIES

Study purpose
Investigate, through multicriteria analysis, how ten sectors of the Brazilian economy perform during two historical periods (2011-2014 and 2014-2017) in a ranking based on five innovation-related criteria using data from PINTEC.

Relevance / originality
Measure the innovation potential of the industry and service sectors, considering that better utilization of labor and financial expenditures on innovation leads to higher revenues and more innovative or substantially improved products.

Methodology / approach
Quantitative methodology, using PROMETHEE II. Data from PINTEC published in 2014 and 2017 were used. Although the data were published in these two years, they refer to two historical periods (2011 to 2014) and (2014 to 2017).

Main results
Expenditures on Innovation proved to be crucial for measuring companies' financial commitment to innovation. Additionally, the Percentage of Postgraduates and Graduates emerged as key indicators, highlighting that sectors with a qualified workforce are more likely to innovate.

Theoretical / methodological contributions
The study's contribution lies in filling the gap in the literature, as there are no studies that use PROMETHEE II for multicriteria analysis to measure innovation indicators in the Brazilian economy.

Social / management contributions
This article aims to assist government agencies in developing public policies to support the analyzed sectors. Additionally, this research provides entrepreneurs with a summary analysis based on a ranking of which sectors performed best according to the criteria.

Keywords: Innovation, Multicriteria Decision Analysis (MCDA), PINTEC, Qualified Human Capital, PROMETHEE II

MULTICRITERIA ANALYSIS OF INNOVATION ECOSYSTEMS AND THE IMPACT OF HUMAN CAPITAL ON BRAZILIAN INDUSTRIES

1. Introduction

Innovation has been the subject of study to understand the economic capacity of organizations and how the factors linked to it increase business competitiveness (Schumpeter, 1934; Damapour, 1991; Porter, 1991; Drucker, 2002, OECD, 2005). Innovation is one of the alternatives for improving organizations' competitive positioning and profitability (Moreira & Vergara, 2015; De Guimarães et al., 2016). In the 21st century, the ability to generate innovations is seen as one of the prerequisites for the success of companies (Feitosa, 2011). To this end, it is possible to state that innovation can be a source of competitive advantage for companies, whether through introducing new products and services or improving existing ones (Taques et al., 2021).

Teixeira (2007) states that the fuel for the innovation process in companies is qualified human capital. The author explains that when a company has qualified employees, it increases the potential for developing innovation so that the ability to introduce improvements in the quality of goods and services becomes possible (Teixeira, 2007; Drucker, 2002; Davenport, 2015). Researchers are key players in innovation systems through the transfer of knowledge (Etzkowitz, 1998) and skilled labor (Brown, 2016). In practical terms, introducing new products and services and other innovation processes are also driven by this professional qualification and exchange of knowledge. This dynamic creates innovative opportunities to meet consumer needs (Tidd et al., 2005).

On the other hand, financial expenditure on innovation is often directed towards Research and Development (R&D) activities, which form the basis of innovation. Therefore, issues relating to investment in innovation are another significant factor to be investigated. In the studies conducted by Lazzarotti (2012) and Santos et al. (2014), investments in resources that can generate innovation have been shown to impact companies' performance.

Innovation is one of the alternatives for improving organizations' competitive positioning and profitability (Moreira & Vergara, 2015; De Guimarães et al., 2016). In Brazil, one of the potential determinants of industrial growth is the investment in innovation (Arruda, Vermulm & Hollanda, 2006; Fischer et al., 2009; CNI, 2010; Soares et al., 2016). However, despite the importance of innovation for growth and business positioning, the Brazilian industrial sector reported a percentage drop in the 2009-2011 innovation rate, falling 2.55% compared to the previous triennium (IPEA, 2013). This indicator assesses the ratio between the number of companies that innovated at least once and the total number of companies surveyed during the period in question.

Despite the relevance discussed in the literature, common problems hinder the innovation process, such as the lack of qualified humnan capital (personnel) and high costs (Jacoski et al., 2014). Research into innovation for the business sector is justified by its importance (Becheikh et al., 2006; Zanello et al., 2016), as well as by its rapid dynamics, which is why new research is needed, given the need to understand the effects of these discoveries. In addition, the activities linked to the innovation process are a critical factor in the performance of the ability to innovate (Santos, Basso & Kimura, 2012).

Thus, this work seeks to measure which sector of Brazilian industry and services has the best results, considering decision criteria such as the value of expenditure on innovation by companies and the number of employees with higher education (undergraduate) and specialization at master's level. These analyses focused on two historical series covering the three-year periods from 2011 to 2014 and 2014 to 2017, based on comparisons between them. To this end, the work uses data from the historical series extracted from the Industrial Survey of Technological Innovation - PINTEC published by IBGE. For this analysis, the following indicators were used, also called criteria: i) Expenditure by companies on innovation; ii) Percentage of employees with post-graduate degrees (master's); iii) Percentage of employees with undergraduate degrees; iv) Net revenue; and v) Percentage of new and/or substantially improved products in total domestic sales.

The assessment is justified by the contribution literature on innovation determinants and best practices, given the gap in the literature regarding studies that analyze the effects of innovation on organizational results based on a multicriteria analysis. In addition, this article aims to investigate which sectors of the Brazilian industry performed best based on the established criteria to aid government bodies in forming public policies to encourage these sectors. This research aims to provide researchers, practitioners and entrepreneurs with a summary analysis based on ranking and innovation prospects.

