RELATIVE EFFICIENNCY OF BRAZILIAN FEDERAL UNIVERSITIES IN TEACHING, RESEARCH AND EXTENSION ACTIVITIES

Franciane de Oliveira Alvarenga [1]
Pierre Ohayon [2]

▪ Received: 14/01/2020 ▪▪ Approved: 30/04/2020 ▪▪▪ Second Approved Version: 17/07/2021

ABSTRACT

This study aimed to evaluate Brazilian Federal Universities' relative efficiency in teaching, research, and extension activities. Evaluations of efficiency and productivity are crucial since these activities promote socio-economic growth and are funded with public resources. This descriptive, longitudinal, and quantitative research adopted data envelopment analysis to examine 34 Brazilian federal universities between 2013 and 2017. The results showed that 2014 was the worst, and 2016 was the best year regarding efficiency levels for teaching activities, and nine universities were 100% efficient in these activities in the period examined. As for research activities, the results showed that nine universities were 100% efficient in the period; 2014 was the year with the lowest levels of efficiency, and 2017 the year with the best. Finally, results for extension activities show that universities have more difficulties to be fully efficient. Only three universities were considered 100% efficient, with 2014 as the year that universities had the best efficiency levels and 2017 the worst year. Only the Federal University of Minas Gerais and the Federal University of Health Sciences of Porto Alegre perfectly fulfilled their mission by showing total efficiency in all teaching, research, and extension activities during the period studied.

Keywords: Data Envelopment Analysis. Federal Universities. Teaching, Research, and Extension. Relative efficiency.

[1] Doutora em Ciências Contábeis pela Universidade Federal do Rio de Janeiro – UFRJ, Professora na Universidade Federal de São João del-Rei – UFSJ. Endereço: Av. Prefeito Lourival Gonçalves de Andrade, 1407, Vila Belizário, São João del-Rei- MG, Brasil, CEP 36.307-161. Telefone: (32)98840-0090. E-mail: francianealvarenga@ufsj.edu.br
http://orcid.org/0000-0002-4008-1429

[2] Doutor em Administração pela Universidade de São Paulo – USP, Professor na Universidade Federal do Rio de Janeiro – UFRJ. Endereço: Av. Borges de Medeiros, 3535 apto 902, Lagoa, Rio de Janeiro-RJ, Brasil, CEP 22.470-00. Telefone: (21)99919-8025. E-mail: pohayon@facc.ufrj.br
https://orcid.org/0000-0002-2209-0006

EFICIÊNCIA RELATIVA DE UNIVERSIDADES FEDERAIS BRASILEIRAS NAS ATIVIDADES DE ENSINO, PESQUISA E EXTENSÃO

RESUMO

Objetivou-se avaliar o nível de eficiência relativa de Universidades Federais Brasileiras nas atividades de ensino, pesquisa e extensão, uma vez que elas impulsionam o crescimento socioeconômico, fazendo-se necessário que os gastos públicos sejam feitos de forma eficiente, atentando-se à produtividade. Para isso, utilizou-se a técnica Análise por Envoltória de Dados. A pesquisa é caracterizada como descritiva e de abordagem quantitativa, sendo composta por 34 universidades federais brasileiras, adotando-se uma análise longitudinal entre os anos de 2013 e 2017. Para as atividades de ensino, observou-se que nove universidades apresentaram eficiência total ao longo do período analisado, sendo que 2014 foi o ano que apresentou os piores níveis de eficiência e 2016 o melhor. Já para as atividades de pesquisa, os resultados apontaram que nove universidades foram 100% eficientes ao longo do período de análise, apontando que 2014 foi o pior ano (com menores níveis de eficiência) e 2017 o melhor. Por fim, em relação às atividades de extensão, os resultados mostram que as universidades têm mais dificuldades para se manterem totalmente eficientes, visto que apenas três universidades são consideradas 100% eficientes em relação ao grupo de análise nos anos compreendidos, apontando que 2014 foi o ano que as universidades tiveram melhores níveis de eficiência e 2017 o pior ano. Sabendo que a missão das universidades é realizar atividades de ensino, pesquisa e extensão, observou-se que apenas a Universidade Federal de Minas Gerais e a Universidade Federal de Ciências da Saúde de Porto Alegre se mantiveram 100% eficientes em todas as atividades em conjunto e nos anos analisados.

Palavras-Chave: Análise por Envoltória de Dados. Universidades Federais. Ensino, Pesquisa e Extensão. Eficiência Relativa.

1 INTRODUCTION

The analysis of organizations' efficiency directly affects their managers' practices and decision-making processes. The study of financial and non-financial variables allows to define the level of efficiency and to verify the path that led to the observed results, thus offering the opportunity for improvement. According to Dufrechou (2016), the most efficient public institutions alleviate budget constraints by achieving the same outcomes with fewer resources or more outcomes with the current investments.

Among the government's various social obligations, those related to education represent the most efficient social, economic, and environmental development policies. For Sonje et al. (2018), investments in education are crucial to form human capital and promote economic growth. Also, public spending, particularly in education and health, decisively contributes to the economy, generating positive externalities such as increased productivity, job creation, and technological innovation (Cândido Junior, 2001).

The focus on the government's efficiency in Brazil started in 1980 because of the scarcity of resources and the increased demand for social policies. In 1995, the country went through a managerial reform, stressing efficiency, effectiveness, and transparency in the use of public resources. From this moment, studies on the correct allocation of public resources and society's economic and social development gained prominence (Bresser-Pereira, 1999; Marini & Martins, 2004; Petrucci & Schwarz, 1999).

For Martos (2013), efficiency presupposes the budget's elaboration in the right measure to adequately meet public needs. It means that revenues and expenditures are rationally optimized in the best way possible. Arretche (1999, p. 35 our translation) also believes that efficiency is urgent and necessary in public administration, stating that "the scarcity of public resources requires greater rationalization of spending." Thus, successful government spending means the rational use of resources to guarantee society's fundamental rights through equal access and effective service provision.

The federal universities (FUs) object of this study are part of the Brazilian federal higher education institutions. They are among the several government agencies and organizations responsible for defining and implementing public policies and actions for education. These federal institutions are fundamental public entities that contribute to the country's social and economic development by producing and transmitting knowledge that leads to advances in social, cultural, economic, educational, technological, and moral dimensions.

The federal higher education institutions are nonprofit public organizations. Therefore, assessments based on prices, costs, and investments are replaced by other approaches considering multiple resources and multiple outcomes that cannot be reduced to a regular measurement unit (Ahn, 1987). The institutions use public resources to provide quality education, research, increase and generate knowledge, and engage in community life through extension activities, contributing to the local populations' development.

The institutions' teaching, research, and extension activities follow the principle of inseparability, established in article 207 of the 1988 Brazilian constitution (Brasil, 1988). Therefore, these activities may be understood as functions by which the organizations meet their mission "to prepare or teach, explore or research, and serve or perform extension activities" (Ospina, 1990, p. 138 our translation). These three functions guide their specific budget, contributing to human capital development, and reducing asymmetries in Brazilians' quality of life.

According to Castano and Cabanda (2007), measuring a public organization's efficiency can be done by comparing its performance with similar organizations in the private sector and with international standards. The evaluation of FUs' efficiency and management is crucial to identify whether they fulfill their social role.

This study recognizes the FUs' relevance in the scenario of education in Brazil and aims to evaluate these institutions' relative efficiency in teaching, research, and extension activities. This issue is essential since managers are required to work efficiently, so a potential reduction of resources designated to FUs does not cause demotivation or implications to the outcomes these institutions generate for society.

This study seeks to contribute practically and methodologically to public finances, enabling managers to improve the use of public resources. The research focuses on analyzing and discussing the relationship between resource management efficiency and FU's performance in teaching, research, and extension activities.

Another contribution of this research lies in adopting the data envelopment analysis (DEA) methodology to separately evaluate the universities' teaching, research, and extension activities. DEA allows verifying whether and to what degree the activities are efficient when isolated or if they are efficient only when combined. The method also allows observing if the activities satisfactorily meet the needs of society.

According to current legislation, the tripod formed by teaching, research, and extension is the fundamental axis of Brazilian universities and cannot be segmented. Decree 3860/2001 states that federal higher education institutions are characterized by regularly offering teaching, research, and extension activities, following the principle of inseparability (Brasil, 2001).

According to Santos (2004, p. 31, our translation), this tripod is a catalyst for "*pluriversity*" knowledge, allowing "the insertion of the university in society and the insertion of society in the university." Castro (2004) corroborates this position, arguing that the history of the inseparability of teaching, research, and extension is based on the relationship between scientific knowledge and social demands.

Thus, university education encompasses the transmission of knowledge in the classroom and pure or applied research and extension, which is the objectification of research. These three activities represent the essential values to preserve the university as an agent of transformation and transmutation.

Pivetta et al. (2010) highlight the relevance of the three activities and their relationship, mentioning their complementarity and interdependency. The three activities must be recognized as equally important in the university system, at the risk of developing deficient and reductionist knowledge. In addition, they are crucial to the quality and success of students trained in these institutions. The appropriate training depends, to a large extent, on the level of interaction and connection among these three activities, which are pillars of both unidimensional and multidimensional knowledge. Therefore, it is difficult to conceive a successful university student without the influence of a systemic, expanded, and integrated qualification offered through teaching, research, and extension.

Studies such as Corbucci (2000), Belloni (2000), Oliveira and Turrioni (2006), Costa et al. (2010), Nuintin (2014), Curi (2015), Gomes (2016), and Moreira (2018) also used the DEA methodology to evaluate FUs efficiency, and are used as a reference for this research. However, none of these authors studied the efficiency of management regarding the FUs' social role, i.e., evaluating the universities' efficiency when pursuing their mission through teaching, research, and extension activities, as explored in this study.

2 THEORETICAL FRAMEWORK

2.1 Efficiency at Federal Universities

Evaluation of the public sector's efficiency is a fundamental practice, and public managers must adopt it to guarantee that public resources turn into quality services and improvement of the population's social indicators.

The essence of the concept of efficiency in the public sector is the same as in the private sector. For an action to be efficient, it has to require fewer resources or optimize the existing resources in three ways (Gomes, 2010): spend only what is necessary, use efficient equipment and resources, and combat waste and improve the use of resources.

The principle of efficiency was expressly introduced in the caput of article 37 of the 1988 Brazilian Constitution, through constitutional amendment 19/1998, which dealt with the principles and norms of public administration, to impose control over finances and direct the search for managerial efficiency for effective public management (Brasil, 1988).

Fuentes et al. (2016) mention that higher education's efficiency is crucial for the countries' development and growth. Specifically, human capital and knowledge creation are fundamental factors for national economies that must compete at the international level.

For Baracho (2000), the analysis of public sector efficiency comprises the following aspects: (i) analysis of the service rendered or good purchased or sold, concerning its cost; (ii) analysis of the yield considering a previously established benchmark or standard; (iii) recommendations to improve the yield gained and criticisms of outcomes obtained.

Tavares et al. (2011) emphasize that, in Brazil, the evaluation of higher education has been gaining strength and has focused on government plans given the country's integration into the world scenario. This is due to the new conception of the state's power and role in the globalization model that appears as an option to face the capital accumulation crisis. The authors claim that this relationship constitutes a minimal state with its political, legal, and ideological organizations in the field of social rights, such as education.

Meyer Júnior (1993) adds that evaluation is an important and necessary management tool in universities, making it possible to measure their efforts, their quality, excellence, usefulness, and relevance, to implement new procedures and strategies.

Lapa and Neiva (1996) classify the most common criteria for evaluating FUs into two groups: performance criteria (such as productivity, efficiency, efficacy, and effectiveness) and quality criteria (usefulness and relevance).

