Article

Factors determining the relative efficiency of Brazilian Federal Institutes of Education, Science and Technology

Fatores determinantes da eficiência relativa dos Institutos Federais de Educação, Ciência e Tecnologia brasileiros

Factores que determinan la eficiencia relativa de los Institutos Federales de Educación, Ciencia y Tecnología de Brasil

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Abstract: The Federal Network of Professional, Scientific and Technological Education, linked to the Ministry of Education, has 38 Federal Institutes present in all Brazilian states and the Federal District. Created in 2005, the Expansion Plan for the Federal Network of Vocational Education aimed to expand the presence of these institutions throughout the national territory. Starting from the premise of the importance of federal public education, this paper analyzes the relative efficiency of the management of public financial resources of the Brazilian Federal Institutes of Education, Science and Technology. The research has a quantitative approach and covers the four-year period 2016-2019. As for the type of sampling, the research worked with the research universe, based on a document analysis in the annual analysis reports of the management indicators of these institutions. The research uses Data Envelopment Analysis (DEA) to measure the relative efficiency of these institutes and the Tobit regression analysis model to verify the conditioning factors of these efficiency levels. The result set has shown a great heterogeneity between the institutions analyzed in the period, revealing that only 39.5% of Brazilian IFETs operate above the average relative efficiency score. The institutions that presented the best efficiency scores gradually expanded the course offerings and the number of vacancies over the years to optimize the existing workforce.

Keywords: efficiency; professional education; performance indicators.

Resumo: A Rede Federal de Educação Profissional, Científica e Tecnológica, vinculada ao Ministério da Educação, possui 38 Institutos Federais presentes em todos os estados brasileiros e no Distrito Federal. Criado em 2005, o Plano de Expansão da Rede Federal de Educação Profissional teve como objetivo ampliar a presença destas instituições em todo o território nacional. Partindo da premissa da importância da educação pública federal, este artigo tem como objetivo analisar a eficiência relativa da gestão de recursos públicos financeiros dos Institutos Federais de Educação, Ciência e Tecnologia brasileiros. A pesquisa possui abordagem quantitativa e contempla o quadriênio 2016-2019. Quanto ao tipo de amostragem, a pesquisa trabalhou com o universo de pesquisa, a partir de uma análise documental nos relatórios anuais de análise dos indicadores de gestão dessas instituições. A pesquisa utiliza a Análise por Envoltória de Dados (DEA) para mensurar a eficiência relativa desses institutos e o modelo de análise de regressão Tobit para verificar os fatores condicionantes desses níveis de eficiência. Com o conjunto de resultados identificou-se grande heterogeneidade entre as instituições analisadas no período, revelando que apenas 39,5% dos IFETs brasileiros operam acima do escore médio de eficiência relativa. As instituições que apresentaram os melhores escores de eficiência ampliaram gradativamente a oferta de cursos e o número de vagas ao longo dos anos para otimizar a força de trabalho já existente.

Palavras-chave: eficiência; educação profissional; indicadores de desempenho.

Resumen: La Red Federal de Educación Profesional, Científica y Tecnológica, vinculada al Ministerio de Educación, cuenta con 38 Institutos Federales presentes en todos los estados brasileños y en el Distrito Federal. Creado en 2005, el Plan de Expansión de la Red Federal de Educación Profesional tuvo como objetivo ampliar la presencia de estas instituciones en todo el territorio nacional. Partiendo de la premisa de la importancia de la educación pública federal, este artículo tiene como objetivo analizar la eficiencia relativa de la gestión de los recursos financieros públicos en los Institutos Federales de Educación, Ciencia y Tecnología de Brasil. La investigación tiene un enfoque cuantitativo y abarca el cuatrienio 2016-2019. En cuanto al tipo de muestreo, la investigación trabajó con el universo de investigación, a partir de un análisis documental de los informes anuales analizando los indicadores de gestión de estas instituciones. La investigación utiliza el Análisis Envolvente de Datos (DEA) para medir la eficiencia relativa de estos institutos y el modelo de análisis de regresión Tobit para verificar los factores condicionantes de estos niveles de eficiencia. En el conjunto de resultados se identificó una gran heterogeneidad entre las instituciones analizadas en el período, revelando que sólo el 39,5% de los IFET brasileños operan por encima del puntaje promedio de eficiencia relativa. Las instituciones que presentaron los mejores puntajes de eficiencia ampliaron gradualmente la oferta de cursos y el número de vacantes a lo largo de los años para optimizar la fuerza laboral existente.

Palabras clave: eficiencia; educación profesional; indicadores de desempeño.

1 Introduction

The Federal Network of Professional, Scientific and Technological Education, linked to the Ministry of Education, has 38 Federal Institutes present in all Brazilian states and the Federal District. It was formed by secular educational institutions and its project began during the government of Nilo Peçanha, through Decree no. 7,566, of September 23, 1909, which created the Artifices Apprentice Schools, intended for free primary professional education for the underprivileged living in the state capitals of the Republic (Brazil, 2007). In 2005, with the advent of the Federal Professional Education Network Expansion Plan, federal technological education institutions were integrated, for the purposes of establishing the Federal Institutes of Education, Science and Technology (IFETs), and reached the amount of 659 units nationwide in 2018 (MEC, 2018).

Regarding the provision of services, institutes are legally obliged to guarantee a minimum of 50% of their vacancies for the offer of secondary-level technical courses, primarily in an integrated manner. They must also guarantee a minimum of 20% of their vacancies to cover the offer of undergraduate courses, as well as special pedagogical training programs, with a view to training teachers for basic education, especially in the areas of science and mathematics, and for professional education (Brazil, 2007). Mariz Fernandes (2009) highlights that the model of the Federal Institutes is differentiated and unique due to its performance at different levels of national education and the articulation of teaching with research and extension, in addition to the multicampi and pluricurricular structural organization.

In this sense, this paper analyzes the relative efficiency of the management of public financial resources at the Brazilian Federal Institutes of Education, Science and Technology, in the four-year period 2016-2019. In this context, this research is justified by the effort to scientifically analyze the management of public financial resources in Brazilian Federal Institutes and their level of efficiency. The academic suitability of this research is relevant because there is a gap in relation to this research proposal associated with the Brazilian Federal Institutes. The research has a quantitative approach and covers the four-year period 2016-2019. Regarding the type of sampling, the study worked with the research universe (38 IFETs), based on a documentary analysis of the annual reports analyzing the management indicators of these institutions. The research used Data Envelopment Analysis (DEA) to measure the relative efficiency of these institutes and the Tobit regression analysis model to verify the conditioning factors of these efficiency levels.