This work is divided into 4 sections. In addition to this introduction, section 2 presents the method for analyzing the data used to obtain and explore the results. Section 3 deals with analyzing the results of the multicriteria models, while section 4 discusses the findings and limitations of the research. Finally, the last section presents the final considerations.

2. Materials and Methods

2.1 Database

PINTEC is an innovation survey that provides information on sectoral, regional and national indicators of the innovation activities of Brazilian companies. This study used data from PINTEC published in 2014 and 2017. Although the data used was published in these two years, it refers to two historical series, the first covering the years 2011 to 2014 and the second 2014 to 2017.

Using a multicriteria classification methodology, this study seeks to assess which of Brazil's industrial and service sectors perform best based on criteria linked to innovation. In this sense, it is important to measure the innovation potential of industry and service sectors, given that better use of labor and financial expenditure on innovation can lead to better revenues and more innovative or substantially improved products. To this end, 10 of these sectors of the national economy were selected to measure their performance, as shown in Table 1.

Table 1 - Economic sectors analyzed

- Extractive industries	- Manufacture of machinery, equipment and electrical materials
- Manufacture of food products	- Manufacture of machinery and equipment
- Manufacture of clothing and accessories	- Electricity and gas
- Manufacture of chemical products	- Custom software development
- Manufacture of rubber and plastic products	- Development of custodial software

Source: This research (2024)

The sectors were chosen according to their presence and importance in the Brazilian economy, and for this purpose the sectors with the highest share of aggregate GDP from 2011 to 2017 were adopted. When outlining the methodological framework for assessing innovative performance in the various sectors of the Brazilian economy, five key indicators were selected that cover different dimensions of the innovation process.

2.2 Evaluation structure of the PROMETHEE II method

Multi-criteria decision analysis (MCDA) is widely present in the literature and can be conducted using a variety of PROMETHEE methods. Karasakal, Eryilmaz, and Karasakal (2021) evaluate two classification approaches with PROMETHEE to determine weights and threshold values. Guney, Hernandez-Perdomo, and Rocco (2019) use the PROMETHEE method to assess corporate governance quality in U.S. companies.

Husin et al. (2024) conduct a study on the physicochemical properties of drugs for renal cancer. Using a multicriteria decision-making approach, the authors employ PROMETHEE II to classify the target drugs of the study. Mir et al. (2024) assess the risk of disaster for educational infrastructure in mountainous regions using the PROMETHEE-II method. Another contribution is from Wang et al. (2024), who analyze barriers to adopting resilience in the food supply chain industry.

According to Almeida (2013), multicriteria decision-making methods can be used to compare alternatives against a series of defined criteria. It is necessary to look at their advantages and disadvantages and then compare them until it becomes clear which is the optimum alternative, which is the one with the best use of the criteria considered, or if not the most viable, which is the scenario that comes closest to the optimum.

In the context of the work in question, non-compensatory overclassification models from the PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation) family were developed, using the VISUAL PROMETHEE software, which is freely accessible.

In structuring a problem using a PROMETHEE method, two elements guide all the modeling and interpretation of the problem's results: the criteria for each alternative and the weights (Pi) referring to these criteria. According to De Almeida (2013), the weights are used to obtain π (a, b), in which 45 corresponds to the degree of classification of 'a' over 'b', and this comparison continues for each pair of alternatives, which is obtained from the following formulation expressed below:

$$\pi(a, b) = \sum Pi$$
$$\text{F}i\ (a, b)\ ni = 1 \quad (1)$$

Where:

$$\sum Pi = 1$$
$$ni = 1$$
$$Fi = (a, b) \quad (2)$$

It consists of a function resulting from the difference [Gi (a) – Gi (b)] which corresponds to the performance of the alternatives for each criterion i. In a situation where Fi (a, b) = 1, this means that Gi (a) > Gi (b) otherwise, Fi (a, b) = 0, so the degree of overclassification π (a, b), will be made up of the weight Pi of each criterion i, or which alternative 'a' has the best performance compared to 'b'.

It should be noted that in specific cases involving thresholds of indifference, preference or both, where the function Fi (a, b) can be established in order to contemplate these situations in which the performance of each alternative for each criterion [Gi (a) – Gi (b)], takes on a value between 0 and 1 (De Almeida, 2013).

2.3 Application of the PROMETHEE II method in Innovation Ecosystems

In terms of input data, the first input selected was expenditure on innovation, as this is fundamental data for capturing companies' financial commitment to innovation. The second and third inputs are the proportion of employees with advanced degrees, in this case those with master's degrees and undergraduate degrees. Studies indicate that companies with highly qualified professionals have a greater propensity to innovate, as advanced education is correlated with the ability to absorb knowledge and creativity.

In this sense, net revenue was selected, as it is an essential financial indicator capable of offering a global perspective of companies' economic performance. Finally, to round off the model, the percentage share of new products in domestic sales introduces a more detailed analysis of the percentage share ranges, enriching the evaluation and providing a more refined understanding of innovative performance. Table 2 shows these selected indicators, three of which make up the Inputs, which in this case correspond to the inputs to feed the model and stimulate the process studied, and two indicators make up the outputs.