Corbucci (2007) corroborates the importance of the evaluation, recognizing the complexity of assessing higher education institutions' quality and efficiency. Although some authors use performance indicators in their studies, even if indirectly, they intend to build an idea of what could be called quality teaching. The use of indicators is an advantageous approach since it allows comparing the institutions' performance.

Accordingly, Lapa and Neiva (1996) emphasize that quality is assessed based on usefulness or relevance, and judging quality considers political views of value.

Dufrechou (2016) shows that the most efficient public institutions circumvent budget restrictions, achieving the same results with fewer resources, or improving the results of current investments.

In Brazil, FUs and other federal higher education institutions are audited by the Federal Court of Accounts (TCU), responsible for assisting in the external control of the federal government's accounting, financial, and budgetary supervision. Cruz (2004) notes that the TCU conducts accounting, financial, budgetary, operational, and equity audits, evaluating performance in different modalities. TCU also supervises the correct use of public resources, evaluating managerial aspects, such as efficiency, efficacy, effectiveness, and economy in using resources.

For Oliveira and Turrioni (2006), the TCU's evaluation does not clearly portray the real performance and needs of federal higher education institutions. However, this evaluation is still the best tool for analyzing performance and efficiency.

TCU uses nine indicators to assess these institutions (TCU, 2006) and prepares a report assessing their management in order to fulfill the regulation (Decisão 408/2002/TCU). The indicators are: current cost/equivalent student; full time student/equivalent faculty; full time student/equivalent staff; equivalent staff/equivalent faculty; student's participation rate; graduate-level student's engagement rate; graduate programs' CAPES/MEC classification; faculty qualification index; and graduation rate (TCU, 2006, p. 4, our translation).

When establishing these indicators to be collected and disclosed by higher education institutions, TCU (2006) sought to identify if they were meeting three essential requirements. In their annual report, the institutions have to demonstrate to be operationally verifiable; they need to be comparable with others; they have to be able to display the academic reality adequately.

Thus, institutional reports allow TCU to monitor the management, efficiency, and results from universities, favoring the creation of public policies and the allocation of public resources, thus impacting education and, consequently, social development.

2.2 Data Envelopment Analysis – DEA

DEA is a technique based on linear programming to calculate the relative efficiency of the units. It was introduced by Charnes et al. (1978) based on the studies of Koopmans (1951), Debreu (1951), and Farrell (1957). The emergence of the term and the popularization of the use of linear programming to design and compare efficiencies occurred after the work by Charnes et al. (1978) *Measuring the efficiency of decision making units*, published in 1978, in the European Journal of Operational Research (Daraio & Simar, 2007; Ferreira & Gomes, 2012; Lins & Meza, 2000).

This technique evaluates the relative efficiency (comparing with benchmarks) of a sample of decision-making units (DMUs). Examples of DMUs are private companies; public, financial, and nonprofit institutions; and internal departments or sectors. Due to its flexibility in the evaluation process, DEA has a broad base of practical use in different segments. Revilla et al. (2003) and Hsu & Hsueh (2009), for example, studied the use of DEA to evaluate government programs.

Thus, the DEA allows comparing the performance of an objective DMU with others. The technique measures the relative efficiency of the units to envision performance improvement.

Kozyreff Filho and Milioni (2004) state that the DEA's goal is to compare several DMUs that perform similar tasks and differ in the quantities of inputs they consume and the outputs they produce. Once the set's efficiency is determined, the most efficient DMUs can mark the inefficient ones, used as a reference in the establishment of goals to improve performance. This efficiency is called relative efficiency.

The DEA analysis measures the relative efficiency of each unit based on the best performances observed. Therefore, efficiency will be specific according to the study's variables and the group in which the DMU is inserted. The best performances determine the production's frontier, constituting limits to the achievable outcomes using a given set of resources. Thus, a unit's efficiency indexes are measured from its relative position from the frontiers. Each result is interpreted as a description of its determining skills and objective restrictions, assuming that the unit's outcomes will increase when circumventing restrictions and expanding skills (Lapa et al., 1997).

According to Avkiran (2001), this analysis allows public policy managers and university leaders to better allocate available resources and improve productivity.

According to Wen-Chih et al. (2012), the DEA allows to individually optimize each observation, one in relation to the others, thus forming an efficiency frontier. According to the Pareto-Koopmans concept, this efficiency frontier is defined by the maximum level of production for a given level of input. The units operating at the frontiers are classified as efficient and the others as inefficient. The efficiency index is calculated according to the projection of inefficiencies in relation to the frontiers. Two forms of projection are used in the classical models: the input minimization models (which calculate the maximum reduction of inputs to produce the same outputs) and the output maximization models (which calculate the maximum expansion of outputs produced with a given input).

Thus, according to Colin (2007), DEA allows (1) the identification of the most efficient DMUs, (2) the distinction of the least efficient DMUs compared to the most efficient ones in a group, (3) the diagnosis of inputs unproductively used, and (4) recognizing DMUs with best practices as benchmarks.

In mathematical terms, the DEA calculates efficiency by the ratio of a weighted sum of outputs to a weighted sum of inputs. The weight for each weighting factor (inputs and outputs) is obtained by solving a fractional programming problem, in which each unit analyzed maximizes its efficiency (Mello et al., 2003).

The weights for input and output variables of the general DEA model can be obtained from the model solution proposed by Charnes et al. (1978), according to the following equations:

$$\max E_j = \sum_{r=1}^{s} u_r . y_{r0} \Big/ \sum_{i=1}^{m} v_i . x_{i0}$$

That is:

$$\left(\sum_{r=1}^{s} u_r y_{rj} \middle/ \sum_{i=1}^{m} v_i x_{ij} \right) \leq 1, \;\; j = 1,2,\ldots,n$$

$$u_r \geq 0, \quad r = 1,2,\ldots,s$$

$$v_i \geq 0, \quad i = 1,2,\ldots,m$$

where DMU_0 is the DMU under analysis; y_{r0} and x_{io} the output and input data for the DMU_0; *j* the DMU index, *j* = 1 ..., *n; r* the output index, with *r* = 1, ..., *s; i* the input index, *i* = 1, ..., *m*; y_{rj} the value of the *r*-umpteenth output for the *j*-umpteenth DMU; x_{ij} the value of the *i*-umpteenth input for the *j*-umpteenth DMU; u_r the weight associated with the r-umpteenth output; and v_i the weight associated with the *i*-umpteenth input. Note that: if E_j = 1, DMU_0 is efficient when compared to the other units considered in the model, and if $0 \leq E_j < 1$, DMU_0 is inefficient.

According to Silva et al. (2012), DMUs that are considered efficient will have a coefficient of 1% or 100%, called the Pareto-efficient frontier (PEF). The only constraint of the technique is that the DMU is within or at the efficiency frontier.

Mello et al. (2005) point out that the efficiency estimated by the DEA is a quantity linked to the quotient between a weighted sum of outputs and a weighted sum of inputs. To prevent arbitrary weights (eliminating the analysis's subjectivity), the method allows each analyzed organization to choose the most appropriate weights, that is, those that maximize this ratio. However, this cannot be done entirely freely since the result has to be *an efficiency*, i.e., a number between 0 (zero) and 1 (one). The following equation presents the mathematical programming:

$$\text{Maximizing } \frac{uY_0}{vX_0} \text{ subject to } \frac{uY_k}{vX_k} \leq 1, \text{ for all K}$$

where *u* are the weights assigned to the outputs of company O, *Y* are the outputs of company O, *v* are the weights assigned to the inputs of company O, *X* are the inputs of company O, and *K* represents the number of companies. Thus, the weights that a company chooses, when applied to itself and to the others (in the total of *k* companies), cannot give a higher quotient to the unit. This restriction is applied as many times as the number of companies. It is a restriction for each analyzed company.

Charnes et al. (1978) expanded used multiple inputs and outputs to expand their studies, creating the CCR model (named after the authors). The model considers constant returns to scale at the frontier; therefore, it is also known as *constant returns to scale* (CRS). This model allows an objective assessment of the overall efficiency and identifies the sources and estimates of amounts of the identified inefficiencies (Casa Nova, 2002).

> The essential characteristic of the CCR ratio construction is the reduction of the multiple-output-multiple-input situation (for each DMU) to that of a single "virtual" output and a single "virtual" input. For a DMU, the ratio of this single virtual output to a single virtual input provides a measure of efficiency that is a function of the multipliers. This ratio, which is to be maximized, forms the objective function for the particular DMUo being evaluated (Charnes et al., 1994, p.40).

Coelli et al. (2005) express the model:

MIN $\theta,\lambda\ \theta$

Subjected to: $-y_i + Y\lambda \geq 0$

$\theta x_i - X\lambda \geq 0$

$\lambda \geq 0$

where θ is the efficiency score of a given DMU; y is the output of the DMU, and x is the input. X is the input matrix (n × k), and Y is the output matrix (n × m); λ is the vector of constants that multiplies the matrix of inputs and outputs.

In 1984, Banker et al. (1984) created a new DEA model to eliminate the need for constant returns to scale, the BCC model or variable returns to scale (VRS). In this model, the variable returns are those that can assume increasing and decreasing returns to scale. For Casa Nova (2002), this model distinguishes between technical and scale inefficiencies, estimating pure technical efficiency at a given scale of operations, and identifying the presence of increasing, decreasing, or constant returns to scale to be explored in the future.

For Gomes & Baptista (2004), a DMU operates with constant returns to scale when the scale efficiency score is equal to 1. However, if the scale efficiency measure is less than the unit, increasing or decreasing returns to scale may occur. In this case, the technical efficiency scores should be compared in the model with non-increasing returns and in the model with variable returns, so that, if these values are different, the DMU will have increasing returns to scale, and, if they are identical, it will have decreasing returns to scale.

According to Coelli et al. (2005), the BCC model can be represented as follows:

MIN $\theta,\lambda\ \theta$

Subjected to: $-y_i + Y\lambda \geq 0$

$\theta x_i - X\lambda \geq 0$

$N_1\lambda \geq 0$

where N_1 is a vector ($N \times 1$) of unit numbers.

Marinho and Cardoso (2007) offer a hypothetical example of building efficiency frontiers using two DEA models (Figure 1). The authors indicate that the CCR model admits an efficiency frontier with constant returns to scale, that is, a straight line passing through the origin of the Cartesian axes; and the BCC model admits variable returns to scale.

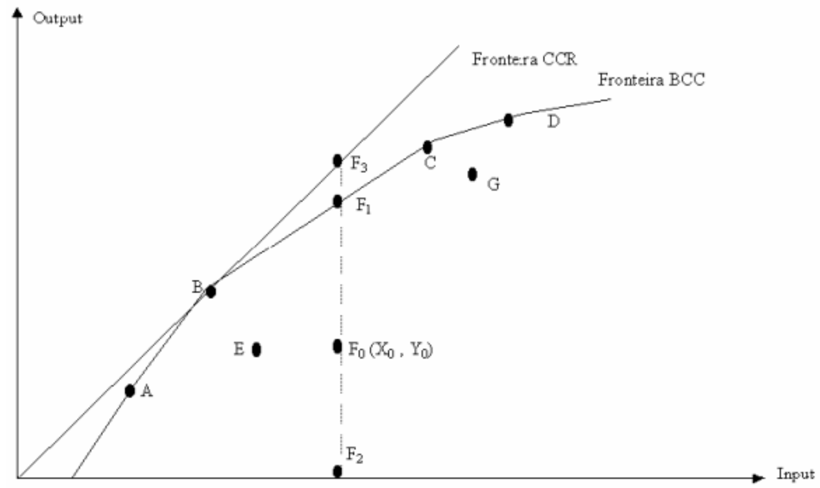

Figure 1 – Efficiency frontiers – CCR and BCC models
Source: Marinho and Cardoso (2007, p. 17)

As shown in Figure 1, Marinho and Cardoso (2007) mention that the alleged units A, B, C, D, and F1, located on the BCC model's frontier, are efficient in this model. The F3 unit is efficient in the CCR model, but it would not be part of the sample analyzed in the BCC model, as no unit can be located above the efficiency frontier of any model. Units E, F0, F2, and G are not efficient in either model, as they are located below the frontiers. For example, according to the CCR model, the F0 unit could expand its output up to the production level of the F3 unit, without increasing the use of inputs set at the same level as the F2 unit.

