Research, Society and Development, v. 11, n. 5, e59411528760, 2022
(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v11i5.28760

Efficiency assessment of Brazilian Universities: a data envelopment analysis model

Avaliação de eficiência de universidades brasileiras: um modelo de análise envoltória de dados

Evaluación de la eficiencia de las universidades brasileñas: un modelo de análisis envolvente de datos

Received: 04/02/2022 | Reviewed: 04/09/2022 | Accept: 04/12/2022 | Published: 04/17/2022

Denise Pinho Pereira
ORCID: https://orcid.org/0000-0002-3336-9002
Federal University of Tocantins, Brazil
E-mail: denisepp@uft.edu.br
Waldecy Rodrigues
ORCID: https://orcid.org/0000-0002-5584-6586
Federal University of Tocantins, Brazil
E-mail: waldecy@uft.edu.br
Wagner Vilas Boas
ORCID: https://orcid.org/0000-0003-0220-3197
Federal University of Brasilia - Brazil
E-mail: wagner.wvbs@gmail.com
David Nadler Prata
ORCID: https://orcid.org/0000-0002-1414-4000
Federal University of Tocantins, Brazil
E-mail: ddnprata@uft.edu.br
Marcelo Lisboa Rocha
ORCID: https://orcid.org/0000-0002-4034-0021
Federal University of Tocantins, Brazil
E-mail: mlisboa@uft.edu.br
Daniela Mascarenhas de Queiroz Trevisan
ORCID: https://orcid.org/0000-0003-3677-0851
Federal University of Tocantins, Brazil
E-mail: danielatrevisan@uft.edu.br

Abstract
This article aims to analyze the efficiency level of 53 Brazilian Federal Universities (IFES) with the purpose to determine the goals that non-efficient universities should reach to the production frontier. The method used was the Data Envelopment Analysis - DEA model CCR (Constant Returns to Scale), using management indicators stipulated by the Federal Court of Auditors (TCU) for 2017 as inputs and outputs. 35.48% of the largest Brazilian universities and 31.82% of the intermediate size universities were considered efficient. Results propose goals for each inefficient institution to reach the production frontier, with the intention to promote their Indicators and to improve the Graduation Success Rate and the overall concept of the Coordinating Agency for Improvement of Personal Graduate Education – CAPES. The conclusion is that the assessment of the performance of the universities using TCU indicators concentraded most of the institutions considered as “efficient” in the South and Southeast regions of the country.
Keywords: Data envelopment analysis; Efficiency; Federal Universities.

Resumo
Este artigo analisa o nível de eficiência de 53 Universidades Federais brasileiras (IFES) para determinar as metas que as universidades não eficientes devem atingir na fronteira produtiva. O método utilizado foi a Análise Envoltória de Dados – modelo DEA CCR (Constant Returns to Scale), utilizando como entradas e saídas os indicadores de gestão estipulados pelo Tribunal de Contas da União (TCU) para o ano de 2017. 35,48% das maiores universidades brasileiras e 31,82% das universidades de médio porte foram consideradas eficientes. Os resultados propõem metas para que cada instituição ineficiente alcance a fronteira de produção, com o intuito de promover seus Indicadores e melhorar o Índice de Sucesso na Graduação e o conceito geral de Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – CAPES. A conclusão é que a avaliação do desempenho das universidades por meio dos indicadores do TCU concentrou a maioria das instituições consideradas “eficientes” nas regiões Sul e Sudeste do país.
Palavras-chave: Análise envoltória de dados; Eficiência; Universidades Federais.

Resumen
Este artículo tiene como objetivo analizar el nivel de eficiencia de 53 Universidades Federales Brasileñas (IFES) con el fin de determinar las metas que las universidades no eficientes deben alcanzar en la frontera de producción. El método

utilizado fue el Análisis Envolvente de Datos - DEA modelo CCR (Retornos Constantes a Escala), utilizando como entradas y salidas los indicadores de gestión estipulados por el Tribunal de Cuentas Federal (TCU) para 2017. El 35,48% de las mayores universidades brasileñas y el 31,82% de las universidades de tamaño intermedio fueron consideradas eficientes. Los resultados proponen metas para que cada institución ineficiente alcance la frontera productiva, con la intención de promover sus indicadores y mejorar la Tasa de Éxito de Graduación y el concepto general de la Agencia Coordinadora para el Mejoramiento de la Educación Personal de Posgrado – CAPES. La conclusión es que la evaluación del desempeño de las universidades a través de los indicadores del TCU concentró la mayoría de las instituciones consideradas como “eficientes” en las regiones Sur y Sudeste del país.
Palabras clave: Análisis envolvente de datos; Eficiencia; Universidades Federales.