The research is structured as follows: (i) this introduction section contextualizes the topic and presents the problem, sets the goals, provides the justification and the contributions which added new knowledge to the subject; (ii) the second section deals with a brief theoretical framework on efficiency in educational institutions; (iii) the third section presents the research methodology; (iv) the fourth section outlines the results achieved and discussions based on their analysis; (v) the fifth section presents considerations in the research results; and (vi) the sixth section lists the references used.

2 Theoretical framework

The need to analyze performance in work organizations has led to studies in the field of administrative sciences developing over the years. In the field of organizational studies, efficiency is associated with open organizational systems and arrangements, which carry out constant exchanges of materials with their environment (Sergeant; Feres, 1972; Etizioni, 1975; Lovell, 1993). In the field of economics, even though it assumes a relativistic character, the study of efficiency has become important because this is the main step in a process that can lead to a substantial saving of resources (Forsund; Hjalmarsson, 1974).

From the perspective of public management, efficiency can be analyzed in micro or macro dimensions in which public financial resources are applied. The most widely accepted concept of efficiency in economics that involves the discussion around public educational institutions is the one developed by Pareto, in which a state of a given system is optimal if and only if there is no viable alternative to that system in which at least one person is better off and no one else is worse off (Czyżewski et al., 2016; Sav, 2016, 2017).

Chakraborty et al. (2013) elect Levin's research (1974) and Levin et al. (1976) as one of the first works that measured efficiency in educational production based on a parametric non-stochastic linear programming model. Their studies concluded that schools with smaller class sizes and higher paid, more experienced teachers produce higher performance scores. The study also estimates an average relationship rather than an individual school-specific relationship between inputs and outputs. In technical efficiency the possibility of increasing production is evaluated, maintaining the combination of resources or the way of working, that is, without changing the academic and pedagogical project of the institution.

Robst (2000, 2001) carried out research to determine whether the source of public higher education resources influences the degree of efficiency in American universities. Based on data extracted from the report "The Chronicle of Higher Education", a significant relationship was noticed between the share of total education spending provided by state allocations and the degree of efficiency. Regardless of the source of funding, American public universities have increased tuition revenues amid reductions in state appropriations. The most efficient institutions were those with the largest number of students.

On this same premise, Wolszczak-Derlacz and Parteka (2011) examined the technical efficiency of 259 educational institutions from seven European countries between 2001 and 2005. The findings of this study indicate that the size of the institution is an important factor in its efficiency: the greater the number of students or the number of faculties, the greater the efficiency of the institutions. Chakraborty *et al.* (2001) measured technical efficiency in each of the 40 school districts in the state of Utah, in the United States. The study has important policy implications, given that in districts with a large number of low-income students, efficiency can be improved through some reallocation of resources to leveling programs and training students to enter schools.

Tochkov and Nenovsky (2012) estimated the relative technical and cost efficiency of Bulgarian universities based on the correlation between public funding and efficiency levels. Overall, the most efficient universities focus on fewer areas of study and offer a greater number of courses in natural sciences, medicine and engineering. In the Latin American context, Dufrechou (2016) analyzed the efficiency of spending on public education and the role of possible conditioning factors in upper middle-income countries compared to high-income economies in the period 1970-2010. The research identifies a converging efficiency trend for the entire sample, to the detriment of a modest expansion in public spending.

A survey comparing the efficiency of education spending in 20 European countries during the period 2006-2009, carried out by Agasisti (2014, 2016) confirms that there is no linear relationship between spending and educational performance, in which there are examples of countries that manage to obtain good results even when investing few resources. Still, the research results provide relevant information: (i) the group of most efficient countries is quite similar between 2006 and 2009; (ii) the resource savings in the range of ten percent are still possible despite a slight improvement in the pure efficiency of public expenditure; and that (iii) the positive correlations between students' efficiency and technological literacy and teachers' salaries suggest the promotion of initiatives to foster the human capital of professionals involved in education.

Considering the above, Tochkov and Nenovsky (2012) warn that the task of introducing a performance-based approach to the public financing system for education takes on greater urgency during processes of economic slowdown. In this context, the research suggests that the government applies resources based on criteria correlated to efficiency rankings. Within the scope of the Ministry of Education (MEC), its budget is distributed among its Secretariats according to the objectives and priorities for the area, according to Decree No. 7,313, of September 22, 2010 (Brazil, 2010). In the specific case of Federal Institutes, the Department of Professional and Technological Education (SETEC) is responsible for distributing public financial resources according to the budget matrix presented by the Planning and Administration Forum (FORPLAN) of the National Council of Institutions of the Federal Network for Professional, Scientific and Technological Education (CONIF).

3 Methodology

This section aims to present the organization and research proposal, as well as the resources to achieve the assumptions of this study. The research is longitudinal, considering the delimitation of the period 2016-2019 to analyze the level of relative efficiency of IFETs. The time frame involves the 2016-2019, a four-year period, for two reasons: (i) it comprises the Union's Multi-Year Plan (PPA) for the period from 2016 to 2019, as set out in Law No. 13,249/2016; and (ii) it occurs after the consolidation of the Expansion Plan for the Federal Professional Education Network in accordance with Law No. 11,195/2005. In this way, it is considered the predictability of the budget during this period and the full use of its physical facilities.

The work considers the research universe, considering that in this type of sampling, according to Lakatos and Marconi (2010), all individuals who make up that structure are selected. Thus, the research covers the 38 Brazilian IFETs, which were analyzed regarding their level of relative efficiency during the four-year period 2016-2019. The data analyzed were extracted from the Analysis Report of Management Indicators of Federal Institutions of Professional, Scientific and Technological Education, published annually by SETEC, a secretariat linked to the Ministry of Education.

As for the data analysis technique, the research used Data Envelopment Analysis (DEA) to measure the relative efficiency of the 38 Federal Institutes of Education, Science and Technology and generate efficiency scores. After presenting the efficiency scores through the DEA, the Tobit regression analysis model was used to verify the factors conditioning these efficiency levels, which are explained in sequence.