Both the CCR and the BCC models can be analyzed from the input-oriented or output-oriented perspectives. Haynes and Dinc (2005) mention that the DEA technique can be both input and output-oriented. The input-oriented model seeks to maximize the proportional reduction in input variables while keeping the output level constant. On the other hand, the output-oriented model maximizes the proportional increase of the output variables while maintaining the same level of inputs.

According to Gomes & Baptista (2004), the choice of orientation does not have a great influence on the magnitude of the technical efficiency value, and the choice criterion will depend on the purpose of the study, that is, whether the objective is to regularize the consumption of inputs or enable the increased output.

In this context, the implementation of the DEA technique establishes three main phases (Golany & Roll, 1989): 1) definition and selection of DMUs to be analyzed; 2) selection of relevant and appropriate variables (inputs and outputs) to establish the efficiency of the selected DMUs and 3) application of DEA models.

This research differs from others using the DEA methodology. It seeks to analyze the relative efficiency from the point of view of the FUs' mission, focused on the tripod: teaching, research, and extension activities.

3 METHODOLOGY

3.1 Typology

This descriptive and quantitative research uses DEA and descriptive statistical techniques to assess the relative efficiency of Brazilian federal universities (FUs) in teaching, research, and extension activities. The study sought to reveal and interpret the FUs' reality identifying their specific characteristics and indicators, classifying and explaining phenomena observed in these institutions.

The research is classified as non-experimental and positivist since the researched phenomenon is considered in its natural state (Bertassi, 2016).

Data and indicators from the studied FUs were extracted from documentary and ex-post-facto research. For Marconi and Lakatos (2007), the main characteristic of documentary research is that the data collection's source is restricted to documents, and the investigation is conducted at the time or after the events.

The research did not use random forms of selection. It adopted non-probabilistic intentional sampling, gathering the FUs that fit the established research criteria (Marconi & Lakatos, 2007).

Data envelopment analysis (DEA) was used to infer the relative efficiency of FUs in teaching, research, and extension activities, as well as their evolution, and checking the weight of the selected variables.

3.2 Procedures, data collection techniques, and period of analysis

Data were extracted from federal universities' annual management reports. The documents were available online or were requested to the federal ombudsman, through the Electronic System of the Citizen Information Service (e-SIC), based on the Brazilian freedom of information law 12527/2011 (Brasil, 2011).

These reports present the institutions' results and allow the Federal Court of Accounts (TCU) to monitor the application of public resources, thus enabling performance evaluations. The management report is one of the FUs' accountability instruments, containing financial and equity information, performance indicators, and other data. The reports show the funds received, how and where they were applied, and the quantitative and qualitative outcomes. However, it is not enough to know the outcomes and the FU indicators; it is crucial to analyze these data to evaluate if the resources were efficiently used, as well as to compare these results with other institutions.

This was a longitudinal study examining the period from 2013 to 2017. The period was chosen because it is immediately after the end of *Reuni*, a federal public policy ended in 2012 that channeled resources to FUs. The data were examined to find the relative efficiency of FUs regarding their teaching, research, and extension activities, using the DEA methodology.

3.3 Object of study and sampling

Golany and Roll (1989) emphasize the importance and care in determining the sample size before defining the variables. A large number of DMUs can decrease homogeneity within the analyzed set, increasing the possibility that the results will be affected by factors the model has disregarded. On the other hand, if the sample size is smaller than the number of inputs and outputs, the analysis can result in all DMUs being efficient. Some authors recommend that the number of DMUs should be at least twice the inputs and outputs. Although there is no general rule, Banker et al. (1984) suggest that the number of DMUs should be at least three times the number of variables, while Cook et al. (2014) propose that it should be at least twice the number of variables.

The Brazilian federal universities are the units of analysis, and the sample was formed of 34 FUs (Table 1).

Table 1
List of federal universities analyzed

	NAME	ACRONYM	YEAR OF INAUGURATION
1	Federal University of Bahia	UFBA	1946
2	Federal University of Alfenas	UNIFAL	2005
3	Federal University of Health Sciences of Porto Alegre	UFCSPA	2008
4	Federal University of Goiás	UFG	1960
5	Federal University of Itajubá	UNIFEI	2002
6	Federal University of Juiz de Fora	UFJF	1960
7	Federal University of Lavras	UFLA	1994
8	Federal University of Mato Grosso	UFMT	1970
9	Federal University of Mato Grosso do Sul	UFMS	1979
10	Federal University of Minas Gerais	UFMG	1927
11	Federal University of Pernambuco	UFPE	1967
12	Federal University of Rondônia	UNIR	1982
13	Federal University of Roraima	UFRR	1987
14	Federal University of Santa Catarina	UFSC	1960
15	Federal University of Santa Maria	UFSM	1960
16	Federal University of São João del-Rei	UFSJ	2002
17	Federal University of Uberlândia	UFU	1978
18	Federal University of Viçosa	UFV	1969
19	Federal University of ABC	UFABC	2005
20	Federal University of Acre	UFAC	1974
21	Federal University of Amazonas	UFAM	1962
22	Federal University of Espírito Santo	UFES	1961
23	Federal University of the State of Rio de Janeiro	UNIRIO	1979
24	Federal University of the West of Pará	UFOPA	2009
25	Federal University of Pampa	UNIPAMPA	2008
26	Federal University of Paraná	UFPR	1950
27	Federal University of Recôncavo da Bahia	UFRB	2005
28	Federal University of Rio de Janeiro	UFRJ	1965
29	Federal University of Rio Grande	FURG	1969
30	Federal University of Rio Grande do Sul	UFRGS	1968
31	Federal University of São Francisco Valley	UNIVASF	2002
32	Federal University of Jequitinhonha and Mucuri Valleys	UFVJM	2005
33	Rural Federal University of Amazonia	UFRA	2002
34	Rural Federal University of Rio de Janeiro	UFRRJ	1968

Source: Elaborated by the authors based on the Ministry of Education (BRASIL, 2017)

From the universe of 63 FUs until 2017, 29 were excluded because of missing data or failing to provide data. In 11 cases, the FUs did not have data on teaching (they failed to provide primary data or were new institutions and data was not yet available), making it impossible to calculate TCU indicators. Also, 07 new FUs still did not have complete data on research activities. As for the extension activities, 27 FUs failed to provide the data. This scenario may represent a limitation of the sample.

3.4 The DEA method

The data development analysis (DEA) method was chosen to help achieve this research's objectives. In addition, the study also adopted the BCC efficiency analysis model, which determines the efficiency frontier taking into account variable returns of scale, where an increase in the input may promote a not necessarily proportional increase or decrease in outputs.

In addition, the output-oriented BCC efficiency analysis model was used since the search for efficiency by maximizing production is more consistent with the nature of the teaching, research, and extension activities of FUs, that is, maximizing the movement towards the frontier through the proportional increase of outputs, keeping the inputs constant. Thus, a set of benchmarks was created for inefficient units, providing separate (in)efficiency scores for the FUs' teaching, research, and extension activities.

With data from the period 2013 to 2017, referring to 34 FUs, the DEA calculations were performed using the free software EMS – version 1.3, which allowed evaluating the level of FUs relative efficiency.

3.5 Variable selection

To separately analyze the relative efficiency in each activity (teaching, research, and extension), the variables were directed to the activities which they identified with. To calculate the relative efficiency related to undergraduate teaching activities, the variables shown in Figure 2 were considered.

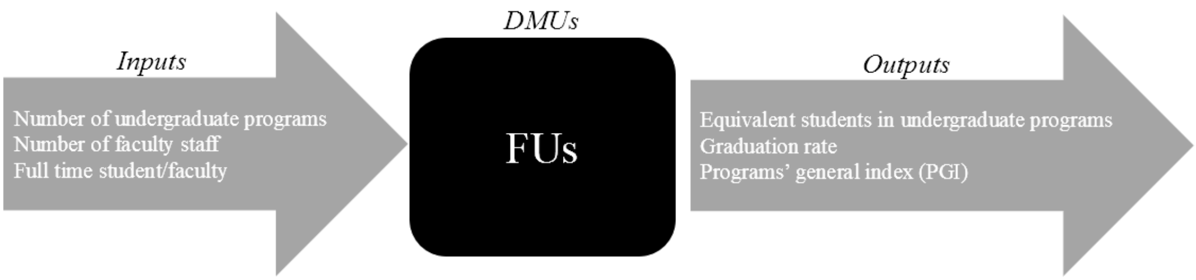

Figure 2 – Teaching variable
Source: Elaborated by the authors (2019)

The number of undergraduate programs refers to students training for the labor market in different professions. The expansion of education increases wages and labor productivity. It also contributes to economic growth and poverty reduction, promoting social equality (Barros et al., 2002).

Along with the offer of courses, qualifying students also depends on the professor's performance. Neves and Malta (2014) mention the importance of faculty staff in developing teaching, research, and extension activities, since these professionals contribute to the learning process, becoming mediators and connectors in the students' knowledge in search of a social structure. Therefore, the faculty's performance in higher education is not restricted to the classroom, research, or administration. Professors have to develop these activities in a concomitant and complementary way. Thus, the greater the number of professors in relation to that of students, the better the attention and support these students will receive, favoring greater productivity of teaching resources.

The graduation rate refers to the number of students who obtain a degree in the expected period. This rate reflects the institution's quality and managerial capacity when using resources. Thus, it is not enough to train the largest number of students (graduation rate), which means that the institution has to be evaluated based on the quality of its actions. In this context, the programs' general index (PGI) is included as an output, contributing to measure the higher education institution's quality, calculating the weighted average of all scores obtained during the evaluation of the institutions' undergraduate programs.

Regarding research activities, the variables shown in Figure 3 were considered to calculate relative efficiency.

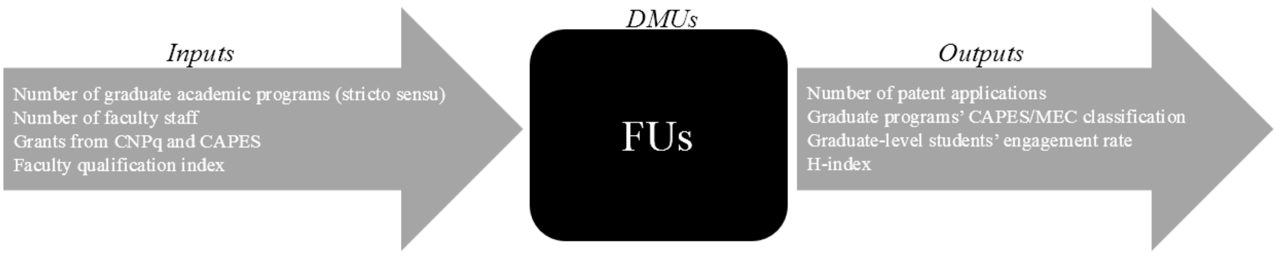

Figure 3 – Research variables
Source: Elaborated by the authors (2019)

The number of faculty staff was considered input since these professionals are the main channel through which FUs carry out their mission. In addition, they perform teaching and research activities. Menezes and Santos (2001) mention that the faculty qualification index is linked to the quality of undergraduate and graduate education and the volume of research produced in an institution.