1. Introduction

Issues related to performance evaluation are increasingly on the agenda of Federal Universities (IFES). In the 1980s and 1990s, the IFES assessment process was intensified in the past century, establishing systems for assessing student performance, as well as the systematization of indicators on the conditions of this performance, such as infrastructure conditions, human resources in particular qualification of the teaching staff. Among the instruments used in this period are the Institutional Evaluation Program of Brazilian Universities (PAIUB) and the National Examination of Courses.

From the beginning of the 21st century, with the significant increase in the number of federal educational institutions in the country through the process of expanding higher education, the Ministry of Education realized the need to create an evaluation system that was broader and more integrated. For this purpose, Law 10.861 of April 14, 2004, created the National Higher Education Assessment System (SINAES) with the objective of evaluating all aspects that revolve around teaching, research, extension, social responsibility, student performance, institution management, faculty, and facilities (Brasil, 2004).

From this same context, the external evaluation that is the responsibility of the Federal Court of Auditors (TCU) established Decision 408/2002 (Brasil, 2002) delimiting a series of performance indicators to be included in the respective Management Reports of each university, with the objective of aiding the administration regarding the historical monitoring of its indexes, providing important support for institutional self-assessment.

These assessments are composed of performance indicators that allow analyzing the quality by higher education institutions in Brazil. The information that is obtained with these indexes can guide the IFES in the creation of public policies aimed at improving undergraduate and graduate courses, strengthening research, as well as improving the organization. That said, it is extremely important that the focus of federal public institutions be on the development of quality indicators that promote a clear interpretation of the data and make it possible to analyze the efficiency and productivity of the actions performed, to optimize the available resources, directing them those for the priority areas that were detected in the evaluation process.

Megginson et al. (1998) define efficiency as the relationship between input and product (input and output). An efficient institution achieves higher products (results, productivity, performance) related to the inputs (labor, material, money, machines, and time) necessary to achieve them. The organization that minimizes the cost of the resources used to reach a certain purpose is considered efficient or can maximize the results with a certain amount of inputs.

Dufrechou (2016), discusses that more efficient public institutions reduce budgetary problems, obtaining equal results with fewer resources, and Irina-Ştefana (2014) points out that performance measurement can provide information with quantitative and qualitative information that can lead managers improving the quality of public services.

Ferreira and Gomes (2009) argue that from an economic point of view, efficiency is a relative concept defined by the comparison between different production units that use the same inputs to produce the same product. Tupy and Yamaguchi (1998) complement that the efficiency of a productive unit, is understood as a comparison between observed values and optimum values of inputs and products. This comparison can take the form of a relationship between the quantity of the product obtained and its maximum level, given the quantity of the input used, or the relationship of the quantity of input used and its minimum required to produce, given the quantity of product obtained, or some combination of the two.

Given this context, the research objective is to analyze the efficiency level of Brazilian Federal Universities, through the projection of the production frontier of each Higher Education Institution and later to verify the Federal Higher Education Institutions that are benchmarks for the other IFES inefficient, in addition to determining the goals that non-efficient IFES need to reach to reach the production frontier.

2. Methodology

2.1 Data Envelopment Analysis

As a model of quantitative analysis, an application of Data Envelopment Analysis (DEA) was carried out, with the aim of evaluating the efficiency of Federal Universities, as well as identifying which were the inefficient units and what they needed to do to improve their performance. The DEA method is used in different segments of research, including government programs (Revilla et al., 2003; Hsu & Hsueh, 2009).

Amaral (1999) reports that Data Envelopment Analysis is a non-parametric method that allows to evaluate the relative efficiency of the so-called Decision-Making Units - DMU's, where each unit is characterized by an operation plan that relates the quantities of inputs consumed and the products (output) generated. Efficiency is relative because it compares the productivity of the DMU° executed plan (observed) in relation to the productivity of the operation plans executed by the other DMU's.

Charnes, Cooper, and Rhodes (1978) developed the technique of building production boundaries and production efficiency indicators, with multiple inputs and multiple products, from studies on the concept of efficiency and on its measurement. This technique was called Data Envelopment Analysis (DEA). This model has the primary objective of comparing several DMU's (Decision Making Units) that perform similar tasks and differ in the quantities of inputs they consume and the outputs they produce.

Charnes et al. (1997) highlights that there are several formulations of DEA models. However, in this research we used the model called CCR (Charnes et al., 1978), also known as CRS (Constant Returns to Scale), which evaluates the total efficiency, identifies the efficient and non-efficient DMU's efficient and determines how far from the linear efficiency boundary the non-efficient units are.

In the case of formulations, as they are radial models, there is also a need to fix the analysis point of view (input orientation or output orientation). In this study, the choice was to orient the outputs since the objective is to keep the quantity of inputs (inputs) unchanged, seeking a greater production of outputs (products). Figure 1 presents the model's calculation format as a mathematical programming problem.