Table 2 - Description of models indicators

Indicator	Description	Objectives	Process
Spending by Companies on Innovation (R$)	Spending on innovative activities includes spending on internal Research and Development (R&D) activities and external R&D procurement, as well as other activities.	Maximize	Input
Post-graduate (%)	Percentage of workers with post-graduate degrees in the workforce by sector as a proportion of the overall number of workers employed.	Maximize	Input
Graduation (%)	Percentage of workers in the workforce with a bachelor's degree by sector as a proportion of the overall number of workers employed.	Maximize	Input
Net Revenue (R$)	Net revenue from sales of products in each sector.	Maximize	Output
Percentage share of new or substantially improved products in total domestic sales (%)	Refers to the proportion of a company's domestic sales that are attributed to new or substantially improved products.	Maximize	Output

Source: IBGE (2016)

In order to seek a better evaluation based on a comparison, two models were created, one comprising the three years of the first time lapse and the second comprising the three years immediately afterward, characterizing the following historical series:

Table 3 - Establishing the time lapse of the models

	Inputs (Years)		Outputs (Years)
Model 1	2011	→	2014
Model 2	2014	→	2017

Source: This research (2024)

As can be seen in Table 3, the input data was collected in previous years compared to the output data because it takes a certain amount of time for the investments in the most varied scenarios to be processed, and only then can the results be achieved. As this is a problem that makes it impossible to obtain the results instantly, it was decided to use the data as described in Table 3.

In order to build the multicriteria model, it is necessary to establish the objective (maximize or minimize) of each criterion, and in this sense the maximize direction was adopted for all the criteria. In other words, all the criteria adopted in this study seek to maximize them in order to achieve the best results in terms of innovation.

3. Results

This section discusses the data and results of our assement on Brazilian innovation systems. Subsection 4.1 reports a comprehensive exploration of descriptive statistics, which serve as a fundamental aspect in understanding the breadth of our study. These statistics, meticulously presented in Table 4 and Table 5, and illustrated through box-plots visualizations, offer a holistic perspective on key metrics, aiding in pattern identification, inter-group comparisons, and data dispersion evaluation. Moving forward to subsection 4.2, we develop the multicriteria analysis using PROMETHEE II. Based on a net flow framework, this methodology facilitates the ranking of sectors by subtracting outflows from inflows. We elucidate this process and highlight sectoral performances from 2011 to 2014, reporting notable findings such as the exemplary performance of chemical product manufacturing. In subsection 4.3, we discuss our findings, scrutinizing sectoral dynamics over time while considering unique sector characteristics and the nuanced implications of innovation investment.

3.1 Descriptive statistics

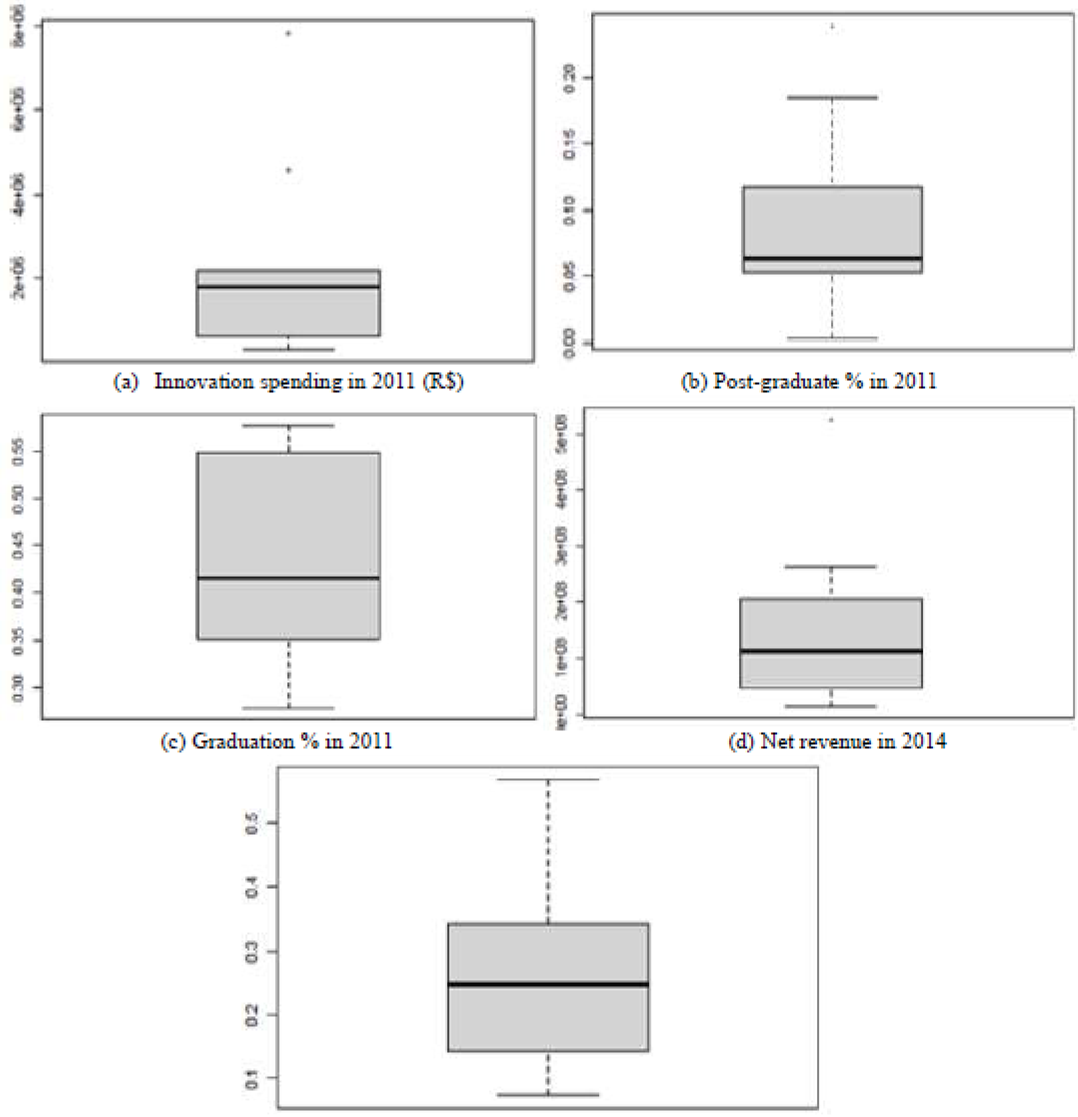
The initial endeavor involved meticulously examining and analyzing the model's descriptive statistics. This pursuit aimed to foster a comprehensive understanding of the studied scenario, thereby facilitating the identification of patterns, conducting inter-group comparisons, and enabling assessments of data dispersion. The comprehensive presentation of these descriptive statistics can be found in Table 4.