Although undergraduate students carry out research and engage in scientific initiation, most relevant research is performed in graduate programs. Severino (2006, p. 51-52, our translation) states that "the graduate program is one of the best sections of the Brazilian educational system when it comes to the quality achieved. These programs have contributed significantly to the construction of a more accurate description of the national reality, thanks to the systematization and institutionalization of scientific research practice, while preparing new generations of researchers." Thus, the number of graduate programs was used as an input.

A greater number of graduate programs may encourage undergraduate students to engage in research conducted at a higher education level. This involvement helps students consolidate knowledge obtained in the classroom and engage with more advanced studies.

Government funding for research was a variable considered an input. CAPES and CNPq are the main sources of government funding for research. The more grants researchers are awarded, the greater the opportunities for research development.

Over the years, scientists' growing responsibility for solving social and economic problems has led to marketable innovations achieved from academic research. Thus, Chaves (2009) argues that FUs have been major generators of technological innovation. Therefore, the number of patent applications registered with the Brazilian National Institute of Industrial Property (INPI) was considered a variable. The decision to adopt the number of applications instead of the actual patent is due to the often slow, difficult, and costly process of acquiring a patent. In addition, the fact that the patent is granted does not mean that it will be licensed to any interested party or exploited in any way. Mueller and Perucchi (2014) showed that the average period between request and response, which may or may not be favorable to the patent's granting, is ten years, and that the value of the patent depends on the potential for commercialization or economic exploitation that the patent presents.

The graduate program's CAPES/MEC classification is a system to evaluate the FUs. It uses five criteria, with different weights in the composition of the final score/classification: a) program's proposal; b) faculty; c) student body, dissertations, and theses; d) intellectual production, and; e) social insertion. Thus, the outcomes support the establishment of policies for the graduate academic programs (in Brazil called *stricto sensu*), as well as for the implementation of scholarships, grants, support, among other measures.

Regarding the dissemination of research, the h-index was considered an output. It is an indicator of quality in scientific production and helps assess the relevance of researchers' work. The h-index quantifies productivity and impact of individual or group research based on the most cited articles. Costas and Bordons (2007, p.194) affirm that the h-index is considered a good bibliometric indicator, preferable to using only the total number of articles produced, the total number of citations, the number of citations per article, or the number of articles most cited.

Finally, to calculate the relative efficiency regarding the extension activities, Figure 4 shows the used variables.

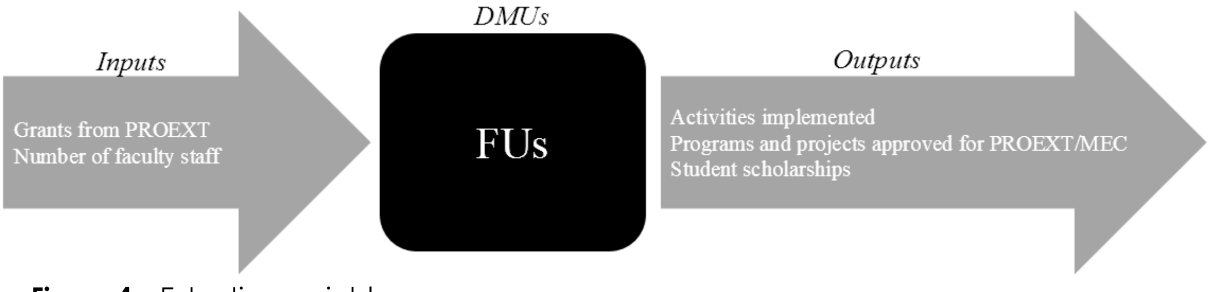

Figure 4 – Extention variables
Source: Elaborated by the authors (2019)

Again, the number of faculty staff was considered an input, highlighting the importance of their performance in integrating the institution with society.

In 2008, the government established the University Extension Program (PROEXT/MEC) to expand the interaction between universities and society and formalize resource allocation to extension-based projects. The research considered the grants the governments offered through this program as an input.

The number of programs and projects submitted and approved (output) demonstrates how one of the university's pillars has gained significance. Also, professors are increasingly willing to elaborate, submit, and develop extension projects.

It is worth mentioning that extension activities do not always count on grants from the PROEXT/MEC. However, FUs carry out such actions using their own resources or via private partnerships, so the number of extension activities was also considered an input.

The student scholarships granted by PROEXT/MEC were also considered an output. This sort of financial aid stimulates the interaction of university students with other sectors of society. These activities contribute to their academic and professional careers and the exercise of citizenship.

4 RESULTS AND DISCUSSION

This study used the DEA method to assess the relative efficiency of Brazilian FUs regarding teaching, research, and extension activities. First, the data's descriptive statistics were collected, followed by an analysis of the FUs' relative efficiency when conducting its activities.

4.1 Descriptive statistics of variables

The first analysis used the correlation matrix among the input and output variables to verify if they were positively correlated (Chen et al., 2012).

For teaching activities, Table 2 shows that the selected variables meet the criteria. All of them are positively correlated, and the variables number of faculty staff (FACUL) and equivalent students in undergraduate programs (EQUIV) showed the highest degree of correlation.

Table 2
Correlation matrix for teaching

PROGRAMS	FACUL	FTS/FAC	EQUIV	GRADRATE	PGI	**TEACHING**
1.0000	0.8686	0.3574	0.8485	0.3393	0.2496	PROGRAMS
	1.0000	0.4703	0.9600	0.4472	0.4995	FACUL
		1.0000	0.5811	0.4523	0.4795	FTS/FAC
			1.0000	0.5218	0.5184	EQUIV
				1.0000	0.5090	GRADRATE
					1.0000	PGI

Source: Elaborated by the authors (2019)

Table 3 presents descriptive statistics of teaching activities. The average in relation to the number of programs (PROGRAMS) was 80.24, and the standard deviation was 43.59, indicating a not so uniform sample since FUs have different sizes and have been operating for more or less time. Therefore, the maximum number of programs was observed in the UFRJ (180), and the minimum in UFCSPA (11).

Due to the same situation of magnitude and time, the variable number of faculty staff (FACUL) shows proportional dispersion, pointing to an average of 1426.46, with a standard deviation of 983.71. The maximum number of faculty staff in an institution is 4126 for UFRJ, and the minimum was 254 for UFOPA.

Regarding the variable full-time student/faculty (FTS/FAC), there is an average of 12.06 students per professor, with a standard deviation of only 2.57, showing a situation closer to uniformity as it is a relational variable. The maximum for this variable was 18.6 for UFAC, and the minimum for 3.82 for UNIPAMPA.

There is an average of 19,517.62 and a standard deviation of 12,410.46 for the variable equivalent students in undergraduate programs (EQUIV). There is a discrepancy between the sizes and how long the university has been operating. The maximum number of students was 54,449 (UFRJ), and the minimum was 1,843.73 (UFOPA).

The variable graduation rates (GRADRATE) had an average of 47.04, with a standard deviation of 13.01. The FUs' performance regarding this variable, which compares the number of students who obtain a degree with the new students enrolled, showed a maximum number of 90 for UFRB and a minimum of 3.98 for UFOPA.

Finally, the programs' general index (PGI) presented an average of 3.45 with a standard deviation of 0.5. The variable indicates more uniformity in the quality of the FUs' programs. The maximum of this variable was 4.35 for UFRGS, and the minimum was 1.93 for UFOPA.

Therefore, the variables present a more substantial dispersion regarding the FUs' size and how long the university has been operating. When analyzing the relationship variables, it is observed that the standard deviation reduces significantly, indicating that, despite the difference in size, the FUs present equivalent performance.

Table 3
Descriptive statistics of teaching variables

Statistics	PROGRAMS	FACUL	FTS/FAC	EQUIV	GRAD	PGI
Average	80.24	1429.46	12.06	19517.62	47.04	3.45
Standard deviation	43.59	83.71	2.57	12410.46	13.01	0.50
Maximum	180.00	4126.00	18.60	54449.00	90.00	4.35
Minimum	11.00	254.00	3.82	1843.73	3.98	1.93

Source: Elaborated by the authors (2019)

For research activities, Table 4 shows the correlation of the selected variables, which meet the assumptions, since they are all positively correlated. The correlation of the variables number of graduate academic programs (stricto sensu) (GAP) with the number of faculty staff (FACUL) was the one with the highest degree of correlation, followed by the correlation between graduate academic programs and grants from CNPq and CAPES (GRANT).

Table 4
Correlation matrix for research

GAP	FACUL	GRANT	FQI	PAT	CLASS	ENGAG	HINDEX	**RESEARCH**
1.0000	0.9577	0.8329	0.3215	0.6986	0.6846	0.8043	0.7215	GAP
	1.0000	0.7832	0.1944	0.6747	0.5811	0.6956	0.6769	FACUL
		1.0000	0.3056	0.6088	0.6979	0.7547	0.7946	CNPQ/CA
			1.0000	0.3534	0.5167	0.5204	0.3697	FQI
				1.0000	0.5443	0.6206	0.5333	PAT
					1.0000	0.7826	0.6296	CLASS
						1.0000	0.6989	ENGAG
							1.0000	HINDEX

Source: Elaborated by the authors (2019)

Table 5 presents the descriptive statistics of the research activities. The number of graduate academic programs (stricto sensu) (GAP) the average is 35.52, and the standard deviation is 27.76, indicating a considerable dispersion among the FUs. Therefore, the maximum number of graduate academic programs is 120 from UFRJ, and the minimum is 04 from UFCSPA.

The variable number of faculty staff (FACUL) presents the same statistics for all activities.

Regarding the variable grants from CNPq and CAPES (GRANT), there is an average of BRL 22,819,693.51 received, with a standard deviation of BRL 33,097,204.82. The maximum amount received was BRL 179,992,154.66 for UFRJ, and the minimum was BRL 620,416.61 for UFOPA.

The variable faculty qualification index (FQI) showed an average of 4.29 and a standard deviation of 0.39, with greater uniformity among the FUs' faculty qualification indexes. The maximum observed was 4.29 for FURG and UFMS, and the minimum was 3.18 for UFAC.

As for the variable number of patent applications (PAT), the average was 10.59 with a standard deviation of 14.14, pointing to a discrepancy between innovation depending on the FU. The maximum number of applications was 70 for UFMG, and the minimum was zero for several FUs.

Regarding the variable graduation program's CAPES/MEC classification (CLASS), the average was 3.90, with a standard deviation of 0.68. This result indicates uniformity in the quality of FU programs among universities. The maximum for this variable was 6.43 for UNIRIO and the minimum 2.89 for UFRR.

The variable graduate-level students' engagement rate (ENGAG) had an average of 0.12 with a standard deviation of 0.07, demonstrating that the FU where students engage more often was the UFRGS (30%). In contrast, those with the lowest engagement were UNIPAMPA and UFAC (2%).

Finally, the variable h-index (HINDEX) demonstrated an average of 15.9 and a standard deviation of 9.42. The indicator showed a greater variation among the list of publications and citations of the academics related to the FUs. The highest index was 45 for UFRJ, and the lowest was 03 for UFRR.

Thus, despite the relative uniformity of professors' qualifications and the program's classification, the resources received, the number of programs, and the H index present the greatest dispersions.