In the model in the form of multipliers, weights are decision variables and contribute to cases where inputs and outputs may have different orders of magnitude. The envelope model allows to determine the goals for each inefficient DMU to become efficient, as well as to identify which efficient units are considered benchmarks for non-efficient units. Then, in the envelope model, the benchmarks of inefficient units are those in which the λ (lambda) coefficients obtained are different from zero.

It is important to understand that the standard boundary model allows each DMU to choose the weights for each variable in a way that improves its result, and the DMU will choose weights that favor its efficiency, reducing the discrimination power of the models by pointing out many DMU's in the set as being efficient. This benevolence is limited in the CCR and BCC models in which many units are considered efficient, generating many ties at the level of 100% efficiency (Ferreira & Gomes, 2009).

To improve this model discrimination problem, Mello et al. (2005) presents the concept of inverted frontier in which it offers a solution when exchanging inputs for outputs of the original model. This inverted frontier is made up of DMU's with the worst management practices (and can be called an inefficient frontier). It can also be said that DMU's belonging to the inverted border have the best practices from an opposite perspective. For this reason, the author proposes that in order DMU's, an aggregate efficiency index must be calculated, which is the arithmetic mean between efficiency in relation to the original frontier and inefficiency in relation to the inverted frontier.

Figure 1 - CCR models in the form of multipliers and in the form of the envelope according to Mello et al. (2005) oriented to outputs.

CCR Model in multiplier form	**CCR Model in envelope form**
$$Min\ h_0 = \sum_{i=1}^{r} v_i \,.\, x_{i0}$$ Subject to: $$\sum_{j=1}^{s} u_j \,.\, y_{j0} = 1$$ $$\sum_{j=1}^{s} u_j \,.\, y_{jk} - \sum_{i=1}^{r} v_i \,.\, x_{ik} \leq 0\ \forall k$$ $v_i\,, u_j \geq 0, \forall\, j, i$ where: u_j = weight calculated to output j v_i = weight calculated to input i x_{ik} = quantity of input i to unit k of a specific sector y_{jk} = quantity of output j to unit k of a specific sector x_{i0} = quantity of input i to the unit in analysis y_{j0} = quantity of output j to the unit in analysis s = number of outputs r = number of inputs h_0 = is the inverse of efficiency (h_0 =1/ Eff_0)	$$Max\ h_0$$ Subject to: $$x_{i0} - \sum_{k=1}^{n} x_{ik}\lambda_k \geq 0, \forall i$$ $$-h_0 y_{j0} + \sum_{k=1}^{n} y_{jk}\lambda_k \geq 0, \forall j$$ $\lambda_k \geq 0, \forall k$ where: x_{i0} = quantity of input i to the unit in analysis x_{ik} = quantity of input i to unit k of a specific sector λ_k = is the contribution of *DMU* k to the formation of target of DMU_0 (under analysis) y_{j0} = quantity of output j to the unit in analysis y_{jk} = quantity of output j to unit k of a specific sector h_0 = is the inverse of efficiency (h_0 =1/ Eff_0)

Source: Authors.

There is yet another solution that can be applied called the compound frontier in which the composite efficiency scores are obtained through the arithmetic mean between the standard efficiency and the inefficiency (1 minus efficiency) related to the inverted frontier. Finally, there is still the possibility of normalizing these scores, dividing all these efficiency scores by the highest score found. (Mello et. al. 2008).

2.2 Empirical research procedures

The main source of data used to choose the variables inputs and outputs was the Annual Management Report of the Federal Court of Accounts for the 2017 information, which contains the indicators that TCU requests annually from universities as an evaluation of the performance of their productive activities in general.

The survey comprised 53 (fifty-three) of the total number of Brazilian Federal Universities. After a review of studies

(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v11i5.28760

on the application of Data Envelopment Analysis in Higher Education in recent years, it was decided to use the variables employed by Costa et al. (2012):

Outputs:

- Graduation Success Rate (TSG)
- Concept for Graduate Studies (CAPES)

Inputs:

- Current Cost / Equivalent Student (CCAE)
- Full Time Student / Equivalent Teacher (ATIPE)
- Full Time Student / Equivalent Employee (ATIFE)
- Faculty Qualification Index (IQCD)

To meet the objectives of this work, it was considered the orientation to outputs, that is, to the product generated, the Capes / MEC Concept for Graduate Studies and the Graduate Success Rate. Since when it comes to providing public service as universities are, the inputs are difficult to change, as there are legal standards to be followed in the IFES, such as the Annual Budget Law that is defined according to federal government criteria, as well as the form of entry of technicians and teachers at the university through a public tender, which imposes legal procedures for increasing and reducing staff.