Table 4 – Descriptive statistics: Box plot variables model 1

	Innovation spending in 2011 (R$)	**Post-graduate % in 2011**	**Graduation % in 2011**	**Net revenue in 2014**	**(% of substantially improved products in total sales in 2014**
Max	7.814.360,57	23,81	58	525.606.581,00	57
Q3	2.188.277,02	11,02	52	186.762.263,82	34
Average	2.266.535,66	0,09	43	150.243.708,98	27
Median	1.793.904,56	6,25	41	112.821.141,50	25
Q1	667.002,92	5,37	35	53.669.513,00	16
Min	310.073,74	0,32	28	12.719.474,00	7

Source: This research (2024)

In this first model, which covers the time series from 2011 to 2014, it can be seen that the sector with the lowest level of employment of employees with undergraduate and post-graduate degrees in 2011 is the Clothing and Accessories sector, which may indicate that this sector has a low level of salaries, as well as low levels of production complexity.



(a) Innovation spending in 2011 (R$)

(b) Post-graduate % in 2011

(c) Graduation % in 2011

(d) Net revenue in 2014

(e) (% of substantially improved products in total sales in 2014

Figure 1 - Box plot variables model 1

The Food Products Manufacturing sector has the highest values in the indicators relating to "Expenditure by Companies on Innovation in 2011" and "Net Revenue in 2014". These figures may be directly related, but more detailed analysis is needed to confirm this relationship.

In other words, even though this line of business has invested less financially than other lines of business in innovation issues, it has still achieved more than 50% of new or improved items in total internal sales. This phenomenon may be linked to possible past investments, which made the branch invest less, because it already has a solid base to achieve these levels of innovation.

Box-plot graphs were generated to aid in the visualization and analysis of the descriptive data, delineating the values corresponding to the utilized criteria. These graphs are systematically arranged to align with the sequence of indicators delineated in Table 4.

Notably, the initial plot pertains to the expenditure on innovation in the year 2011, as depicted in Figure 1(a). Most of the data is concentrated below the average, with a few outliers above it. Two outliers in the Food Manufacturing and Chemical Products Manufacturing sectors may have pushed up the average value. The data set seems to have a positive asymmetric distribution, where the higher values are more dispersed than the lower values.

As for the indicator that deals with the percentage of employees with post-graduate degrees, the box plot (1b) shows that most of the data is concentrated in a moderate range, with 1 outlier, which in this case corresponds to the Electricity and Gas sector. In this scenario, it can be inferred that there is a greater concentration of data above the average, but with a strong tendency towards heterogeneity.

The box plot (1c), which deals with the percentage of workers with a degree, shows that most of the data is grouped in a moderate range, with a reasonable dispersion around the average. The presence of outliers indicates some variability in the data, but in general, the distribution appears to be relatively concentrated and uniform.

Box Plot of net revenue (1d), shows only 1 outlier, which in this case refers to the Food Manufacturing sector. However, the data distribution suggests a positive asymmetry since the median is below the mean, and the notable difference between Q3 and Q1 indicates significant variability. The lowest value identified in the data is R$ 12,719,474.00 and the highest is R$ 525,606,581.00, indicating the presence of outliers at both extremes.

The Box Plot (1e) interpretation of the data relating to the Enhanced Product Share Range suggests that most of the values are concentrated in a moderate range, but the presence of outliers, especially on the upper side, highlights significant variability in the data. The average is influenced by higher values, indicating a positive asymmetry in the distribution.