Table 5
Descriptive statistics of research variables

Statistics	GAP	FACUL	GRANT	FQI	PAT	GPC	ENGAG	HINDEX
Average	35.52	1429.46	22819693.51	4.29	10.59	3.90	0.12	15.90
Standard deviation	27.76	983.71	33097204.82	0.39	14.14	0.68	0.07	9.42
Maximum	120.00	4126.00	179992154.66	5.24	70.00	6.43	0.30	45.00
Minimum	4.00	254.00	620416.61	3.18	0.00	2.89	0.02	3.00

Source: Elaborated by the authors (2019)

For extension activities, Table 6 shows the correlation between the selected variables. They meet the assumptions since they are all positively correlated. The correlation of the resource variables from PROEXT/MEC with the programs and projects approved by PROEXT/MEC had the highest degree of correlation.

Table 6
Correlation matrix for extension

FACUL	GRANTPRO	IMPLEM	SCHOL	PPPROEXT	**EXTENSION**
1.0000	0.4079	0.3433	0.6327	0.4421	FACUL
	1.0000	0.1135	0.2844	0.8794	GRANTPRO
		1.0000	0.1908	0.1279	IMPLEM
			1.0000	0.3587	SCHOL
				1.0000	PPPROEXT

Source: Elaborated by the authors (2019)

Table 7 presents the descriptive statistics of the extension activity, considering that the variable number of professors has the same statistics for the three activities.

For the variable grants from PROEXT/MEC, an average of resources received of BRL 807,122.27 with a standard deviation of BRL 914,430.78 was observed. There was significant dispersion among the FUs regarding the number of successful applications and grants received. The maximum amount received was BRL 5,169,360.95 for UFVJM. The minimum was zero for many FUs.

The variable for activities implemented revealed an average of 1018.22 with a standard deviation of 1791.94. This may indicate a discrepancy between the actions and benefits aimed at society since the maximum number was 12,148 for UFSC, and the minimum was 06 for UFOPA.

Regarding the students' scholarships, an average of 354.99 students with scholarships, with a standard deviation of 367.43 was observed. The maximum for this variable was 1,962 for students of the UFMG, while some FUs were not benefited at all.

Finally, there are programs and projects approved for PROEXT/MEC, with an average of 6.58 and a standard deviation of 7.3, indicating dispersion among FUs. The maximum number was 32 from UFMG, and some had no project approved or funded.

Table 7
Descriptive statistics of extension variables

Statistics	FACUL	GRANTPRO	IMPLEM	SCHOL	PPPROEXT
Average	1429.46	807122.27	1018.22	354.99	6.58
Standard deviation	983.71	914430.78	1791.94	367.43	7.30
Maximum	4126.00	5169360.95	12148.00	1962.00	32.00
Minimum	254.00	0.00	6.00	0.00	0.00

Source: Elaborated by the authors (2019)

Thus, the variables for the extension activities are those with the most dispersion. This finding reinforces the idea that these activities deserve attention throughout their development and must be closely followed by the government's higher agencies – such as the Ministry of Education –, and society as a whole.

4.2 Results of relative efficiency

The first analysis is related to the relative efficiency in teaching activities, as shown in Table 8.

Table 8
Efficiency in teaching activities

	TEACHING				
DMU	**2013**	**2014**	**2015**	**2016**	**2017**
UFBA	0.925155	0.863185	0.916086	1.000000	0.983961
UNIFAL-MG	0.962835	0.902772	0.993641	0.982029	1.000000
UFCSPA	1.000000	1.000000	1.000000	1.000000	1.000000
UFG	0.945537	0.869036	0.953743	0.917936	1.000000
UNIFEI	1.000000	0.905797	0.962001	1.000000	1.000000
UFJF	1.000000	0.990197	0.997805	1.000000	0.979048
UFLA	1.000000	1.000000	0.990491	0.983768	1.000000
UFMT	1.000000	0.845809	0.965158	1.000000	0.906125
UFMS	0.853388	0.786349	0.797385	0.818331	0.818063
UFMG	1.000000	1.000000	1.000000	1.000000	1.000000
UFPE	0.902446	0.888178	0.896057	0.903914	0.902201
UNIR	0.763417	0.677736	0.742390	0.792896	0.696670
UFRR	1.000000	0.808342	0.889680	1.000000	0.852224
UFSC	0.958865	0.989805	0.977708	0.981836	0.995818
UFSM	0.964134	0.955475	0.942152	0.991473	0.975895
UFSJ	0.991572	0.935016	1.000000	1.000000	1.000000
UFU	0.993838	0.926355	1.000000	0.968242	0.984252
UFV	1.000000	1.000000	1.000000	1.000000	1.000000
UFABC	1.000000	1.000000	1.000000	1.000000	1.000000
UFAC	0.789204	0.929282	0.876732	0.826720	0.840901
UFAM	0.797957	0.762137	1.000000	0.912575	0.849185
UFES	0.916003	0.887548	0.895576	0.984931	0.944555
UNIRIO	1.000000	1.000000	0.901226	1.000000	0.971817
UFOPA	1.000000	1.000000	1.000000	1.000000	1.000000
UNIPAMPA	1.000000	0.866101	0.912742	1.000000	0.921234
UFPR	0.999700	0.981065	1.000000	1.000000	1.000000
UFRB	0.849618	1.000000	1.000000	1.000000	0.997407
UFRJ	1.000000	1.000000	1.000000	1.000000	1.000000
FURG	0.804311	0.791640	0.803600	0.814863	0.860067
UFRGS	1.000000	1.000000	1.000000	1.000000	1.000000
UNIVASF	1.000000	0.883158	1.000000	0.941442	0.926698
UFVJM	1.000000	1.000000	1.000000	1.000000	1.000000
UFRA	1.000000	1.000000	1.000000	1.000000	1.000000
UFRRJ	1.000000	0.921319	1.000000	1.000000	0.950751

Source: Elaborated by the authors (2019)

Nine universities remained efficient throughout the years analyzed (UFCSPA, UFMG, UFV, UFABC, UFOPA, UFRJ, UFRGS, UFVJM, and UFRA). In 2013, 18 FUs were considered efficient, 12 in 2014, 16 in 2015, 20 in 2016, and 15 in 2017. UFMS, UFPE, UNIR, UFSC, UFSM, UFAC, UFES, and FURG did not show maximum efficiency in any of the years.

Table 9 supported the analysis of the FUs' relative efficiency based on a simple arithmetic mean. Efficiency is reduced from 2013 to 2014, increasing the standard deviation from then on. From 2014 to 2016, the average rises again, reducing the standard deviation, whereas from 2016 to 2017, the average falls, increasing the standard deviation. The average between the years was 0.949272, with a standard deviation of 0.072461, with the worst average in 2017. The maximum efficiency was observed in all of the years analyzed, and the minimum was observed in 2014, with 0.6777736 (UNIR). The general mean over the years for minimum efficiency was 0.734622. One-quarter of the FUs had an efficiency lower than 0.930250 in 2013, dropping to 0.872567 in 2014. In 2015, this quartile level increased to 0.913578, and its best level was observed in 2016 (0.971640), decreasing in 2017 to 0.9226. It is worth mentioning that of the 34 FUs studied, the third quartile group (25% of the best FUs) had an efficiency level equal to 100% in all years. The median remained at 100% in 2013 and 2016, with the worst median in 2014.

Table 9
Descriptive statistics of efficiency in teaching activities

Statistics	2013	2014	2015	2016	2017	General mean
Average	0.953470	0.922538	0.953358	0.965322	0.951673	0.949272
Standard deviation	0.073779	0.085333	0.068376	0.062420	0.072400	0.072461
Maximum	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
Minimum	0.763417	0.677736	0.742390	0.792896	0.696670	0.734622
1st quartile	0.930250	0.872567	0.913578	0.971640	0.922600	0.922127
Median	1.000000	0.932149	0.995723	1.000000	0.990035	0.983581
3rdquartile	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000

Source: Elaborated by the authors (2019)

The worst year for teaching activities was 2014, and the best year was 2016. These findings corroborate the study by Toledo (2017), who pointed out that in 2014 Brazilian FUs went through budget cuts, which jeopardized even some of the institutions' routine activities.

The analysis considered the weights of each variable. For inputs, the variable with the highest weight in 2013, 2016, and 2017 was the full-time student/faculty (FTS/FAC) ratio, whereas the variable number of faculty staff (FACUL) had the highest weight in 2014 and 2015. As for outputs, the variable equivalent students in undergraduate programs (EQUIV) had the highest weights in all years except 2014, when the variable programs' general index (PGI) stood out (Table 10). These findings corroborate the study by Nuintin (2014), who considered the variables FTS/FAC and EQUIV as the highest weight variables.

Table 10
Weight of teaching activities variables

TEACHING						
Weights	**programs{I}**	**facul{I}**	**fts/fac{I}**	**equiv{O}**	**gradrate{O}**	**pgi{O}**
2013	0.07	0.43	**0.50**	**0.60**	0.11	0.29
2014	0.06	**0.57**	0.37	0.38	0.12	**0.50**
2015	0.05	**0.51**	0.44	**0.58**	0.05	0.38
2016	0.09	0.41	**0.49**	**0.57**	0.13	0.31
2017	0.12	0.41	**0.47**	**0.47**	0.08	0.45

Source: Elaborated by the authors (2019).

Analysis considering only the FUs' efficiency different from 100% in any of the years showed that the institutions achieved a level very close to the benchmarks (the FUs adopting the best practices). The arithmetic means of the efficiency disregarding the years where the institutions reached 100% efficiency was 0.904522. Thus, it is possible to say that teaching activities are, in general, well-performed among Brazilian FUs. In 2013, the mean for the 16 FUs that did not achieve 100% efficiency was 0.901124. The year when the higher number of universities (22) did not reach total efficiency in teaching activities was 2014, with a mean of 0.880287. The FU with the worst efficiency in 2014 was UNIR, with 0.6777736. In 2015, the mean rose to 0.911898 with 18 FUs that did not achieve 100% efficiency. The best year for teaching activities was 2016, showing a mean of 0.915783 and only 14 FUs below 100% efficiency. In 2017, 19 FUs were below 100%, and the mean slightly dropped to 0.913520.

Regarding efficiency in research activities, Table 11 shows that only nine universities were 100% efficient over the period analyzed: UFCSPA, UFLA, UFMG, UFRR, UNIRIO, UFOPA, UFPR, FURG, and UFRGS. In 2013, 19 FUs were considered efficient, 17 in 2014, 17 in 2015, 20 in 2016, and 19 in 2017. The universities with the lowest efficiency were UNIFAL, UFG, UFMT, UFPE, UFSC, UFABC, and UFES.