According to Casado (2007), DEA is a non-parametric technique that employs mathematical programming to construct production frontiers of production units (DMUs) that employ similar technological processes to transform multiple inputs into multiple products. Gomes and Baptista (2004) consider that DEA presents two basic

analysis models: (i) CCR model (model with constant returns) developed by Charnes, Cooper and Rhodes (1978); (ii) BCC model (model with variable returns), developed by Banker, Charnes and Cooper. Therefore, in accordance with the proposal of this study, Belloni (2000) states that the BCC model is the most appropriate for analyzing the efficiency of educational institutions, considering their heterogeneity in relation to size, number of resources used and variation in results disclosed according to data collection.

According to Mello *et al.* (2005), the application of the DEA model with variable returns to scale (BCC) and product orientation is modeled in (1), where xik represents the input i of DMUk; yjk represents the output j of DMUk; λ k is the contribution of DMUk to the formation of the DMU0 target and h0 corresponds to the efficiency.

$$\text{Max } h_0$$
$$\text{subject to}$$

$$x_{i0} - \sum_{k=1}^{n} x_{ik}\lambda_k \geq 0, \forall i$$

$$- h_0 y_{j0} + \sum_{k=1}^{n} y_{jk}\lambda_k \geq 0, \forall j$$

$$\sum_{k=1}^{n} \lambda_k = 1$$

$$\lambda_k \geq 0, \forall k$$

According to Dyson *et al.* (2001), the practical application of DEA presents procedural issues that must be examined and resolved: (i) the units of analysis carry out similar activities and produce comparable products or services, so that a common set of results can be defined; (ii) the resources available to all units are similar and can be brought to a common denominator as cost; and (iii) the units operate in similar environments. Still according to the authors, the selection of variables must observe some aspects such as: (i) the number of DMUs must be at least 2 times the product mxs, being the number of inputs and the number of outputs (in this research m = 1 X s = 5, totaling a minimum of 5 DMUs, compared to the analysis of 38 DMUs); (ii) the selected variables must be positively correlated after correlation analysis Table 1; and (iii) the activity levels indices should not be mixed with volume performance measures.

Table 1 contains the results of the linear correlation analysis between the input variable current expenditure (GCORR) and the product variables: entrance × enrollment ratio (RIM), graduates × enrollment ratio (RCM), academic efficiency of graduates (EAC), graduate ratio student × teacher (RAP), school flow retention (RFE), faculty degree index (ITCD) and enrollment × vacancy ratio (RIV) of federal institutes in Brazil in the years 2016 to 2019.

Table 1 – Correlation Matrix between study variables

Variables	GCORR	RIM	RCM	EAC	RAP	RFE	ITCD	RIV
GCORR	1.00	0.12	0.15	0.07	0.09	-0.17*	0.34***	-0.03
RIM	0.12	1.00	0.58***	0.20*	0.17*	-0.40***	0.22*	-0.27*
RCM	0.15	0.58***	1.00	0.55***	0.22*	-0.54***	0.16*	-0.35***
EAC	0.07	0.20*	0.55***	1.00	0.12	-0.05	0.02	-0.24**
RAP	0.09	0.17*	0.22*	0.12	1.00	-0.30***	0.15	0.21*
RFE	-0.17*	-0.40***	-0.54***	-0.05	-0.30***	1.00	-0.26**	0.24**
ITCD	0.34***	0.22*	0.16*	0.02	0.15	-0.26**	1.00	-0.36***
RIV	-0.03	-0.27*	-0.35***	-0.24**	-0.21*	0.24**	-0.36***	1.00

Note: Linear correlation analysis (-1 to 1) between the input variable current expenditure (GCORR) and the product variables: entrance × enrollment ratio (RIM), graduates × enrollment ratio (RCM), academic efficiency of graduates (EAC), student ratio × professor (RAP), RFE, faculty degree index (ITCD) and enrollment × vacancy ratio (RIV) of federal institutes in Brazil in the years 2016 to 2019. *: significant at 5% probability; **: significant at 1% probability; ***: significant at 0.0001% probability.

Source: Prepared by the authors.

Fulfilling one of the requirements of the DEA methodology, there was a negative linear correlation between the GCORR × the RFE variable (ρ = -0.17) and between the GCORR × the RIV variable (ρ = -0.03). The variables RFE and RIV still correlated negatively with RIM, RCM, EAC and RAP. Due to this factor, these variables were not used in the DEA-BCC analysis. The variables used in the application of DEA are shown in Table 1.

Table 1 – Variables selected for the DEA-BCC model

Variable	Description
GCORR	total expenditure of the Institution, deducting expenses with inactive staff and pensioners, court orders and investment expenses, action 20RW (Support for Professional, Scientific and Technological Training) and action 8252 (Distance Professional and Technological Education
RIM	percentage of entrants to total enrollment
RCM	percentage of graduates out of total enrollment
EAC	proportion of graduates compared to the total number of enrollments completed at the institution, whether through completion or dropout
RAP	relationship between students and teachers
ITCD	sum of all permanent teachers weighted by their title (Graduation: 1, Further Education: 2, Specialization: 3, Master's: 4 and Doctorate: 5), divided by the total number of teachers

Source: Prepared by the authors.

When analyzing the relative efficiency of Brazilian IFETs, it is highlighted that the efficient level will be given by a comparative method, measured in relative terms based on the application of a DEA. In this case, the volume of resources used is compared with the results achieved by the analysis units in a given period. Thus, as explained by Moreira (2018), the analysis units that comparatively present the best results are treated as efficient, serving as a reference for the others. Corroborating Moreira´s study, Agasisti (2016) highlights that educational performance measured by efficiency test scores is at least incomplete, in which several inputs (student skills, school characteristics, institutional characteristics, money invested in the sector, among others) must be combined to evaluate the performance of educational systems.

After presenting the efficiency scores through the DEA, the Tobit regression analysis model was used to verify the factors conditioning these efficiency levels. According to Moreira (2018), several studies that used the DEA technique to measure the efficiency of certain units also used the Tobit model, combining the econometric model to identify factors determining efficiency. When considering that the relative efficiency results are located between the values of 0 and 1, the use of Tobit regression becomes useful to achieve the research objectives.

According to McDonald and Moffitt (1980), the Tobit technique assumes that the dependent variable has several of its values grouped into a limit value, generally zero, and uses all observations to estimate a regression line. Greene (1997) presents the definition of the Tobit model, in which y: dependent variable that will be estimated; $\beta\_"0"$: intercept of the regression equation; $\beta\_"j,"$ j = 1, …, k: measures the marginal effect of xj on y; xj, j=1, …, k: represent the independent variables of the model; and ε: represents the error term of the equation:

$$y = +\beta\_"0" + \beta\_"1" \ x\_"1" \ \beta\_2 \ x\_2 + \cdots + \ \beta\_k \ x\_k + \varepsilon$$

The variables used in the Tobit linear regression analysis model application are shown in Table 2.