To minimize problems related to the heterogeneity of IFES, this work sought to insert a complementary technique called cluster analysis or cluster analysis. In this research, after delimiting the sample with 53 (fifty-three) Federal Institutions of Higher Education, these were divided into two groups to classify the proximity between them, considering two variables in this process. The Teaching Staff Qualification Index (IQCD) and CAPES Concept variables were used for Graduate Studies.

The similarity between the samples was calculated in the IBM SPSS software based on the Euclidean distance, using the hierarchical grouping by the Ward method. The Ward method is a hierarchical grouping procedure in which the similarity measure used to join clusters is calculated as the sum of squares between the two groupings made over all variables. This method tends to result in clusters of approximately equal sizes due to its minimization of internal variation (Hair, 2009).

After the result of the IFES grouping, the performance indicators of each decision-making unit (university) delimited in the study were processed in the SIAD v.3.0 software (Integrated Decision Support System) (Meza et al. 2005).

3. Results and Discussion

3.1 Analysis of the efficiency of Brazilian Federal Universities

After performing the cluster analysis with the sample of 53 IFES, Table 1 shows the formation of the two groups, after analyzing the dendrogram, and the average values of the two variables used in the conglomerate.

Table 1 - Groups formed.

GROUP 1		GROUP 2	
UFRGS	UFBA	UFERSA	UFAM
UFRJ	UFRPE	UNIRIO	UFTM
UFMG	UFPA	UFMS	UFT
UFPEL	UFF	UFPI	UFRA
UFSC	UFRN	UNIR	UFFS
UFV	UFABC	UFSJ	UFAC
UFRRJ	UFPB	UFS	UFRR
UFLA	UFGD	UFMA	
Unifesp	FURG	UFAL	
UFC	UFOP	UNIFEI	
UNB	UFES	UFMT	
UFPR	UFJF	UNIFAL	
UFSCAR	UFCG	UNIVASF	
UFSM	UTFPR	UFVJM	
UFPE	UFG	UNIPAMPA	
UFU			
Mean IQCD= 4,53 Mean Capes Concept = 4,31		Mean IQCD= 4,16 Mean Capes Concept = 3,42	

Source: Authors.

Table 2 shows the scores calculated for standard efficiency, inverted efficiency, composite efficiency and for the normalized composite efficiency of the IFES in Group 1. The result showed that eleven universities with score 1 were considered efficient: UFMG, UFCG, UFPR, UFRJ, UFRGS, UFV, UNB, UFPA, UFJF, UTFPR and UFPEL which represent 35.48% of the total IFES in Group 1.

Continuing the analysis of Table 2 referring to Group 1, we have that IFES with scores below 1 in the standard efficiency result were considered by the method as inefficient, in the total of 20 (twenty) Educational Institutions, even with the lowest weights advantageous processed by the model. 64.52% of the total of thirty-one IFES in Group 1 are represented, and the three universities with the lowest indexes were UFF with 0.76, FURG with 0.80 and UFPB with 0.82.

Table 2 - Efficiency Frontier - Group 1.

DMU	Standard	Inverted	Composite	Normalized Composite
UFMG	1	0,8455	0,5772	1
UFCG	1	0,8495	0,5752	0,9965
UFPR	1	0,8845	0,5578	0,9663
UFRJ	1	0,9337	0,5332	0,9237
UFRGS	1	0,9402	0,5299	0,9180
UFV	1	0,9625	0,5188	0,8987
UNB	1	0,9632	0,5184	0,8981
UFPA	1	0,9735	0,5132	0,8892
UFJF	1	0,9919	0,5040	0,8732
UTFPR	1	0,9947	0,5026	0,8708
UFPEL	1	0,9952	0,5024	0,8704
UFLA	0,9646	0,9958	0,4844	0,8392
UFC	0,9625	0,9173	0,5226	0,9053
UFSC	0,9523	0,8788	0,5368	0,9299
UFOP	0,9487	0,8890	0,5298	0,9179
UFSM	0,9473	0,8925	0,5274	0,9137
UFBA	0,9436	1	0,4718	0,8174
UFG	0,9431	0,9230	0,5100	0,8835
UFRRJ	0,9406	0,9455	0,4976	0,8620
UFU	0,9380	0,9314	0,5033	0,8719
UFRPE	0,9099	1	0,4550	0,7882
UFABC	0,9065	1	0,4532	0,7852
UFES	0,8909	0,9679	0,4615	0,7995
UFPE	0,8770	0,9538	0,4616	0,7997
UFRN	0,8683	0,9720	0,4481	0,7763
UFSCAR	0,8624	0,9545	0,4540	0,7865
Unifesp	0,8541	0,9470	0,4535	0,7857
UFGD	0,8351	1	0,4176	0,7234
UFPB	0,8285	0,9768	0,4259	0,7378
FURG	0,8061	1	0,4030	0,6982
UFF	0,7663	1	0,3832	0,6638

Source: Own elaboration based on SIAD data (2020).