Table 5 – Descriptive statistics: Box plot variables model 2

	Innovation spending in 2014	**Post-graduate % in 2014**	**Graduation % in 2014**	**Net revenue in 2017**	**(% of substantially improved products in total sales in 2017**
Max	7.106.515,74	19	62	667.024.159,16	49
Q3	2.671.620,21	11	46	234.590.278,51	31
Average	2.424.906,16	8	45	172.447.090,56	24
Median	1.916.461,74	6	44	108.317.788,62	25
Q1	1.151.547,33	5	41	51.853.713,97	14
Min	430.415,76	1	31	14.972.712,33	4

Source: This research (2024)

Table 5 shows the descriptive statistics for model 2, which covers the range of aggregated data from 2014 to 2017. The descriptive statistics are are the same as those for the 2011-2014 period, as is the case with the Food Products Manufacturing sector, which maintains its position with the highest levels in the indicators "Expenditure by Companies on Innovation" and "Net Revenue", while the Clothing and Apparel and Accessories Manufacturing sector continues to have the lowest values in the indicators relating to the educational level of the employees being assessed - undergraduates and post-graduates.

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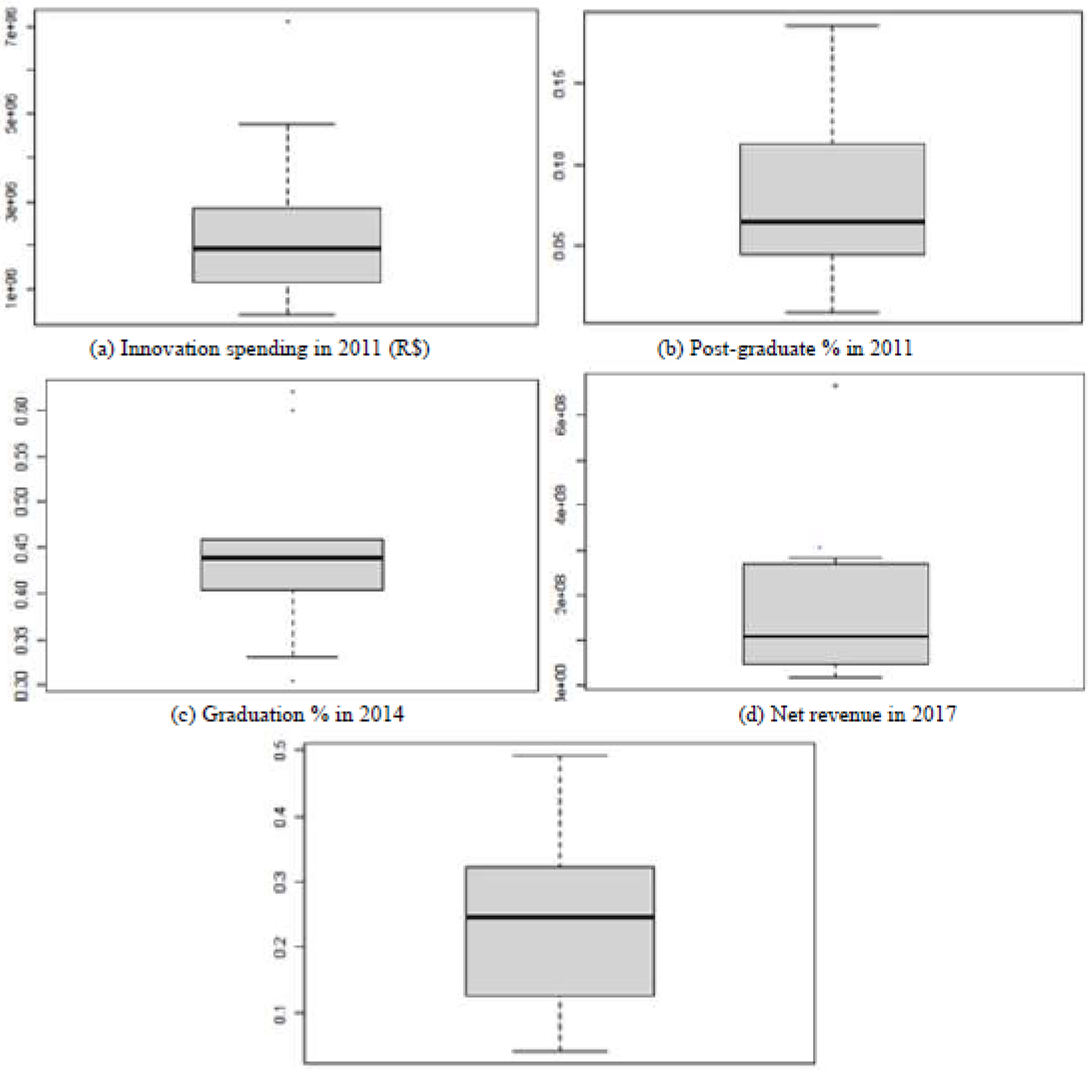

(a) Innovation spending in 2011 (R$)
(b) Post-graduate % in 2011
(c) Graduation % in 2014
(d) Net revenue in 2017
(e) (% of substantially improved products in total sales in 2017

Figure 2 - Box plot variables model 2

The Customizable Software Development sector had the highest value for the indicator "Percentage Share of New or Substantially Improved Products in Total Internal Sales in 2017" and also had the highest number of employees with a degree in 2014, but in 2017 it had the lowest Net Revenue. Meanwhile, the Extractive Industry sector showed the highest value in the indicator for the number of employees with post-graduate degrees, but it was the sector with the lowest share of products that received innovation incentives in total domestic sales. Box Plots in the figure 2 were constructed with the values of the criteria used to enhance the analysis of the descriptive data.