Table 2 – Variables selected for the Tobit model

Variable	Description
EFI	efficiency score generated through DEA-BCC
NCAMPI	number of campi belonging to IFETs
QALN	number of students enrolled
QPROF	number of teachers
QVAGAS	number of vacancies offered
RFE	number of students retained / enrollments
RIV	number of entrants / number of vacancies

Source: Prepared by the authors.

The dependent variable (y) is the result of the efficiency score generated through Data Envelopment Analysis (DEA) with product orientation (BCC). This score varies from 0 to 1, with each federal institute acquiring a positive index. The independent variables are made up of indicators reported by IFETs in their management reports between 2016 and 2019. In this sense, these variables intend to explain the level of influence of these indicators, attesting or refuting their level of influence in relation to efficiency performance of the institutions analyzed in this study. According to Moreira (2018), the use of the Tobit model with panel data combines information about different analysis units collected in different periods of time (in the case of this research, the IFETs between 2016 and 2019). The following section presents an analysis and discussion of the results.

4 Analysis and discussion of the results

As a research proposal, based on the methodological procedures used, we seek to measure and identify the factors determining the relative efficiency of the management of public financial resources at the Brazilian Federal Institutes of Education, Science and Technology, during the period from 2016 to 2019. This section analyzes and discusses the main results of the research. The descriptive statistics of the current expenditure variable (GCORR) refer to the total settled expenditure of each IFETs, as shown in Table 2.

Table 2 – Descriptive statistics of the current expenditure input variable (GCORR) between 2016 and 2019

GCORR	Average	Standard deviation	Coefficient of variation	Maximum	Minimum
2016	280,309,465	125,844,328	44.9%	630,438,660	58,784,423
2017	318,466,775	139,697,737	43.9%	744,430,366	80,171,215
2018	342,946,851	150,645,962	43.9%	805.387.470	93,896,246
2019	363,953,533	162,642,231	44.7%	875,667,601	102,593,950

Source: Prepared by the authors.

It is possible to observe great dispersion and heterogeneity presented by the GCORR of IFETs during the period analyzed in relation to the way in which these institutions apply public financial resources to finance their activities. For instance, there is high variation in standard deviation which can demonstrate the disparity in resources allocated to each unit of analysis. In this premise, it is necessary to reflect on the characteristics that involve each IFETs, the size of their structure (considering the multi-campi perspective), as well as the type of number of courses offered, whether at a technical or higher level, which distinguishes these HEIs from other institutions that make up the Federal Education Network. Throughout the period analyzed, there was a decrease in the percentage of investment of public financial resources for the activities of IFETs from 2016 onwards, as shown in Table 3.

Table 3 – Evolution of the current expenditure input variable (GCORR) between 2016 and 2019

Year	GCORR		
	Total	Growth	Accumulated
2016	10,651,759,670.84	0.00%	0.00%
2017	12,101,737,444.41	11.98%	11.98%
2018	13,031,980,324.00	7.14%	19.12%
2019	13,830,234,272.23	5.78%	24.90%

Source: Prepared by the authors.

In contrast, considering the percentage accumulated between the years 2016-2019, public financial resources allocated to these institutions have positive growth when observing the volume allocated (an accumulated increase of 24.90% between 2016-2019), as shown in Table 3. Descriptive statistics of the product variables used to measure the efficiency of federal institutes in Brazil in the years 2016 to 2019: intake × enrollment ratio (RIM), graduates × enrollment ratio (RCM), academic efficiency of graduates (EAC), student × teacher ratio (RAP) and faculty degree index (ITCD) are shown in Table 4.

Table 4 – Descriptive statistics of the variables RIM, RCM, EAC, RAP and ITCD of federal institutes in Brazil in the years 2016 to 2019

RIM	Average	Standard deviation	Coefficient of Variation	Maximum	Minimum
2016	33.80	10.40	30.70%	60.20	17.10
2017	35.60	9.16	25.70%	63.20	22.20
2018	38.60	7.66	19.80%	57.80	25.00
2019	40.80	9.94	24.40%	81.00	28.30
RCM					
2016	11.60	4.95	42.90%	26.50	3.70
2017	19.60	6.42	32.80%	35.30	8.72
2018	19.00	5.32	28.00%	31.20	8.54
2019	17.20	7.46	43.40%	48.10	7.65
EAC					
2016	45.70	9.38	20.50%	63.70	28.30
2017	47.20	11.80	25.00%	78.00	21.90
2018	51.60	11.00	21.40%	78.90	25.70
2019	52.90	10.00	18.90%	75.70	35.70
RAP					
2016	19.70	3.26	16.60%	25.40	12.30
2017	22.10	3.84	17.40%	32.20	15.10
2018	24.00	3.65	15.20%	32.20	17.40
2019	24.90	4.56	18.30%	40.60	16.50
ITCD					
2016	3.85	0.28	7.27%	4.23	3.03
2017	3.82	0.33	8.64%	4.28	2.96
2018	3.97	0.24	6.05%	4.33	3.44
2019	4.12	0.21	5.10%	4.44	3.66

Source: Prepared by the authors.

From the data obtained with the descriptive analysis, it is observed that the entrance × enrollment ratio presents an average result of 33.80 in 2016, rising to 40.80 in 2019, representing an increase of 20.7%. The result of this indicator denotes that the institutions analyzed presented a high rate of annual renewal of the student body, either by offering new courses or opening new places in existing courses. According to the data obtained for the research, the IFSP is the institution that has the highest average in relation to tickets x enrollment, reaching 50.40, while IFSUDESTEMG has the lowest average of the indicator (26.86 tickets per enrollment). Although there is no recommended target in relation to the RIM indicator, this index is an important guide for monitoring dropout rates throughout the student's educational path.

Hence, the results of the descriptive statistics indicate variation in the indicator ratio of graduates × enrollment (RCM). From the data obtained, the RCM indicator experienced an average growth of 69% from 2016 to 2017, showing a reduction in the following years. The ratio of graduates to enrollments presents an average result of 11.60 in 2016, rising to 19.60 in 2017, and loses strength in the following years: 19.00 graduates to enrollments in 2018 and 17.20 graduates to enrollments in 2019. According to data obtained for the research, IFRS is the institution that has the highest average in relation to graduates x enrollment, reaching 28.17, while IFPB has the lowest average of the indicator (8.35). It was also observed that 15 IFETs of the 38 institutions surveyed are above the general average in reference to the period analyzed.