Table 3 shows the scores calculated for standard efficiency, inverted efficiency, composite efficiency and for the standardized composite efficiency of the IFES in Group 2, which is the group with the lowest average in the graduate indexes. The result achieved in the standard efficiency item shows that 07 (seven) federal universities were considered efficient with a score of 1: UFPI, UFERSA, UFVJM, UNIVASF, UFRA, UFSJ and UNIFAL, representing 31.82% of the total IFES in Group 2.

It is also verified that the 15 (fifteen) IFES considered inefficient by the standard model, which represent 68.18% of the total of twenty-two universities in Group 2, with emphasis on the three with the lowest indexes, the UFFS with 0.80, UFAC with 0.81 and UFS with 0.87, according to Table 3.

Table 3 - Efficiency Frontier - Group 2.

DMU	Standard	Inverted	Composite	Normalized Composite
UFPI	1	0,7763	0,6119	1
UFERSA	1	0,7976	0,6012	0,9826
UFVJM	1	0,8382	0,5809	0,9494
UNIVASF	1	0,8623	0,5689	0,9297
UFRA	1	0,9089	0,5456	0,8916
UFSJ	1	0,9394	0,5303	0,8667
UNIFAL	1	0,9260	0,5370	0,8776
UNIR	0,9980	0,9258	0,5361	0,8762
UFMA	0,9917	0,8574	0,5671	0,9269
UNIFEI	0,9800	0,9268	0,5266	0,8606
UFTM	0,9790	0,9917	0,4936	0,8068
UFRR	0,9655	1	0,4828	0,7890
UNIPAMPA	0,9487	0,9187	0,5150	0,8417
UFAL	0,9257	1	0,4629	0,7565
UFMT	0,9206	0,8458	0,5374	0,8783
UFAM	0,9165	0,8562	0,5302	0,8665
UFT	0,9119	0,8795	0,5162	0,8437
UNIRIO	0,9085	1	0,4542	0,7424
UFMS	0,9083	0,8538	0,5272	0,8617
UFS	0,8705	0,9473	0,4616	0,7544
UFAC	0,8113	1	0,4057	0,6630
UFFS	0,8055	1	0,4027	0,6582

Source: Own elaboration based on SIAD data (2020).

It is important to understand that the benchmarks of inefficient units are determined by their projection on the efficiency frontier, the benchmark being a unit in which the other inefficient unit can mirror itself. These references for inefficient units are those in which the obtained coefficients are different from zero and the benchmarks of the units considered efficient are themselves. Table 4 presents the result of the references in Group 1 and Table 5 for Group 2.

Table 4 - Benchmarks of IFES for inefficient Group 1.

DMU	UFRGS	UFRJ	UFMG	UFPEL	UFV	UNB	UFPR	UFPA	UFJF	UFCG	UTFPR
UFMG			100								
UFPEL				100							
UTFPR											100
UFRGS	100										
UFPA								100			
UFRJ		100									
UNB						100					
UFPR							100				
UFCG										100	
UFJF									100		
UFV					100						
UFSC	53.5		19.2	17.9							9.3
UFRRJ	13.1			54.1			32.7				
UFLA	80.9			1.5		17.7					
Unifesp	29.6	11.4	25.6	33.4							
UFC	39.6		47.3	1.6							11.6
UFSCAR			67.9	9.8		3.9					18.3
UFSM				28.3			28	39	4.6		
UFPE		5.8	80.3							13.9	
UFU			60.4	18.7				19.2			1.8
UFBA			25			64.1		10.9			
UFRPE	0.3			52.1			47.5				
UFF		39.9	44.8							15.4	
UFRN			45.6	16.1				38.3			
UFABC			40.9	9.7		25.8					23.6
UFPB	43.2		3.3	23.3			30.2				
UFGD		3.8	60.6	35.6							
FURG	60.3			38							1.8
UFOP			50.1	28.1				14.9			6.9
UFES			13.6	33.5				38.9			14
UFG			18	28				41			14
Benchmarks	**9**	**5**	**16**	**18**	**1**	**5**	**5**	**8**	**2**	**3**	**10**

*Note: Percentage values. Source: Own elaboration based on SIAD data (2020).

Tabela 5 - Benchmarks of IFES for inefficient Group 2.