The Box Plot (2b) for the Percentage of Employees with Post-graduate Degrees indicator shows no outliers. Furthermore, the minimum value is 1% and the maximum value is 19%, indicating the presence of outliers at both extremes. This suggests that most of the data is concentrated in a moderate range, the average is affected by higher values, indicating a tendency towards positive asymmetry in the distribution.

Box plots (2c) shows three outliers, two of which are positive and concern the Custom Software Development and Custom Software Development sectors. The negative outlier refers to the Clothing and Accessories sector. All in all, the Box Plot values imply that the majority of the data is grouped in a relatively narrow range, suggesting consistency in the distribution.

When it comes to Net Revenue in 2017, you can see from the Box Plot (2d) that there is 1 outlier, which refers to the Food Products sector. However, the other values behave above average, as can be seen in the graphical representation. In addition, the distribution suggests a positive asymmetry, since the median is below the mean, indicating an influence of higher values.

Regarding the percentage of substantially improved products in total sales in 2017 (2e), it can be inferred from the data that there is a concentrated distribution in the interquartile range of 14% to 31%. The median, close to the average of 24%, suggests a slight positive asymmetry. Most of the data is centered in a moderate range, with some variability at the extremes, suggesting an overall symmetrical or slightly asymmetrical positive distribution.

3.2 Multicriteria analysis with PROMETHEE II

PROMETHEE II is designed based on a model in which it is necessary to perform the ranking based on the net flow, which refers to subtracting the outflow from the inflow. Almeida (2013) defines the two concepts of outflow as the "intensity of preference" of the specific alternative over all the other alternatives in the set, where the higher the value of the flow, the better the alternative. Input flow, on the other hand, is the opposite, being the "intensity of preference" of all the alternatives over the specific alternative, and the lower the input flow, the better the alternative.

It should be noted that the flow values are used to rank the alternatives, and do not have a direct algebraic relationship of better or worse performance between them. The rankings used for the models in this study are described in Table 6.

Table 6 - Net flow: Model 1

Ranking	Sector	Net Flow	Outflow	Input Flow
1st	Manufacture of chemical products	0.5556	0.7778	0.2222
2nd	Manufacture of food products	0.3778	0.6889	0.3111
3rd	Electricity and gas	0.2444	0.6222	0.3778
4th	Custom software development	0.0667	0.5333	0.4667
5th	Manufacture of machinery and equipment	0.0000	0.4889	0.4889
6th	Manufacture of electrical materials	0.0000	0.4889	0.4889
7th	Extractive industries	-0.1111	0.4444	0.5556
8th	Manufacture of rubber and plastic products	-0.1556	0.4222	0.5778
9th	Customizable software development	-0.1556	0.4222	0.5778
10th	Manufacture of Clothing and accessories	-0.8222	0.0889	0.9111

Source: This research (2024)

The best-performing sector in the 2011-2014 period according to PROMETHEE II's net flow analysis was chemical products manufacturing, followed by food products manufacturing and electricity and gas.

The worst sectors in this ranking were those related to manufacturing rubber and plastic products, developing customizable software and lastly the clothing and accessories sector. It should be noted that VISUAL PROMETHEE provides a visualization of the criteria that acted positively and negatively in constructing this ranking.

Table 7 - Behavior of criteria: Model 1

Positive criteria	Sectors	Negative criteria
- Spending by Companies on Innovation (R$) - Graduation - Post-graduate - Ranges of percentage share of new or substantially improved products in total domestic sales - Net income (R$)	1st - Manufacture of chemical products	-
- Innovation spending by companies - Post-graduate - Net Revenue (R$)	2nd - Manufacture of food products	- Graduation - Percentage share of new products
- Post-graduate - Graduation - Net Revenue (R$)	3rd - Electricity and gas	- Expenditure by Companies on Innovation (R$) - Percentage share of new products
- Post-graduate - Graduation - Percentage share of new products	4th - Custom software development	- Spending by Companies on Innovation (R$) - Net Revenue (R$)
- Spending by Companies on Innovation (R$) - Graduation - Percentage share of new products	5th - Manufacture of machinery and equipment	- Post-graduate - Graduation
- Expenditure by Companies on Innovation (R$) - Net Revenue (R$) - Percentage share of new products	6th - Manufacture of electrical materials	- Post-graduate - Graduation
- Post-graduate - Net Revenue (R$)	7th - Extractive industries	- Expenditure by Companies on Innovation (R$) - Graduation - Percentage share of new products
- Expenditure by Companies on Innovation (R$)	8th - Manufacture of rubber and plastic products	- Post-graduate - Graduation - Net Revenue (R$) - Percentage share of new products
- Graduation - Percentage share of new products	9th - Customizable software development	- Spending by Companies on Innovation (R$) - Post-graduate - Net Revenue (R$)
-	10th - Manufacture of clothing and accessories	- Spending by Companies on Innovation (R$) - Post-graduate - Graduation - Net Revenue (R$) - Percentage share of new products

Source: This research (2024)

The behavior of the criteria according to the method used here is described in Table 7, therefore shows which criteria made it possible to raise the sector's position in the ranking or which did the opposite. In this case, the first-placed sector on the list (Manufacture of chemical products) had all its indicators show positive results. In other words, it can be understood from this that this sector invested in innovation, increased the number of undergraduate and post-graduate employees, and had new or improved products and higher net revenues.