The Academic Efficiency of Graduates (EAC) indicator shows a history of gradual growth between 2016 and 2019, corresponding to an average increase of 15.6% in the period analyzed. IFAP has the best average in the period analyzed, reaching 67.50 academic efficiency among graduates. The same institution, in 2016, had the EAC indicator at 52.92, compared to 78.92 in 2019, representing a growth of approximately 49%. On the other hand, IFMS has the lowest average EAC among the institutions analyzed, reaching 33.92. Even so, it is worth highlighting that the IFMS presents an annual evolution in the period analyzed, starting from an index of 28.29 in 2016 to 36.87 in 2019. It is noted that of the universe of 38 IFETs analyzed in this research, 44, 73% of them operate with academic efficiency above 50%.

The average number of student x teacher ratio (RAP) shows significant growth in the period analyzed, going from an average of 19.70 students per teacher in 2016 to 24.90 students per teacher in 2019, representing a 26% increase in the index. The result of this indicator shows that institutions that had a smaller number of students per teacher expanded the number of vacancies through new courses, optimizing the existing workforce. From the annual report of the management indicators of IFETs, it is noticed that some units significantly improved their performance in this indicator. As an example, IFSERTÃO had the lowest RAP among the IFETs analyzed in 2016, with 12.30

students per teacher. In 2019, the student x teacher ratio jumped to 24.19, representing an increase of 96.5%. IFSULDEMINAS presents the best average in the indicator, of 32.5 students per teacher in the period. However, it has the highest RAP in 2019, with a ratio of 40.6 students per teacher.

A goal for Federal Network institutions to "increase the ratio of students per teacher to 18 (eighteen), by using the credits and offering academic innovations that provide the acquisition of higher-level skills" (Brasil, 2014) was incorporated in Law #13,005, of June 25, 2014, which approves the National Education Plan (PNE). According to the data obtained, only IFG had not reached the target established for the student x teacher indicator. Despite experiencing growth between 2016 and 2018 (from 15.32 to 17.59), in 2019 the institution showed a reduction of approximately -7%, reaching a RAP of 16.49.

The faculty degree indicator (ITCD) shows growth in the analyzed period, with an upward trend from 2017 onwards. The index in 2016 presents an average of 3.85, closing the analyzed period in 2019 with 4.12, growth 7% on average. The improvement in the indicator may be related to the encouragement of these institutions to qualify their teaching staff, as well as the use of recruitment processes that involve hiring teachers with more advanced degrees. In this indicator, IFGOIANO presents the best ITCD average among the institutions analyzed (4.31). In contrast, IFAP has the lowest average teaching staff degree index (3.4). According to data from the annual report on IFET management indicators, in 2019, 85.33% of teachers in the Federal Network had a master's or doctorate degree, which highlights the high academic level of the teachers. The report also mentions the increase in the number of teachers with a Doctorate degree, demonstrating that the institution of the Knowledge and Skills Regime (RSC), by Law #12,772/2012, had not lowered the interest of Federal Network teachers in academic training (SETEC, 2020).

The frequency distribution of the efficiency scores generated from the application of the DEA-BCC method with product orientation is shown in Table 5.

Table 5 – Absolute distribution and percentage of IFETs by efficiency level between 2016 and 2019

Efficiency range	Cumulative frequency			
	2016	2017	2018	2019
1.00	1 (2.63%)	1 (2.63%)	1 (2.63%)	2 (5.26%)
0.90 – 0.99	0 (0.0%)	1 (2.63%)	1 (2.63%)	2 (5.26%)
0.80 – 0.89	0 (0.0%)	1 (2.63%)	1 (2.63%)	0 (0.0%)
0.70 -0.79	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
0.60 – 0.69	1 (2.63%)	1 (2.63%)	0 (0.0%)	4 (10.53%)
0.50 – 0.59	3 (7.90%)	6 (15.79%)	7 (18.42%)	3 (7.90%)
0.40 – 0.49	2 (5.26%)	4 (10.53%)	5 (13.15%)	6 (15.79%)
0.30 – 0.39	9 (23.68%)	9 (23.68%)	7 (18.42%)	9 (23.68%)
0.20 – 0.29	14 (36.85%)	11 (28.95%)	12 (31.57%)	9 (23.68%)
0.10 – 0.19	8 (21.00%)	4 (10.53%)	3 (7.90%)	3 (7.90%)
0.00 – 0.09	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

Source: Prepared by the authors.

It's noted that IFETs have their best performance in 2019, in which 2 institutions achieved 100% efficiency in the use of public financial resources. Still in 2019, it is possible to see that 4 IFETs have an efficiency greater than 90%, increasing the results obtained in 2017 and 2018 by 100%. In the overall context, 71% of the IFETs analyzed operate with an index below 50% in efficiency in the management of public financial resources. Although the results show that more than half of the institutions analyzed have efficiency scores between 30% and 70%, an evolution trend can be seen over the period analyzed. The descriptive statistics of the efficiency scores obtained in the research address this evolutionary perspective of Brazilian IFETs, as shown in Table 6.

Table 6 – Descriptive statistics of the efficiency scores of federal institutes between 2016 and 2019

Efficiency	Average	Standard deviation	Coefficient of variation	Maximum	Minimum
2016	0.3089	0.1736	56.19%	1.0000	0.1456
2017	0.3907	0.2013	51.52%	1.0000	0.1414
2018	0.3919	0.2029	51.78%	1.0000	0.1506
2019	0.4380	0.2272	51.88%	1.0000	0.1646
Overall average	0.3824	0.2069	51.40%	1.0000	0.1545

Source: Prepared by the authors.

It can be seen the evolution of the performance of the IFETs investigated over the period analyzed, considering the increase in the average efficiency of these institutions and those that have the minimum efficiency score. From the descriptive analysis, the heterogeneity of these institutions in relation to maximum and minimum efficiency results can be seen. When comparing the average efficiency score obtained by these institutions in 2019, an increase of 41.5% was observed in relation to 2016. In order to measure the level of relative efficiency of each IFETs analyzed, it was carried out a distribution of efficiency scores for each institution analyzed by year, as shown in Table 7.