DMU	UFERSA	UFPI	UFSJ	UNIFAL	UNIVASF	UFVJM	UFRA
UFPI		10					
UFERSA	10						
UFVJM						10	
UNIVASF					10		
UFRA							10
UFSJ			10				
UNIFAL				10			
UFMS	54.3	45.7					
UNIRIO	10						
UNIR	82.3	17.7					
UFS	88.9		11.1				
UFMA	32.2					67.8	
UFAL	8.6	91.4					
UNIFEI	1.0	17.3	81.7				
UFMT	62.8	19.5				17.7	
UNIPAMPA	37.7					9.0	53.3
UFAM	35.9	64.1					
UFTM				3.4	15.3		81.4
UFT	39.5	15.8				44.7	
UFFS	34.4					65.6	
UFAC	83.6	16.4					
UFRR	18.9	15.2				65.9	
Benchmarks	**15**	**10**	**3**	**2**	**2**	**7**	**3**

*Note: Percentage values. Source: Own elaboration based on SIAD data (2020).

It is noticeable that the applied model resulted in several benchmarks for each inefficient IFES, some with strong partnership indexes and others with weak indexes, but the important thing is to understand that the non-efficient units, through the result of these references, consider the efficient IFES as references to followed to improve their performance indicators.

According to Table 6 for Group 1 described, the current values of inputs and the desirable values for these inputs are presented. These targets or targets are calculated with a view to projecting inefficient IFES at the efficiency frontier, considering their benchmarks. A reference is considered for the expected values, for each input and output in a situation in which the inefficient university, according to the model, becomes efficient.

Interpreting the result in Table 6, it is analyzed that, in relation to the outputs produced, the inputs CCAE, ATIFE, ATIPE or IQCD, in some cases, are higher than necessary in relation to the performance of the set of IFES analyzed. The use of the DEA model does not allow us to request that this factor never suffer an indication of decrease, which should always be remembered when interpreting the data.

Even with the suggestions for decreasing some of the inputs of some IFES analyzed, the model requested goals or targets for all CAPES and TSG outputs, which is the main objective of the analysis of the inefficient ones, that is, considering their benchmarks, an increase in products was proposed for reach the production frontier. A percentage was defined for the outputs of each analyzed inefficient institution.

Table 6 - Current Value and Target for each variable, considering each non-efficient IFES of Group 1.

UFSC (efficiency:0,952338)				**Unifesp (efficiency:0,854128)**			
Variable	Current	Target	Target Variation x Current %	Variable	Current	Target	Target Variation x Current %
CCAE (*input*)	21.483,49	21.483,49	0,0%	CCAE (*input*)	25.857,25	25.857,25	0,0%
ATIPE (*input*)	14,30	14,30	0,0%	ATIPE (*input*)	13,83	13,83	0,0%
ATIFE (*input*)	10,74	10,30	-4,1%	ATIFE (*input*)	12,03	8,86	-26,3%
IQCD (*input*)	4,71	4,71	0,0%	IQCD (*input*)	4,92	4,92	0,0%
CAPES (*output*)	4,87	5,11	5,0%	CAPES (*output*)	4,64	5,43	17,1%
TSG (*output*)	48,78	51,22	5,0%	TSG (*output*)	45,73	53,54	17,1%
UFC (efficiency:0,962488)				**UFPE (efficiency:0,876993)**			
Variable	Current	Target	Target Variation x Current %	Variable	Current	Target	Target Variation x Current %
CCAE (*input*)	18.293,02	18.293,02	0,0%	CCAE (*input*)	19.447,83	19.447,83	0,0%
ATIPE (*input*)	14,58	14,58	0,0%	ATIPE (*input*)	15,17	15,03	-0,9%
ATIFE (*input*)	12,71	10,18	-19,9%	ATIFE (*input*)	10,04	8,58	-14,5%
IQCD (*input*)	4,47	4,47	0,0%	IQCD (*input*)	4,47	4,47	0,0%
CAPES (*output*)	4,60	4,78	3,9%	CAPES (*output*)	4,21	4,80	14,0%
TSG (*output*)	53,79	55,89	3,9%	TSG (*output*)	57,24	65,27	14,0%
UFRRJ (efficiency:0,940625)				**UFLA (efficiency:0,964628)**			
Variable	Current	Target	Target Variation x Current %	Variable	Current	Target	Target Variation x Current %
CCAE (*input*)	25.352,23	25.352,23	0,0%	CCAE (*input*)	17.487,31	17.487,31	0,0%
ATIPE (*input*)	11,56	11,56	0,0%	ATIPE (*input*)	15,20	15,20	0,0%
ATIFE (*input*)	7,25	7,25	0,0%	ATIFE (*input*)	9,39	9,39	0,0%
IQCD (*input*)	4,90	4,63	-5,5%	IQCD (*input*)	4,81	4,38	-8,9%
CAPES (*output*)	4,71	5,01	6,3%	CAPES (*output*)	4,65	4,82	3,7%
TSG (*output*)	37,00	48,11	30,0%	TSG (*output*)	43,11	46,62	8,1%
UFSCAR (efficiency:0,862402)				**UFU (efficiency:0,937996)**			
Variable	Current	Target	Target Variation x Current %	Variable	Current	Target	Target Variation x Current %
CCAE (*input*)	20.284,15	20.284,15	0,0%	CCAE (*input*)	18.491,43	18.491,43	0,0%
ATIPE (*input*)	14,20	14,20	0,0%	ATIPE (*input*)	13,21	13,21	0,0%
ATIFE (*input*)	11,21	11,21	0,0%	ATIFE (*input*)	8,58	8,58	0,0%
IQCD (*input*)	4,85	4,73	-2,5%	IQCD (*input*)	4,82	4,25	-11,7%
CAPES (*output*)	4,26	4,94	16,0%	CAPES (*output*)	4,19	4,47	6,6%
TSG (*output*)	53,69	62,26	16,0%	TSG (*output*)	56,95	60,71	6,6%
UFABC (efficiency:0,906491)				**UFOP (efficiency:0,948711)**			
Variable	Current	Target	Target Variation x Current %	Variable	Current	Target	Target Variation x Current %
CCAE (*input*)	17.651,93	17.651,93	0,0%	CCAE (*input*)	18.330,51	18.330,51	0,0%
ATIPE (*input*)	12,41	12,41	0,0%	ATIPE (*input*)	11,24	11,24	0,0%
ATIFE (*input*)	11,06	11,06	0,0%	ATIFE (*input*)	8,18	8,18	0,0%
IQCD (*input*)	5,00	4,21	-15,8%	IQCD (*input*)	4,28	3,92	-8,4%
CAPES (*output*)	3,94	4,35	10,3%	CAPES (*output*)	3,91	4,12	5,4%
TSG (*output*)	45,62	50,33	10,3%	TSG (*output*)	49,00	51,65	5,4%