Table 11
Efficiency in research activities

	RESEARCH				
DMU	**2013**	**2014**	**2015**	**2016**	**2017**
UFBA	1.000000	0.961076	0.831808	0.955840	0.969274
UNIFAL-MG	0.919879	0.837802	0.883704	0.969462	0.888257
UFCSPA	1.000000	1.000000	1.000000	1.000000	1.000000
UFG	0.947149	0.997208	0.905633	0.993443	0.919794
UNIFEI	1.000000	0.916842	1.000000	1.000000	1.000000
UFJF	1.000000	0.754205	0.876194	0.883236	0.940911
UFLA	1.000000	1.000000	1.000000	1.000000	1.000000
UFMT	0.915332	0.747105	0.800576	0.880514	0.913325
UFMS	0.917936	0.827130	0.998901	0.820345	1.000000
UFMG	1.000000	1.000000	1.000000	1.000000	1.000000
UFPE	0.900982	0.907029	0.973710	0.975991	0.922084
UNIR	0.992359	1.000000	0.866852	0.973331	1.000000
UFRR	1.000000	1.000000	1.000000	1.000000	1.000000
UFSC	0.995223	0.921829	0.899604	0.897827	0.959601
UFSM	0.923361	0.885818	1.000000	0.913159	0.965065
UFSJ	0.891266	0.809389	0.957671	1.000000	1.000000
UFU	1.000000	0.959693	0.895977	0.972006	1.000000
UFV	1.000000	0.954836	0.987362	1.000000	1.000000
UFABC	0.920895	0.919709	0.906454	0.955932	0.951294
UFAC	1.000000	1.000000	1.000000	1.000000	0.850702
UFAM	1.000000	1.000000	1.000000	1.000000	0.950480
UFES	0.850123	0.765462	0.846167	0.911577	0.963020
UNIRIO	1.000000	1.000000	1.000000	1.000000	1.000000
UFOPA	1.000000	1.000000	1.000000	1.000000	1.000000
UNIPAMPA	1.000000	1.000000	1.000000	1.000000	0.892857
UFPR	1.000000	1.000000	1.000000	1.000000	1.000000
UFRB	1.000000	1.000000	1.000000	1.000000	0.916506
UFRJ	0.990393	1.000000	1.000000	1.000000	1.000000
FURG	1.000000	1.000000	1.000000	1.000000	1.000000
UFRGS	1.000000	1.000000	1.000000	1.000000	1.000000
UNIVASF	0.908100	1.000000	1.000000	1.000000	1.000000
UFVJM	0.983671	0.985222	0.978665	1.000000	0.937910
UFRA	1.000000	1.000000	0.988435	1.000000	1.000000
UFRRJ	0.979912	0.690894	0.766989	0.834168	1.000000

Table 12 presents the simple arithmetic mean of the relative efficiency of FUs in research activities. The mean is reduced from 2013 to 2014 (the worst mean – 0.936507 – in 2014), increasing gradually until 2017. The greater standard deviation was also in 2014. The average between the years was 0.959532 with a standard deviation of 0.059318. Efficiency reached the maximum in all years, and the minimum was in 2014, with 0.690894 for UFRRJ. The average of the lowest efficiency levels was 0.795810. In addition, one-quarter of the FUs had an efficiency lower than 0.929308 in 2013, reducing to 0.909483 in 2014, and reaching, in 2015, the mean of 0.901111. In 2016, the efficiency level in this quartile increased to 0.959314 – its best level – and falling again in 2017 to 0.943303, maintaining an average between the years of 0.928504. As for the third quartile (25% of the best FUs), these institutions presented 100% efficiency in research activities in all years. Even though the median was not 100% in 2014 and 2015, it was very close to total efficiency.

The worst year for research activities was 2014, and the best year was 2017. Moreno (2018) mentions that in 2017 federal universities had the lowest transfer of funds from the federal government, operating with 90% losses compared to 2013. This context suggests that FUs suffered the 2014 budget cuts' impact but gradually managed to work with the situation and achieve better results with lower expenses.

Table 12
Descriptive statistics of efficiency in research activities

Statistics	2013	2014	2015	2016	2017	General level
Mean	0.971664	0.936507	0.951903	0.968730	0.968855	0.959532
Standard deviation	0.043109	0.091609	0.068697	0.051399	0.041778	0.059318
Maximum	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
Minimum	0.850123	0.690894	0.766989	0.820345	0.850702	0.795810
1st quartile	0.929308	0.909483	0.901111	0.959314	0.943303	0.928504
Median	1.000000	0.998604	0.999451	1.000000	1.000000	0.999611
3rdquartile	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000

Source: Elaborated by the authors (2019)

The weights of each variable were observed to complement the analysis. For input, the variable with the highest weight in all years was faculty qualification index FQI. For output, the variable was graduate programs' CAPES/MEC classification (CLASS), also for all years (Table 13). Nuintin (2014) also presents FQI as a variable influencing FUs' efficiency. Costa et al. (2012) showed that FQI and CLASS could be considered as factors of inefficiency for Brazilian federal higher education institutions.

Table 13
Weights of variables of research activities

RESEARCH								
Weights	**gap{I}**	**facul{I}**	**grant{I}**	**fqi{I}**	**pat{O}**	**class{O}**	**engag{O}**	**hindex{O}**
2013	0.09	0.11	0.17	**0.62**	0.16	**0.49**	0.20	0.14
2014	0.09	0.16	0.29	**0.46**	0.15	**0.35**	0.20	0.30
2015	0.07	0.20	0.26	**0.47**	0.23	**0.31**	0.25	0.20
2016	0.07	0.21	0.25	**0.47**	0.22	**0.35**	0.25	0.18
2017	0.08	0.16	0.18	**0.58**	0.19	**0.51**	0.19	0.12

Source: Elaborated by the authors (2019)

In the analysis of the FUs' efficiency different from 100% (as conducted for teaching activities), the arithmetic means was 0.913211, close to benchmarks. Therefore, research activities are also well-performed among Brazilian FUs, in general. For 2013, the average was 0.935772 with 15 FUs, dropping in 2014 to the lowest efficiency level in the period (0.83015) and the highest number of FUs (17) failing to achieve 100%. In 2015, the average rose to 0.903806 with 17 UFs; in 2016, it was 0.924059 with 14 UFs, and 2017 with 15 UFs and an average of 0.929405 (considered the best year for research activities).

Finally, Table 14 demonstrates the efficiency in extension activities. The results indicate that universities have more difficulties to remain efficient in this regard since only three universities are considered to have maximum efficiency during the entire period from 2013 to 2017: UFCSPA, UFMG, and UFSC. In 2013, 12 FUs achieved 100% efficiency, 18, in 2014, 19, in 2015, 15, in 2016 and only 04, in 2017. The FUs UFBA, UFMT, UFMS, UFPE, UNIR, UFRR, UFSM, UFAM, and UFES did not achieve 100% efficiency in extension activities in any of the analyzed years.

Table 14
Efficiency in extension activities

	EXTENSION				
DMU	**2013**	**2014**	**2015**	**2016**	**2017**
UFBA	0.698861	0.714957	0.585720	0.511326	0.211569
UNIFAL-MG	0.825355	1.000000	0.954107	1.000000	0.652273
UFCSPA	1.000000	1.000000	1.000000	1.000000	1.000000
UFG	0.900576	0.876949	1.000000	1.000000	0.158446
UNIFEI	0.771069	1.000000	1.000000	1.000000	0.244942
UFJF	0.898634	1.000000	1.000000	0.882379	0.621852
UFLA	1.000000	1.000000	0.764234	1.000000	0.722335
UFMT	0.765990	0.708209	0.689941	0.553465	0.339443
UFMS	0.977231	0.844044	0.888257	0.949487	0.344092
UFMG	1.000000	1.000000	1.000000	1.000000	1.000000
UFPE	0.713318	0.853558	0.721917	0.400064	0.198942
UNIR	0.710833	0.621075	0.618353	0.160408	0.185065
UFRR	0.734376	0.322843	0.856751	0.401091	0.292629
UFSC	1.000000	1.000000	1.000000	1.000000	1.000000
UFSM	0.720929	0.983811	0.771545	0.848320	0.343725
UFSJ	0.945984	1.000000	1.000000	1.000000	0.708567
UFU	0.846740	0.967960	1.000000	0.827883	0.405055
UFV	1.000000	1.000000	1.000000	1.000000	0.809127
UFABC	1.000000	1.000000	1.000000	0.800897	0.344542
UFAC	0.769941	0.804728	1.000000	1.000000	1.000000
UFAM	0.733245	0.814169	0.705069	0.434141	0.155239
UFES	0.898715	0.879471	0.851281	0.583124	0.333467
UNIRIO	0.711541	1.000000	1.000000	1.000000	0.690417
UFOPA	1.000000	0.908299	1.000000	1.000000	0.857192
UNIPAMPA	0.754205	1.000000	0.719166	0.799361	0.286747
UFPR	0.910581	1.000000	0.848680	0.871308	0.413890
UFRB	1.000000	1.000000	0.726850	0.312607	0.264557
UFRJ	0.960430	0.931034	1.000000	0.868961	0.810504
FURG	1.000000	1.000000	0.807363	1.000000	0.175177
UFRGS	0.869036	0.671194	1.000000	1.000000	0.476872
UNIVASF	0.752785	0.652183	1.000000	0.776036	0.267380
UFVJM	1.000000	1.000000	1.000000	0.540132	0.238812
UFRA	1.000000	1.000000	1.000000	1.000000	0.301814
UFRRJ	1.000000	1.000000	1.000000	0.606281	0.652188

Source: Elaborated by the authors (2019)

Table 15 supports the analysis of the simple arithmetic mean of FUs' efficiency for extension activities. The results show an increase in efficiency from 2013 to 2015. After that, it decreases until 2017, which was the worst level of efficiency and had the most significant standard deviation. The average between the years was 0.791578 with a standard deviation of 0.187903. In all years, the level of efficiency reached the maximum, and the minimum was in 2017 with 0.1555239 for UFAM. The average of the lowest levels was 0.384614. One-quarter of the FUs showed efficiency less than 0.757151 in 2013, increasing to 0.846423 in 2014, decreasing again in 2015 to 0.7805. In 2016, it decreased to 0.588914, and finally to 0.2665263 in 2017 (its worst level), maintaining an average of 0.647650. Regarding the third quartile group (25% of the best FUs), these institutions showed 100% efficiency in all years, except in 2017, when they presented a level of

0.704029. In addition, the median was 1.0 only in 2014 and 2015. The worst median was in 2017 (0.3444317), which was the worst year regarding extension activities (2014 was the best). This situation may reflect the decrease in funding through PROEXT/MEC in 2015 and 2016 and the fact that the federal government did not fund activities through PROEXT/MEC in 2017 (PROEXT/MEC, 2018).

Table 15
Descriptive statistics of efficiency in extension activities

Statistics	2013	2014	2015	2016	2017	General level
Mean	0.878540	0.898661	0.897330	0.797861	0.485496	0.791578
Standard deviation	0.117279	0.156766	0.134596	0.248527	0.282349	0.187903
Maximum	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
Minimum	0.698861	0.322843	0.585720	0.160408	0.155239	0.384614
1st quartile	0.757151	0.846423	0.780500	0.588914	0.265263	0.647650
Median	0.899646	1.000000	1.000000	0.876843	0.344317	0.824161
3rdquartile	1.000000	1.000000	1.000000	1.000000	0.704029	0.940806

Source: Elaborated by the actors (2019)

Table 16 shows that the most important input variable, from 2013 to 2015, was GRANTPRO. As for outputs, PPPROEXT was the most significant from 2013 to 2016, and SCHOL was the most important output in 2017.

Table 16
Weights of variables of extension activities

EXTENSÃO					
Pesos	**facul{I}**	**grantpro{I}**	**implem{O}**	**schol{O}**	**ppproext{O}**
2013	0.32	**0.68**	0.09	0.18	**0.74**
2014	0.02	**0.98**	0.00	0.00	**1.00**
2015	0.39	**0.61**	0.09	0.23	**0.68**
2016	**0.58**	0.42	0.14	0.23	**0.63**
2017	**1.00**	0.00	0.39	**0.61**	0.00

Source: Elaborated by the authors (2019)

As conducted above for the other two activities, the FUs' efficiency disregarding the years the institutions reached 100% efficiency shows a mean of 0.683880 for the period, presenting a constant decrease since 2013. Despite the drop in the means for efficiency in extension activities from 0.812290 in 2013 to 0.784655 in 2014, the number of FUs that did not reach 100% efficiency decreased from 22 to 16. In 2015, the means dropped to 0.767282, and the number of FUs reduced to 15. In 2016 and 2017, this situation worsened, with an average of 0.638277 in 2016 and 0.416895 in 2017, and increased from 19 to 30 FUs, respectively. Therefore, 2017 was the worst year, reinforcing the idea that, without funding from PROEXT/MEC, FUs are unable to develop extension activities.