Table 7 – Distribution of Brazilian federal institutes by efficiency level between 2016 and 2019

"to be continued"

| Federal Institute | Efficiency level | | | | | |
	2016	2017	2018	2019	Average	Classification
IFAP	1,000	1,000	1,000	1,000	1,000	1
IFAC	0.680	0.934	0.939	0.907	0.865	2
IFRR	0.590	0.826	0.875	1,000	0.823	3
IF SERTÃO	0.540	0.624	0.585	0.662	0.603	4
IFMS	0.542	0.577	0.581	0.695	0.599	5
IF SUL DE MINAS	0.366	0.511	0.510	0.910	0.574	6
IFB	0.455	0.556	0.525	0.571	0.527	7
IFRO	0.392	0.566	0.537	0.609	0.526	8
IFTM	0.387	0.521	0.555	0.545	0.502	9
IFS	0.309	0.514	0.509	0.518	0.463	10
IFTO	0.387	0.433	0.461	0.495	0.444	11
IFNMG	0.343	0.454	0.432	0.478	0.427	12
IF SUDESTE MG	0.321	0.435	0.467	0.466	0.422	13
IF FARROUPILHA	0.305	0.417	0.416	0.424	0.390	14
IF GOIANO	0.312	0.417	0.411	0.415	0.389	15
IFRS	0.227	0.306	0.293	0.641	0.367	16
IF BAIANO	0.302	0.329	0.361	0.457	0.363	17
IFC	0.265	0.341	0.338	0.337	0.320	18
IFMG	0.248	0.325	0.313	0.380	0.316	19
IFAM	0.251	0.305	0.300	0.386	0.311	20
IFF	0.239	0.312	0.319	0.344	0.304	21
IFRJ	0.238	0.322	0.330	0.317	0.302	22
IFAL	0.228	0.313	0.304	0.312	0.289	23
IFPR	0.238	0.300	0.299	0.295	0.283	24
IFSUL	0.219	0.291	0.304	0.305	0.280	25
IFG	0.210	0.278	0.287	0.294	0.267	26
IFMT	0.200	0.278	0.280	0.302	0.265	27

Table 7 – Distribution of Brazilian federal institutes by efficiency level between 2016 and 2019

"continuation"

Instituto Federal	Nível de eficiência					
	2016	2017	2018	2019	Média	Classificação
IFPA	0,244	0,267	0,242	0,262	0,254	28
IFPI	0,193	0,250	0,265	0,271	0,245	29
IFSC	0,219	0,223	0,220	0,281	0,236	30
IFPB	0,180	0,253	0,251	0,250	0,234	31
IFPE	0,179	0,247	0,246	0,249	0,230	32
IFRN	0,153	0,207	0,209	0,305	0,218	33
IFES	0,146	0,203	0,203	0,221	0,193	34
IFBA	0,161	0,194	0,208	0,207	0,193	35
IFMA	0,163	0,187	0,185	0,192	0,182	36
IFCE	0,146	0,189	0,182	0,181	0,175	37
IFSP	0,161	0,141	0,151	0,165	0,155	38

Source: Prepared by the authors.

The results obtained from the distribution of Brazilian federal institutes by level of efficiency between the years 2016 and 2019 allow classifying these according to the relative efficiency of managing public financial resources. The classification of IFETs follows the average efficiency score obtained in the analyzed period. Therefore, it is observed that IFAP appears as a benchmark for efficiency in the management of public financial resources. In this scenario, IFAP increased the number of vacancies offered over the years, which made it possible to increase its student x teacher ratio (RAP) and the new entrants x enrollment ratio (RIM). Classification allows other inferences to be made. Among the five most efficient institutions, IFAC was the only IFET that showed a reduction in efficiency from 2018 to 2019, even though it closed this year with an indicator above the historical average obtained in the period. Other institutions also showed a reduction in relative efficiency in the same period: IFTM, IFSUDESTEMG, IFC, IFRJ, IFPR, IFPB, IFBA and IFCE.

Among the institutions analyzed, some results are significant when considering the evolution of relative efficiency obtained over the years. The IFRR reached 100% efficiency in 2019, starting from a level of 0.590 in 2016. The increase in efficiency in the analyzed period reaches 41%. Even though it does not appear among the five best averages among the institutions analyzed, IFSULDEMINAS increases its efficiency score by 249%, going from 0.366 in 2016 to 0.910 in 2019. In percentage terms, IFRS presents the greatest growth compared to other IFETs, starting from an efficiency score of 0.227 in 2016 and ending 2019 with a score of 0.641, representing a 282% increase in efficiency.

It is also worth noting that the three lowest efficiency scores in relation to the 38 IFETs analyzed are, respectively, IFMA (average of 0.182), IFCE (average of 0.175) and IFSP (average of 0.155). According to data from the IFETs management report, these three units, in absolute numbers, stand out for the largest number of teachers among the institutions analyzed in this research. As such, an analysis of the factors associated with the relative efficiency of federal institutes estimated by Tobit regression is presented in sequence.

To analyze the factors associated with the efficiency of federal institutes, Tobit regression was estimated, considering panel data with random effects, with the dependent variable being the efficiency score generated through the product-oriented DEA method and which assumes variable returns to scale (DEA-BCC). The descriptive statistics of the independent variables, namely: (i) number of campuses (NCAMPI); (ii) number of students (QALN); (iii) number of teachers (QPROF); (iv) number of vacancies offered (QVAGAS); (v) school flow retention (RFE); and (vi) relationship between applicants and vacancies (RIV) are presented in Table 8.

Table 8 – Descriptive statistics of the independent variables used in the analysis of the efficiency of federal institutes, Brazil, 2016-2019

	YEAR	NCAMPI	QLAN	QPROF	QVAGAS	RFE	RIV
Average	2016	15.4	21612	862	7385	40.7	5.59
	2017	15.5	24942	1034	12015	11.9	4.75
	2018	15.6	23374	1073	10908	13.6	4.49
	2019	15.7	24986	1107	12341	15.3	4.65
Standard deviation	2016	7.34	12194	437	6307	9.18	2.98
	2017	7.23	13930	510	12298	5.51	2.35
	2018	7.27	12596	524	8557	4.46	2.16
	2019	7.29	15921	545	12092	5.71	2.47
Coefficient of variation	2016	47.8%	56.4%	50.6%	85.4%	22.6%	53.3%
	2017	46.6%	55.8%	49.3%	102.0%	46.3%	49.5%
	2018	46.6%	53.9%	48.9%	78.4%	32.9%	48.1%
	2019	46.3%	63.7%	49.3%	98.0%	37.4%	53.1%
Maximum	2016	38	55454	2326	36351	58.0	14.5
	2017	37	62355	2859	64639	27.3	10.3
	2018	37	61871	2955	42818	27.2	10.8
	2019	37	82916	3004	68620	29.6	12.1
Minimum	2016	4	4728	228	1628	20.3	1.86
	2017	5	4477	269	1351	4.12	0.87
	2018	5	5832	312	2300	6.51	1.33
	2019	5	5751	310	2763	5.25	1.34

Source: Prepared by the authors.