In addition, it is important to note that the sectors in second place in this ranking, which are the Manufacture of Food Products and Electricity and Gas, respectively, had the criteria of post-graduate degrees and Net Revenue as being positive, while the criteria of Percentage share of new products was common to both and proved to be a negative indicator for this analysis. Therefore, from this, it is possible to extract that even though these sectors invested in employees with 4th degree qualifications, they had higher revenues, but did not achieve the same triumph when analyzing the number of new products.

Looking at the last four places in the ranking, we can see that all of them had the investment in innovation indicator as a negative criterion - except for the rubber and plastics manufacturing sector. In addition, it is noticeable that the indicators for the number of employees with undergraduate and post-graduate degrees also contributed to the lower rankings in these sectors. It is particularly interesting to note that although the Customizable software development sector has invested in employees with post-graduate degrees, it has still been unable to obtain better positions since the other criteria caused it to decline.

Table 8 - Net flow: Model 2

Ranking	Sector	Net Flow	Outflow	Input Flow
1st	Manufacture of chemical products	0.6444	0.8000	0.1556
2nd	Manufacture of food products	0.5556	0.7556	0.2000
3rd	Customizable software development	0.0889	0.5333	0.4444
4th	Manufacture of electrical materials	0.0667	0.5333	0.4667
5th	Electricity and Gas	0.0222	0.5111	0.4889
6th	Manufacture of machinery and equipment	0.0000	0.4889	0.4889
7th	Extractive industries	-0.1111	0.4444	0.5556
8th	Custom software development	-0.1778	0.4000	0.5778
9th	Manufacture of rubber and plastic products	-0.3111	0.3333	0.6444
10th	Manufacture of clothing and accessories	-0.7778	0.1111	0.8889

Source: This research (2024)

The net flow of model 2 it is possible to infer from the Net Flow that there have been some changes in the positioning of the sectors after this period of time, such as the rise of the Custom Software Development sector and the decline of the Custom Software Development sector. Generally speaking, there have been few changes in this new ranking, especially in the last and first placed sectors. Table 9 shows the direction taken by each criterion.

Table 9 - Behavior of criteria: Model 2

Positive criteria	Sectors	Negative criteria
- Expenditure by Companies on Innovation (R$) - Post-graduate - Graduation - Net Revenue (R$) - Percentage share of new products	1st - Manufacture of chemical products	-
- Expenditure by Companies on Innovation (R$) - Post-graduate - Graduation - Net Revenue (R$)	2nd - Manufacture of food products	- Percentage share of new products

- Graduation - Percentage share of new products	3rd - Customizable software development	- Expenditure by Companies on Innovation (R$) - Post-graduate - Net Revenue (R$)
- Spending by Companies on Innovation (R$) - Post-graduate - Graduation - Percentage share of new products	4th - Manufacture of electrical materials	- Net Revenue (R$)
- Post-graduate - Net Revenue (R$)	5th - Electricity and gas	- Expenditure by Companies on Innovation (R$) - Graduation - Percentage share of new products
- Expenditure by Companies on Innovation (R$) - Net Revenue (R$) - Percentage share of new products	6th - Manufacture of machinery and equipment	- Post-graduate - Graduation
- Post-graduate - Net Revenue (R$)	7th - Extractive industries	- Expenditure by Companies on Innovation (R$) - Graduation - Percentage share of new products
- Graduation - Percentage share of new products	8th - Custom software development	- Spending by Companies on Innovation (R$) - Post-graduate - Net Revenue (R$)
- Expenditure by Companies on Innovation (R$)	9th - Manufacture of rubber and plastic products	- Post-graduate - Graduation - Net Revenue (R$) - Percentage share of new products
-	10th - Manufacture of clothing and accessories	- Expenditure by Companies on Innovation (R$) - Post-graduate - Graduation - Net Revenue (R$) - Percentage share of new products

Source: This research (2024)

In this scenario, Table 9 shows that model 2 behaves very similarly to model 1, with a few minor exceptions. However, it is still possible to infer in a broader sense that most of the negative criteria of the sectors in the worst positions are related to the indicator Expenditure in R$ made by companies on innovation, as well as the number of employees with higher levels of training. The opposite is also true: when you look at the top two, you can see that this same indicator boosts their position.

Finally, Table 10 shows a comparison between the positions of the sectors between the periods, in which it can be seen that the changes in the last positions are small, which may be a reflection of the lack of search for innovation and internal development by the companies that make up these sectors.