Based on the understanding that teaching, research, and extension are functions through which the universities' mission is carried out (Brasil, 1988; Ospina, 1990), Table 17 shows that six FUs fulfilled their mission with maximum efficiency in 2013, 2014, and 2015. In 2016, eight FUs achieved maximum efficiency, whereas, in 2017, only two institutions were 100% efficient in teaching, research, and extension activities.

Table 17
Universities with maximum efficiency

2013	2014	2015	2016	2017
UFCSPA	UFCSPA	UFCSPA	UFCSPA	UFCSPA
UFLA	UFLA	UFMG	UFMG	UFMG
UFMG	UFMG	UFOPA	UFSJ	
UFV	UNIRIO	UFRJ	UFV	
UFOPA	UFRB	UFRGS	UNIRIO	
UFRA	UFRA	UNIVASF	UFOPA	
			UFRGS	
			UFRA	

Source: Elaborated by the authors (2019)

Thus, when analyzing the three activities in the period, the only universities that remained 100% efficient were UFCSPA and UFMG. Finally, a simple arithmetic means of the relative efficiency was conducted, covering the three activities and considering the period from 2013 to 2017, to classify the FUs for the best relative efficiency (Table 18).

Table 18
Ranking of the universities analyzed

DMU	AVERAGE	RANKING
UFCSPA	1.000000	**1**
UFMG	1.000000	**1**
UFOPA	0.984366	**2**
UFV	0.983422	**3**
UFSC	0.971874	**4**
UFRJ	0.970755	**5**
UFLA	0.964055	**6**
UFRA	0.952683	**7**
UNIRIO	0.951667	**8**
UFSJ	0.949298	**9**
UFPR	0.935015	**10**
UFRGS	0.934473	**11**
UFJF	0.921631	**12**
UNIFEI	0.920043	**13**
UFABC	0.919982	**14**
UNIFAL	0.918141	**15**
UFU	0.916533	**16**

DMU	AVERAGE	RANKING
UFAC	0.912547	**17**
UFVJM	0.910961	**18**
UFRRJ	0.893500	**19**
UFG	0.892363	**20**
UFSM	0.878991	**21**
UNIPAMPA	0.876827	**22**
UNIVASF	0.873852	**23**
UFRB	0.871170	**24**
FURG	0.870468	**25**
UFMS	0.842729	**26**
UFES	0.834068	**27**
UFRR	0.810529	**28**
UFBA	0.808588	**29**
UFAM	0.807613	**30**
UFPE	0.804026	**31**
UFMT	0.802066	**32**
UNIR	0.720092	**33**

Source: Elaborated by the authors (2019)

UNIR is the university with the worst average considering teaching, research, and extension activities, with a relative efficiency of 0.720092. It is worth mentioning that, although this FU has the worst level, it has 72% efficiency, which is still considered high. The institution shows averages of 0.734622 for teaching, 0.966508 for research, and 0.4559147 for extension activities.

5 FINAL CONSIDERATIONS

This research examined Brazilian federal universities' relative efficiency regarding their teaching, research, and extension activities from 2013 to 2017.

Federal universities demonstrated better efficiency in research activities, followed by teaching and, finally, extension activities – both research and teaching activities presented nine institutions with maximum efficiency each year, but the averages for research activities were higher. The best levels of efficiency in research activities were observed in 2017 and for teaching in 2016. As for extension activities, 2014 was the best year (this year was the worst for teaching and research activities).

The study demonstrated that only six universities achieved maximum efficiency in the three activities in 2013, 2014, and 2015, increasing to eight in 2016 and reducing to two in 2017. Only UFCSPA and UFMG were 100% efficient in all activities together and in all years analyzed.

It is worth mentioning that UFCSPA was the university with the lowest number of undergraduate programs and graduate academic programs (stricto sensu). UFM, on the other hand, had the highest number of patent applications, the largest number of students with scholarships for extension activities, and the largest number of programs and projects approved and benefited by PROEXT/MEC. The main factor influencing their efficiency was the optimization of inputs to maximize outputs, especially concerning the variables of greater weight. They are a) for teaching, full-time student/faculty; and equivalent students in undergraduate programs; b) for research, faculty qualification index, graduate programs' CAPES/MEC classification; and c) extension, grants from PROEXT/MEC, and the number of programs and projects approved for PROEXT/MEC.

The results show that FUs can improve outputs by observing the number and qualification of faculty and seeking a good indicator regarding the full-time students/faculty ratio. The better use of faculty staff should provide better productivity and efficiency.

In addition, managers should seek to maximize the number of equivalent students in undergraduate programs. This variable allows evaluating the ratio between the number of degrees granted and the number of students starting an undergraduate program, taking into account the program's performance, focusing on those who deserve special attention. In addition to providing greater efficiency, maximizing this indicator will bring more resources to FUs since it is equivalent to 80% of the costing and capital budget matrix (OCC), thus resulting in more investments to benefit other activities.

Managers should also focus on increasing the graduate programs' CAPES/MEC classification. Efforts in this direction include improving their academic (*stricto sensu*) program's proposal, offering a highly qualified faculty, a selected student body, producing impactful dissertation and theses, stimulating quality intellectual productions, and social inclusion.

Brazilian federal universities should seek programs to support extension activities. It was demonstrated that resources from PROEXT/MEC are crucial to funding extension activities, helping FUs meet social demands as proposed in programs and projects approved and funded through this mechanism of the Ministry of Education (MEC). The PROEXT/MEC's relevance was corroborated by the numbers observed in 2017 when the government ceased to use the mechanism to fund the extension activities. FUs, therefore, should find alternative sources to fund student scholarships, for example, to support such activities. This type of financial aid stimulates university students' interaction with other sectors of society through activities that improve academic and professional training while developing a sense of citizenship.

The research findings allowed to point out which FUs successfully pursue their mission and offer more return to society. University managers may use the inputs from this research to better use the resources available, especially those that are more likely to affect productivity, implement best practices, and deliver optimal results.

It is important to highlight the impact of the federal government's budget cuts in the FUs' activities, especially after the program *Reuni* (which was a period of expansion of higher education in the country). The budgetary difficulties faced by FUs point to a retraction in working conditions and worsening of services to students and society in general. Furthermore, as much as federal resources have been reduced over the analyzed period, FUs have shown good performance regarding efficiency, demonstrating that they are able to adapt and continue contributing to socio-economic development.

In addition, this study shows that FUs need greater control over their information and results generated, especially with regard to extension activities, which means more investment in technology. Greater control would allow for greater monitoring of activities and better conditions to compare the institutions, which leads to the dissemination of best practices. This concern with control, monitoring, and comparison led the study to restrict the sample, analyzing only the FUs that made the needed data available – which is a limitation of the DEA methodology.

Another point to be highlighted is the importance of standardizing indicators aimed at extension activities since each FU maintains a particular control, more or less rigid. The absence of standardization or government monitoring jeopardizes the analysis of the university's performance in relation to society, considering that the strengthening of the university-society relationship comes from the development of actions with citizen engagement.

Given the difficulty of obtaining data on university extension, the sample was limited to 34 FUs, which is a limitation of this study. Thus, all inferences refer to the selected sample's relative efficiency in the years examined and cannot be extrapolated to other universities and periods.

Finally, future research should include new variables in the model, particularly regarding extension activities. New studies may explore relative efficiency measurement, considering budget expenditures as an input and the variables of the tripod teaching, research, and extension activities as an output, and compare the efficiency of public and private institutions.

REFERENCES

Ahn, T. S. (1987). *Efficiency and related issues in higher education*: a data envelopment analysis approach. Ph.D. dissertation - University of Texas at Austin, Austin.

Arretche, M. (1999).Tendências no estudo sobre avaliação. In: RICO, E. M. (Org.). *Avaliação de políticas sociais:* uma questão em debate. São Paulo: Cortez.

Avkiran, N. K. (2001). Investigating technical and scale efficiencies of Australian universities through data envelopment analysis. *Socio Economic Planning Sciences*, Elsevier, 35(3), 57-80.

Banker, R. D., Charnes, A. & Cooper, W. W. (1984). Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Management Science*, Providence, 30 (9), 1078-1092.

Baracho, M. A. P. (2000). A importância da gestão de contas públicas municipais sob as premissas da governance e accountability. *Revista Tribunal de Contas de Minas Gerais,* Belo Horizonte, 34(1), 129-16.

Barros, R. P; Henriques, R. & Mendonça, R. (2002). *Pelo fim das décadas perdidas:* educação e desenvolvimento sustentado no Brasil. Rio de Janeiro: IPEA.

Belloni, J. A. (2000). *Uma metodologia de avaliação da eficiência produtiva de universidades federais brasileiras.* Ph.D. dissertation in production engineering – Departament of Production Engineering and Systems, Federal University of Santa Catarina, Florianópolis, Brazil.

Bertassi, A. L. (2016). *Controladoria estratégica governamental aplicada ao poder executivo:* uma contribuição teórica. Ph.D. dissertation in administration – School of Business and Management, Methodist University of Piracicaba, Piracicaba, Brazil.

Brasil. Constituição (1988). *Constituição da República Federativa do Brasil.* São Paulo: Saraiva.

Brasil. (2001). *Decreto nº 3.860, de 9 de julho de 2001.* Dispõe sobre a organização do ensino superior, a avaliação de cursos e instituições, e dá outras providências. Brasília. Retrieved October 25, 2018, from http://www.planalto.gov.br/ccivil_03/decreto/2001/d3860.htm

Brasil. (2008). *Decreto nº 6.495, de 30 de junho de 2008.* Institui o Programa de Extensão Universitária - PROEXT. Brasília, 2008. Retrieved October 25, 2018, from http://www.planalto.gov.br/ccivil_03/_Ato2007-2010/2008/Decreto/D6495.htm

Brasil. (2011). *Lei nº 12.527, de 18 de Novembro de 2011.* Lei de Acesso à Informação. Brasília, 2011. Retrieved October 25, 2018, from http://www.planalto.gov.br/ccivil_03/_ato2011-2014/2011/lei/l12527.htm

Brasil. (2017). Ministério da Educação. *Cursos e Instituições.* Brasília. Retrieved September 24, 2017, from http://portal.mec.gov.br/pec-g/cursos-e-instituicoes

Bresser-Pereira L. C. (1999). Reflexões sobre a reforma gerencial brasileira de 1995. *Revista* do Serviço Público, Brasília, 50 (4), 5-29.

Cândido Junior, O.J. (2001). *Os gastos públicos no Brasil são produtivos?* Planejamento e políticas públicas. Brasília: IPEA, n. 23, June 2001. Retrieved May 31, 2018, from https://www.ipea.gov.br/ppp/index.php/PPP/article/viewFile/77/88

Casa Nova, S. P. C. (2002). *Utilização da Análise por Envoltória de Dados (DEA) na análise de demonstrações contábeis*. Ph.D. dissertation in accounting and control – School of Economics, Business, and Accounting, Faculdade de Economia, Administração e Contabilidade, University of São Paulo, São Paulo, Brazil.

Castano, M. C. N. & Cabanda, E. C. (2007). Performance evaluation of the efficiency of Philippine Private Higher Educational Institutions: application of frontier approaches. *International Transactions In Operational Research*, Wiley-Blackwell, 14, 431-444.

Castro, L. M. C. (2004). A universidade, a extensão universitária e a produção de conhecimentos emancipadores. In: REUNIÃO ANUAL DA ANPED, 27, Caxambu. *Anais...* Caxambu: ANPEd. Retrieved May 31, 2018, from http://27reuniao.anped.org.br/gt11/ t1111.pdf

Charnes, A.; et al. (1994). *Data Envelopment Analysis: theory, methodology and applications*. USA, Kluwer Academic Publishers.

Charnes, A., Cooper, W. W. & Rhodes, E. (1978). Measuring the efficiency of decision-making units. *European Journal of Operational Research,* Amsterdam, 2(6), 429-444.