It was observed that the average number of campuses and number of teachers showed growth between the years 2016 and 2019. The increase in these indicators is aligned with the objectives contained in Law #11,892/2008, which establishes the Federal Professional Education Network, Scientific and Technological Institute and creates the Federal Institutes. It can be considered that the increase in current expenditure in the period analyzed corresponds to government efforts to strengthen IFETs, as well as enabling an increase in the supply of services and consolidation of planned campuses.

The disparity between the IFETs analyzed in terms of their structure should be highlighted. In 2019, the IFSP had 37 campuses, while the IFRR had only 5 ones. Several factors influence this number, whether looking at the geographic dimension of the state or even the regional population of each of these locations. However, the number of teachers is proportional when these two IFETs are analyzed, and in 2019 the IFSP had 3,004 teachers on its staff compared to 310 teachers at the IFRR.

The annual reports on IFET management indicators provide data that indicate different performances in this indicator in relation to some analysis units. This is the case of IFMT, which has an average RIV of 2.05 when considering the period between 2016-2019. Although IFMT has the lowest average RIV among IFETs, it gradually increased between 2017 and 2019, indicating that the institution has invested in improving the indicator. The highest average in relation to the indicator registered x vacancies belongs to IFPA (11.54 registered per vacancy). It is worth noting that in 2016, IFPA had a RIV of 14.5. In the following years, the indicator lost strength, closing the years 2017 and 2018 respectively, with 9.78 and 9.91 applicants per vacancy. Despite an improvement in the indicator in 2019 (11.99 applicants per vacancy), IFPA fell short of the best mark achieved in 2016.

Although the average RIV of IFETs has declined, it should be noted that this occurrence is based on the growth of the two variables presented in the indicator, as the volume of subscribers increased from 1,793,409 to 1,981,376 (an increase of 10.48%) and the volume of vacancies jumped from 428,695 to 486,288 (an increase of 13.43%). Therefore, it noticeable that the number of vacancies grows at a faster pace than the growth in the number of applicants, according to the annual reports of IFET management indicators. Corroborating this, we can associate this context with the improvement of indicators such as RAP and RIM.

There is a relationship between the variations in the period analyzed when observing the number of students and the number of vacancies. Both indices showed growth between 2016 and 2017, but both suffered a reduction in 2018 (-6.3% and -9% respectively). The indicators, as well as RFE and RIV, recovered in 2019, demonstrating that the period analyzed was marked by a resumption of vacancies and an increase in the number of enrollees and retention and success strategies as ways of controlling evasion. As shown in Table 9, it is possible to view the coefficients estimated by the model.

Table 9 – Factors associated with the efficiency of federal institutes, Brazil, 2016-2019

Variable	Coefficient	Standard Error	Z	P>|z|	Confidence Interval 95%	
NCAMPI	-0.006190	0.00434	-1.427	0.1537ns	-0.0146937	0.0023145
QALN	-0.000001139	0.00000	-0.625	0.5322ns	-0.0000047	0.0000024
QPROF	-0.0002794	0.00007	-4.231	<0.0001***	-0.0004088	-0.0001500
QVAGAS	0.000006122	0.00000	3,349	0.0008***	0.0000025	0.0000097
RFE	-0.003967	0.00089	-4,480	<0.0001***	-0.0057032	-0.0022317
RIV	0.007467	0.00437	1,709	0.0875ns	-0.0010976	0.0160310
Intercept 1	0.77060	0.03500	22,016	< 2e-16***	0.70196	0.83916
Intercept 2	-2.07700	0.05869	-35,392	< 2e-16***	-2.19200	-1.96195
Rho (ρ)	0.8054					
R2	0.6486					
χ^2	88,126					

Note: Dependent variable: efficiency scores of Brazilian federal institutes, measured using the DEA-BCC with product orientation, Independent variables: number of campuses (NCAMPI), number of students (QALN), number of teachers (QPROF), number of vacancies (QVAGAS), RFE (RFE) and applicants × vacancies ratio (RIV), *: significant at 5% probability; **: significant at 1% probability; ***: significant at 0.0001% probability; Rho (ρ): Linear correlation coefficient; R2: coefficient of determination. ns: not significant at 5% probability.

Source: Prepared by the authors.

According to Scott Long (1997), Tobit regression coefficients are interpreted in the same way as simple linear regression coefficients. However, the linear effect is on the uncensored latent variable, not the observed outcome. For an increase of one unit in the efficiency score, there was a specific decrease in the predicted value of the number of teachers (-0.0002794) and the same occurred for the RFE variable (-0.003967). An increase of one unit is associated with a unit increase in the predicted value of the number of students (0.000006122). The Intercept 1 coefficient is the intercept or constant of the model and the Intercept 2 coefficient is an accessory statistic. The chi-square test (was 88.126 with 296 degrees of freedom, indicating a good fit, as demonstrated by the model residual analysis, described in Figure 1.χ^2).