Table 10 - Ranking of economic sectors

2011-2014					
	Spending by Companies on Innovation (R$)	Post-graduate (%)	Graduation (%)	Net Revenue (R$)	Percentage share of new or substantially improved products in total domestic sales (%)
1st - Manufacture of chemical products	+	+	+	+	+
2nd - Manufacture of food products	+	+	-	+	-
3rd - Electricity and gas	-	+	+	+	-
4th - Custom software development	-	+	+	-	+
5th - Manufacture of machinery and equipment	+	-	+	-	+
6th - Manufacture of electrical materials	+	-	-	+	+
7th - Extractive industries	-	+	-	+	-
8th - Manufacture of rubber and plastic products	+	-	-	-	-
9th - Customizable software development	+	+	-	+	-
10th - Manufacture of clothing and accessories	-	-	-	-	-
2014-2017					
	Spending by Companies on Innovation (R$)	Post-graduate (%)	Graduation (%)	Net Revenue (R$)	Percentage share of new or substantially improved products in total domestic sales (%)
1st - Manufacture of chemical products	+	+	+	+	+
2nd - Manufacture of food products	+	+	+	+	-
3rd - Customizable software development	-	-	+	-	+
4th - Manufacture of electrical materials	+	+	+	-	+
5th - Electricity and gas	-	+	-	+	-
6th - Manufacture of machinery and equipment	+	-	-	+	+
7th - Extractive industries	-	+	-	+	-
8th - Custom software development	-	-	+	-	+
9th - Manufacture of rubber and plastic products	+	-	-	-	-
10th - Manufacture of clothing and accessories	-	-	-	-	-

Source: This research (2024)

Knowing the strengths and weaknesses of an economic sector is crucial for a variety of stakeholders, including companies, investors and governments. This in-depth understanding allows for more informed strategic decision-making. Companies can capitalize on their strengths, developing competitive advantages, while mitigating weaknesses to improve efficiency.

Knowing your strengths inspires innovation and continuous development, while understanding your weaknesses allows you to prepare for challenges and adapt to changes in the market. In addition, this analysis influences recruitment and workforce training decisions, contributing to job creation and the development of specific skills. In a broader context, understanding strengths and weaknesses contributes to resilience to economic, technological and social changes, promoting long-term sustainability. This includes the efficient management of natural resources, the minimization of environmental impacts and the promotion of ethical practices.

3.3 Disussion of Results

By analyzing the results shown above by the multicriteria analysis together with the descriptive statistics, we can infer how the scenarios between the sectors have changed over the years. It is clear that each sector has its own characteristics and the results of investments in innovation reflect these characteristics, since high-value standards in a given criterion do not have the same impact in different sectors.

It is worth noting that this study was divided into 2 different time scenarios, thus encompassing various events that certainly influenced the results obtained, given that economic variations, global paradigm shifts and investment programs in strategic sectors by the public authorities involved this period in which the study was carried out.

It is also important to mention that Brazil has a concentration of sectors throughout its territory. This concentration is not uniform, so it is only natural that certain sectors studied in this study are located in specific states, which means that the benefits or development effects they bring are naturally not spread across the entire national territory, as is the demand that the sectors lack, such as the availability of skilled labor, especially those with undergraduate and post-graduate degrees, which are different in certain Brazilian regions or states.

Finally, it is worth noting that the study was carried out using a low number of evaluation criteria, and with simplifications in terms of statistical tests, which can certainly be better explored in future studies, but the value of the work is not lost as its exploratory nature of the subject has not been replicated in any recent study in the literature.

4. Results

Throughout this study, we sought to evaluate and understand innovative performance in the various sectors of the Brazilian economy, using a multicriteria approach based on the PROMETHEE 2 method.

From these results, it is possible to see which sectors performed best in each historical series and also which criteria made them rise or fall in the *ranking*. These findings are useful for government bodies to formulate incentive policies, for example, for those sectors that are unable to get out of the lowest positions, such as: i) clothing and accessories manufacturing and ii) rubber and plastics manufacturing. These sectors were ranked lowest in the ranking lists of both models, and the negative criteria for these sectors were the number of employees with undergraduate and post-graduate degrees.

In other words, with these findings, government bodies can encourage formal education for these sectors to bring qualified professionals into the market. In addition, financial incentives can be formulated, such as credit access policies for innovative processes.

Another important finding of this study is that the sectors that came out on top in both models had positive criteria, such as spending on innovation and the number of qualified employees with academic qualifications. From this, it is possible to infer that these specific criteria can make a difference in the performance of organizations.

It is plausible for entrepreneurs to see these findings as a way of improving their businesses and to focus on these specific criteria when seeking innovation in their companies. At this point, we would like to point out that further studies could investigate how the behavior of these markets is shaped by the maximization of this indicator in a multicriteria model. Businesses can infer from this study that improved or innovative products can also make a difference in revenue over time.

One limitation is the impossibility of identifying the practical reasons why the criteria were positive or negative for the economic sectors selected for analysis. In other words, although the results show which criteria boosted or lowered the sector in the *ranking, we could not say the real reasons* for it reaching that level.

Furthermore, this study only deals with two specific periods (2011 to 2014 and 2014 to 2017) grouped into two historical series, which suggests that it is possible that innovative processes have not yet taken place, as the analysis does not even consider a decade. Finally, using general data from all regions of the country is also a limitation of this study, leaving aside the many Brazilian locations' demographic, economic, and social considerations.

In future work, we suggest that PINTEC microdata be used to see if the behaviors outlined here are the same when looking at Brazil's regions and states. In addition, we suggest that more comprehensive studies incorporating external factors, the size of each company and the business sectors.

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