Chaves, D. C. R. (2009). *A universidade empreendedora do séc. XXI*: o papel estratégico da propriedade industrial. Master's thesis in sociology – Faculty of Economics, University of Coimbra, Coimbra, Portugal.

Chen, T.,Yeh, T. & Chung, M. (2012). Financial performance of township governments and its four budget cycles. *African Journal of Business Management*, 6 (2), 530-537.

Coelli, T., Rao, D., O'Donnell, C. & Battese, G. (2005). *An introduction to efficiency and productivity analysis*. 2. ed. Berlin: Springer.

Colin, E. C. (2007). *Pesquisa Operacional*: 170 aplicações em estratégia, finanças, logística, produção, marketing e vendas. Rio de Janeiro: LTC.

Cook, W. D. & Zhu, J. (2008). *Data envelopment analysis:* modeling operational processes and measuring productivity. Dordrecth: Kluwer Academic Publishers.

Corbucci, P. R. (2000). *As universidades federais*: gasto, desempenho, eficiência e produtividade. Brasília: Ipea.

Corbucci, P. R. (2007). *Desafios da educação superior e desenvolvimento no Brasil*. Brasília: IPEA.

Costa, E. M., Ramos, F. S. & Souza, H. R. (2010). Mensuração de Eficiência Produtiva das Instituições Federais de Ensino Superior (Ifes). *Finanças públicas* – XV Prêmio Tesouro Nacional. Retrieved October 10, 2015, from http://www3.tesouro.fazenda.gov.br/Premio_TN/XVPremio/qualidade/2qualidadeXVPTN/Tema_2_2.pdf

Costas, R. & Bordons, M. (2007). The h-index: Advantages, limitations and its relation with other bibliometric indicators at the micro-level. *Journal of Informetrics*, Amsterdam, 1, 193-203.

Cruz, I. B. (2004). *A Experiência do TCU com Indicadores de Gestão das IFES.* Seminário Diálogo Público – TCU: Brasília.

Curi, M. A. (2015). *Eficiência de universidades federais no uso de recursos renováveis.* Ph.D. dissertation in administration – Federal University of Lavras, Lavras, Brazil.

Daraio, C. & Simar, L. (2007). *Advanced Robust and Nonparametric Methods in Efficiency Analysis: methodology and applications*. New York: Springer Science & Business Media.

Debreu, G. (1951). The coefficient of resource utilization. *Econometrica*, New York, 19(3), 273-292.

Dufrechou, P. A. (2016). The efficiency of public education spending in Latin America: A comparison to high-income countries. *International Journal of Educational Development,* Elservier, 49, 188-203.

Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society*, Londres, 120(3), 253-290, A, III.

Ferreira, C. M. C. & Gomes, A. P. (2012). *Introdução à análise envoltória de dados*: teoria, modelos e aplicações. Viçosa: UFV.

Fuentes, R., Fuster, B. & Lillo-Bañuls, A. (2016). A three-stage DEA model to evaluate learning-teaching technical efficiency: Key performance indicators and contextual variables. *Expert Systems With Applications*, Elservier, 48, 89-99.

Golany, B. & Roll, Y. (1989). An application procedure for DEA. *Omega – International Journal of Management Science,* Elservier, 17(3), 237-250.

Gomes, J. A.V. (2016). *Eficiência do gasto público em educação superior:* um estudo sobre as universidades federais do estado de Minas Gerais. Final thesis. Graduate Program in Public Administration in National Network (PROFIAP) – Federal University of Viçosa, Viçosa, Brazil.

Gomes, A. P. & Baptista, A. J. M. S. (2004). *Análise envoltória de dados*. In: Santos, M. L. & Vieira, W. C. (Eds.). Métodos quantitativos em economia. Viçosa: UFV.

Haynes, E. K. & Dinc, M. (2005). Data Envelopment Analysis (DEA). In: KEMPFLEONARD, K. (Ed.). *Encyclopedia of social measurement*. (v. 1). New York: Elsevier, p. 609-616.

Hsu, F. & Hsueh, C. (2009). Measuring relative efficiency of government-sponsored R&D projects: a three-stage approach. *Evaluation and Program Planning*, Oxford, 32 (2), 178-186.

Koopmans, T. C. (1951). *Analysis of production as an efficient combination of activities*. Nova York: Wiley.

Kozyreff Filho, E. & Milioni, A. Z. (2004). Um método para estimativa de metas DEA. *Revista Produção*, São Paulo, 14(2), 270-281.

Lapa, J. S., Belloni, J. A. & Neiva, C. C. (1997). *Medida de desempenho de unidades acadêmicas de uma instituição de ensino superior*. Florianópolis: UFSC.

Lapa, J. S. & Neiva, C. C. (1996). Avaliação em Educação: comentários sobre desempenho e qualidade. *Ensaio: avaliação e políticas públicas em educação*, Rio de Janeiro, 4(12), 213-236.

Lins, M. P. E. & Meza, L. A. (2000). *Análise envoltória de dados e perspectivas de integração no ambiente de apoio à decisão*. Rio de Janeiro: COPPE/UFRJ.

Marconi, M. A. & Lakatos, E. M. (2007). *Metodologia científica:* ciência e conhecimento científico, métodos científicos, teoria, hipóteses e variáveis. (5a ed.). São Paulo: Atlas.

Marinho, A. & Cardoso, S. S. (2007). *Avaliação da eficiência técnica e da eficiência de escala do sistema nacional de transplantes*. Discussion paper n. 1260. Rio de Janeiro: IPEA.

Marini, C. & Martins, H. (2004). Um Governo Matricial: estruturas em rede para geração de resultados de desenvolvimento, IX Congresso Interamericano do Clad sobre a Reforma do Estado e da Administração Pública, *Anais...*, Madri.

Martos, E. (2013). *O conteúdo jurídico do princípio da eficiência no direito financeiro*. Master's thesis in law – School of Law of the University of São Paulo, São Paulo.

Mello, J. C. C. B. S., Gomes, E. G., Meza, L. A. & Mello, M. H. C. S. (2003). Uma análise da qualidade e da produtividade de programas de pós-graduação em Engenharia. *Ensaio*: avaliação e políticas públicas em educação, Rio de Janeiro, 11 (39), 167-179.

Menezes, E. T. & Santos, T. H. (2001). Verbete IQCD (Índice de Qualificação do Corpo Docente). *Dicionário Interativo da Educação Brasileira - Educabrasil*. São Paulo: Midiamix. Retrieved November 08, 2019, from https://www.educabrasil.com.br/iqcd-indice-de-qualificacao-do-corpo-docente/

Meyer Júnior, V. (1993). A busca da qualidade nas instituições universitárias. *Enfoque*, Rio de Janeiro, 10 (set), 18-21.

Moreira, N. P. (2018). *Análise espacial e temporal da eficiência relativa em universidades federais brasileiras sob a política pública REUNI*. Ph.D. dissertation in administration – Federal University of Lavras, Lavras, Brazil.

Moreno, A.C. (2018). *90% das Universidades Federais tiveram perda real no orçamento em cinco anos; verba nacional encolheu 28%*. G1 Educação, São Paulo, June 29, 2018. Retrieved November 08, 2019, from https://g1.globo.com/educacao/noticia/90-das-universidades-federais-tiveram-perda-real-no-orcamento-em-cinco-anos-verba-nacional-encolheu-28.ghtml

Mueller, S. P. M. & Perucchi, V. (2014). Universidades e a produção de patentes: tópicos de interesse para o estudioso da informação tecnológica. *Perspectivas em Ciência da Informação,* Belo Horizonte, 19(2),15-36.

Neves, D. S. & Malta; S. C. L. (2014). Ensino, pesquisa e extensão: existem dificuldades docentes no ensino superior para esta integração? *Form@re – Revista do Plano Nacional de Formação de Professores da Educação Básica.* Federal University of Piauí, Teresina, 2(1), 2-12.

Nuintin, A. A. (2014) *Eficiência da aplicação de recursos públicos nas Universidades Federais.* Ph.D. dissertation in administration – Federal University of Lavras, Lavras, Brazil.

Oliveira, C. E. M. & Turrioni, J. B. (2006). Avaliação de desempenho de Instituições Federais de Ensino Superior através da Análise por Envoltória de Dados (DEA). In: ENEGEP, 26., 2006. *Anais...* Fortaleza, p. 1-8. Retrieved November 08, 2017, from http://www.iem.unifei.edu.br/turrioni/congressos/ENEGEP/2006/Avaliacao_de_desempenho_de_instituicoes_federais_de_ensino_superior_atraves_da_analise_por_envoltoria_de_dados_(DEA).pdf

Ospina, G. L. (1990). Definição de uma agenda para o ensino superior nos anos 90. In: CRUB**.** *Universidade, Estado e Sociedade na década de 90*. Brasília.

Petrucci, V. & Schwarz, L. (1999). *Administração pública gerencial:* a reforma gerencial de 1995. Ensaios sobre a reforma administrativa brasileira no limiar do século XXI. Brasília: UnB.

Pivetta, H. M. F., Backes, D. S., Carpes, A., Battistel, A. L. H. T. & Marchiori, M. (2010). Ensino, Pesquisa e Extensão Universitária: Em busca de uma integração efetiva. *Linhas Críticas,* Brasília, 16(31), 377-390.

Revilla, E., Sarkis, J. & Modrego, A. (2003). Evaluating performance of publicprivate research collaborations*. Journal Operational Research Society*, Oxford, 54 (2), 165-174.

Santos, B. S. (2004). *A universidade no século XXI*. São Paulo: Cortez.

Severino, A. J. (2006). A avaliação no PNPG 2005-2010 e a política de pós-graduação no Brasil. In: Ferreira, N. S. C. (Org.). *Políticas públicas e gestão da educação:* polêmicas, fundamentos e análises. Brasília: Líber Livro, 51-74.

Silva, A. A. P., Ferreira, M. A. M., Braga, M. J. & Abrantes, L. A. (2012). Eficiência na alocação de recursos públicos destinados à educação, saúde e habitação em municípios mineiros. *Contabilidade, gestão e governança*, Brasília, 15 (1), 96-114.

Sonje, A.; Deskar-Skrbic, M. & Sonje, V. (2018). Efficiency of public expenditure on education: comparing Croatia with other nms. INTED2018 CONFERENCE 5th-7th March 2018. *Proceedings*... Valencia, Spain, 2317- 2326.

Tavares, M. G. M., Oliveira, M. A. A. & Seiffert, O. M. L. B. (2011). Avaliação da educação superior na revista Ensaio: Avaliação e Políticas Públicas em Educação: ênfases e tendências. *Ensaio: Avaliação e Políticas Públicas em Educação*, Rio de Janeiro, 19 (71), 233-258.

Tribunal de Contas da União. (2006). *Orientações para o cálculo dos indicadores de gestão:* decisão plenária nº 408/2002. Brasília.

Wen-Chih, C., Shu, C. H. & Chih-Wei, L. (2012). Determine product family mix and priority mix for semiconductor fabrication. *European Journal of Operational Research*, Amsterdam, 2, 6.

AUTHORS' CONTRIBUTIONS

Contributions	Franciane de Oliveira Alvarenga	Pierre Ohayon
1. Idealization and conception of the research subject and theme	✓	
2. Definition of the research problem	✓	
3. Development of Theoretical Platform	✓	
4. Design of the research methodological approach	✓	
5. Data collection	✓	
6. Analyses and interpretations of collected data	✓	
7. Research conclusions	✓	
8. Critical review of the manuscript	✓	
9. Final writing of the manuscript, according to the rules established by the Journal.	✓	
10. Research supervision		✓