Source: Own elaboration based on SIAD data (2020).

In the general analysis of Table 6, there is a variation in the results suggested by the model, but in all cases, there is a recommendation to increase TSG and CAPES, which are the main goals for inefficient institutions to reach the production frontier. In some variables, the reduction in inputs was suggested, however, the reductions and additions requested were based on the benchmarks of each inefficient IFES. What can be interpreted in these data is that even with excess inputs presented by inefficient IFES, it did not imply improvements in the Capes Concept and in the Graduation Success Rate. In the case of the excess of IQCD, it can be interpreted as underutilization of qualified teachers.

In relation to Table 7, the DEA-CCR also recommended goals to be achieved for inefficient universities. It can be seen in the results of Group 2 that in some cases it was also proposed to reduce inputs, in addition to the increase in products already expected by the model. The results of the model suggested a reduction in the inputs CCAE, ATIPE, ATIFE, that is, it was shown that there are excesses in the indicators Current Cost per Equivalent Student, Full Time Student per Equivalent Teacher, and Full Time Student per Equivalent Employee.

Table 7 - Current Value and Target for each variable, considering each non-efficient IFES of Group 2.

UNIRIO (efficiency:0,908481)				**UFMS (efficiency:0,908260)**			
Variable	Current	Target	Target Variation x Current %	Variable	Current	Target	Target Variation x Current %
CCAE (*input*)	24.026,72	15.535,78	-35,3%	CCAE (*input*)	22.562,40	16.522,23	-26,8%
ATIPE (*input*)	12,97	11,17	-13,9%	ATIPE (*input*)	13,42	12,06	-10,1%
ATIFE (*input*)	12,95	9,88	-23,7%	ATIFE (*input*)	10,76	10,02	-6,9%
IQCD (*input*)	4,3	4,30	0,0%	IQCD (*input*)	4,29	4,29	0,0%
CAPES (*output*)	3,67	4,04	10,1%	CAPES (*output*)	3,65	4,02	10,1%
TSG (*output*)	22,77	39,88	75,1%	TSG (*output*)	44,28	48,75	10,1%
UNIR (efficiency:0,997953)				**UFAC (efficiency:0,811308)**			
Variable	Current	Target	Target Variation x Current %	Variable	Current	Target	Target Variation x Current %
CCAE (*input*)	23.925,16	14.001,78	-41,5%	CCAE (*input*)	17.320,62	14.566,26	-15,9%
ATIPE (*input*)	13,78	10,13	-26,5%	ATIPE (*input*)	18,06	10,53	-41,7%
ATIFE (*input*)	10,41	8,74	-16,0%	ATIFE (*input*)	14,54	9,11	-37,4%
IQCD (*input*)	3,78	3,78	0,0%	IQCD (*input*)	3,94	3,94	0,0%
CAPES (*output*)	3,54	3,55	0,2%	CAPES (*output*)	3	3,70	23,3%
TSG (*output*)	38	38,08	0,2%	TSG (*output*)	32	39,44	23,3%
UFS (efficiency:0,870458)				**UFMT (efficiency:0,920553)**			
Variable	Current	Target	Target Variation x Current %	Variable	Current	Target	Target Variation x Current %