Figure 1 – Residual analysis of the Tobit regression model for efficiency score data from federal institutes
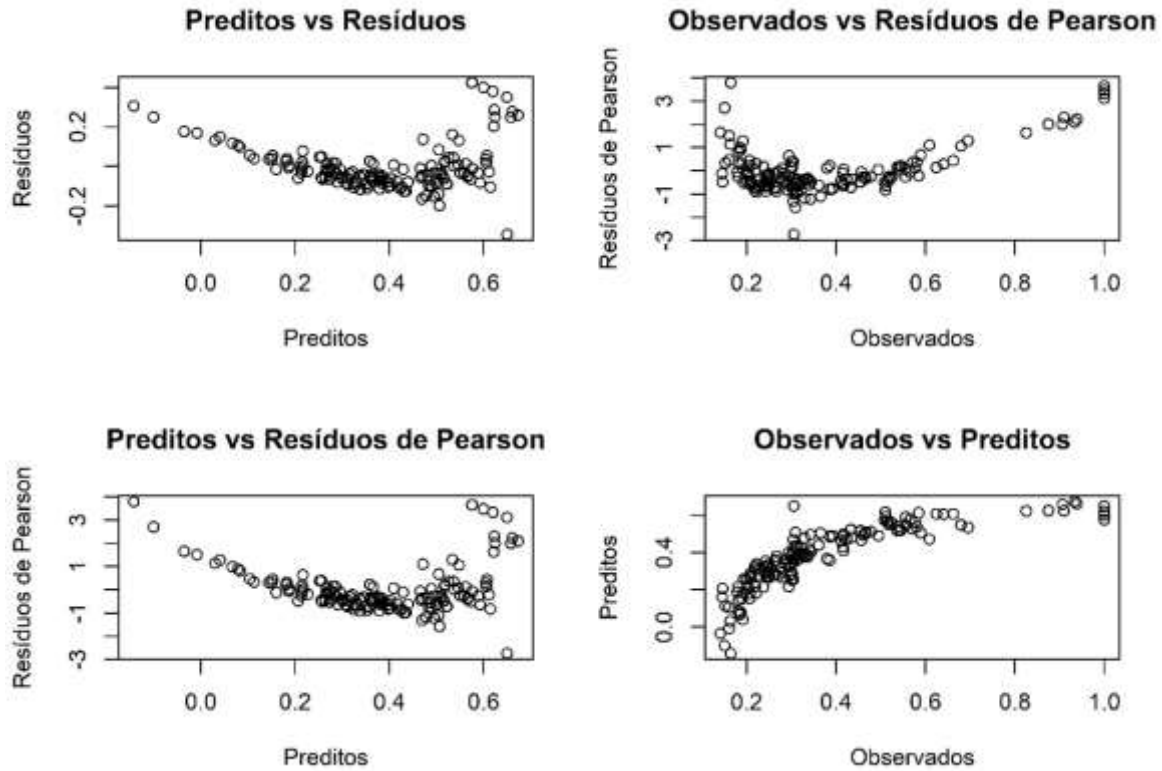
Source: Prepared by the authors.

The correlation between the predicted and observed values is 0.8054. The coefficient of determination is 0.6486, indicating that the efficiency score of federal institutes (dependent variable) is explained by 64.86% by the independent variables number of campuses (NCAMPI), number of students (QALN), number of teachers (QPROF), number of vacancies (QVAGAS), school flow retention (RFE) and relationship enrolled × vacancies (RIV) of federal institutes in Brazil in the years 2016 to 2019.

5 Final considerations

The research sought to measure and identify the factors and determinants of the relative efficiency of the management of public financial resources at the Brazilian Federal Institutes of Education, Science and Technology in the four-year period 2016-2019. In general, it can be considered that the level of relative efficiency of IFETs in relation to the management of public financial resources potentially operated below expectations, revealing that only fifteen of the thirty-eight institutions analyzed have above-average performance. Institutions are very heterogeneous, especially if we consider the variables related to the number of teachers and students, number of campuses and availability of places.

The study observed that institutions with the largest number of teachers have the lowest efficiency scores. The increase in the number of teachers over time in these units did not contribute to an improvement in the student x teacher ratio indicator. This scenario is consistent with the fact that these institutions do not increase the number of vacancies and courses in proportion to the number of teachers. From this perspective, it can be considered that these units have become less efficient because they spend more on teaching costs.

The institutions that presented the best efficiency scores had at the beginning of the analyzed period, lower numbers of students per teacher and gradually expanded the offer of vacancies through new courses, optimizing the existing workforce. It is worth noting that these institutions are concerned with the qualification of the teaching staff, which was the most homogeneous indicator among the variables analyzed.

The Federal Government's commitment to maintaining investment and expanding the activities of these institutions stands out, considering that the current expenditure of IFETs, compared year to year during the period analyzed, was greater than the inflation recorded in the period. The contribution of public financial resources by the Federal Government to the IFETs during the period analyzed indicates that current expenditure had an accumulated growth (24.90%) proportionally greater than the accumulated inflation in the same period (18.41%) as data from IBGE (IBGE, 2022).

Still, it is important to highlight that with the approval of Constitutional Amendment #95, of December 15, 2016, which amends the Transitional Constitutional Provisions Act to establish the New Fiscal Regime, and provides other measures (Brasil, 2016), growth of Brazilian government expenditure has been limited for 20 years. When envisioning a scenario motivated by the growth of enrollments in IFETs and the maintenance of the Federal Government's investment standard, it will become necessary to discuss new forms of complementary financing to guarantee the provision of public services provided by these institutions.

Data Envelopment Analysis (DEA) originates from work aimed at evaluating efficiency in educational institutions and it was developed in the 1970s by Charnes, Cooper and Rhodes. Since then, DEA has been used to evaluate the productive efficiency of educational units. Even so, as it is a relative measure of performance, the efficiency scores obtained by IFETs during the period analyzed in the research are calculated in comparative terms. Thus, the results indicate great heterogeneity between the institutions analyzed. It is also worth highlighting that as it is a relative measure of performance, it cannot be said that the best results observed represent, in fact, efficiency.

As limitations of the research, the lack of availability of data that would provide better adjustment of the model and, consequently, less incomplete measures of efficiency stand out. The management reports analyzed in the period do not present information regarding the number of courses and their characterization in terms of degree (technical, undergraduate, advanced training or postgraduate) or area of knowledge. Thus, it would be possible to discuss the objectives recommended in Law #11,892 that created the IFETs, as an index of verticalization of education and relationship with the training of professionals to work in local productive arrangements (APL).

The evaluation of IFETs needs to be improved, including qualitative efficiency indicators related to their social objective, mainly related to monitoring graduates, measuring the employability of graduating students. However, it is worth highlighting SETEC's efforts with the creation of Nilo Peçanha Platform (PNP) in 2018. The PNP is a virtual environment for collecting, validating and disseminating statistics from the Federal Network, with information about the units that comprise it. The platform is powered by the Statistics Collection, Validation and Dissemination Network (REVALIDE), based on the qualification of data collected, initially, from the National Information System (SISTEC), the Integrated Human Resources Administration System (SIAPE) and the System Integrated Financial Administration of the Federal Government (SIAFI). Other indicators focused on intellectual production, patents and development of other technologies should be incorporated into these reports.

As suggestions for future studies, the research carried out can be expanded in terms of temporal space (analyzing longer periods, comparing indicators leading up to the Federal Network expansion project), crossing data with regional social indicator variables such as Gross Domestic Product (GDP), Human Development Index (HDI), literacy rates, employment and income generation, among others.

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