CCAE (*input*)	15.383,80	15.383,80	0,0%	CCAE (*input*)	21.287,27	16.539,04	-22,3%
ATIPE (*input*)	14,04	11,72	-16,5%	ATIPE (*input*)	10,65	10,65	0,0%
ATIFE (*input*)	13,83	10,41	-24,7%	ATIFE (*input*)	9,15	9,00	-1,7%
IQCD (*input*)	4,39	4,39	0,0%	IQCD (*input*)	4,13	4,13	0,0%
CAPES (*output*)	3,52	4,04	14,9%	CAPES (*output*)	3,5	3,80	8,6%
TSG (*output*)	36	43,28	20,2%	TSG (*output*)	41	44,54	8,6%
UFMA (efficiency:0,991653)				**UFRR(efficiency:0,965546)**			
Variable	Current	Target	Target Variation x Current %	Variable	Current	Target	Target Variation x Current %
CCAE (*input*)	20.478,50	19.207,57	-6,2%	CCAE (*input*)	27.558,23	16.377,26	-40,6%
ATIPE (*input*)	8,89	8,89	0,0%	ATIPE (*input*)	7,76	7,76	0,0%

(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v11i5.28760

ATIFE (*input*)	7,38	7,26	-1,6%	ATIFE (*input*)	6,8	6,20	-8,9%
IQCD (*input*)	4,07	4,07	0,0%	IQCD (*input*)	3,43	3,43	0,0%
CAPES (*output*)	3,52	3,55	0,8%	CAPES (*output*)	2,89	2,99	3,6%
TSG (*output*)	35,36	47,49	34,3%	TSG (*output*)	40,75	42,20	3,6%
UNIPAMPA (efficiency:0,948727)				**UFTM (efficiency:0,979034)**			
Variable	Current	Target	Target Variation x Current %	Variable	Current	Target	Target Variation x Current %
CCAE (*input*)	19.707,85	19.707,85	0,0%	CCAE (*input*)	20.721,93	20.721,93	0,0%
ATIPE (*input*)	9,27	9,27	0,0%	ATIPE (*input*)	11,56	8,50	-26,4%
ATIFE (*input*)	6,76	6,76	0,0%	ATIFE (*input*)	5,1	5,10	0,0%
IQCD (*input*)	4,48	4,31	-3,7%	IQCD (*input*)	4,56	4,27	-6,5%
CAPES (*output*)	3,45	3,64	5,4%	CAPES (*output*)	3,27	3,34	2,1%
TSG (*output*)	39,52	51,80	31,1%	TSG (*output*)	55,06	56,24	2,1%
UFAL (efficiency:0,925730)				**UFAM (efficiency:0,916520)**			
Variable	Current	Target	Target Variation x Current %	Variable	Current	Target	Target Variation x Current %
CCAE (*input*)	18.376,00	16.657,19	-9,4%	CCAE (*input*)	15.736,86	15.251,30	-3,1%
ATIPE (*input*)	13,83	12,32	-10,9%	ATIPE (*input*)	12,93	11,19	-13,4%
ATIFE (*input*)	20,21	9,65	-52,3%	ATIFE (*input*)	10,77	9,08	-15,7%
IQCD (*input*)	4,06	4,06	0,0%	IQCD (*input*)	3,86	3,86	0,0%
CAPES (*output*)	3,51	3,79	8,0%	CAPES (*output*)	3,31	3,61	9,1%
TSG (*output*)	51	55,09	8,0%	TSG (*output*)	43,3	47,24	9,1%
UFT (efficiency:0,911892)				**UFFS (efficiency:0,805456)**			
Variable	Current	Target	Target Variation x Current %	Variable	Current	Target	Target Variation x Current %
CCAE (*input*)	19.155,06	17.720,42	-7,5%	CAE (*input*)	24.543,47	19.952,02	-18,7%
ATIPE (*input*)	9,58	9,58	0,0%	TIPE (*input*)	9,59	9,36	-2,4%
ATIFE (*input*)	8,86	7,88	-11,1%	TIFE (*input*)	7,67	7,67	0,0%
IQCD (*input*)	4	4,00	0,0%	IQCD (*input*)	4,26	4,26	0,0%
CAPES (*output*)	3,26	3,57	9,7%	CAPES (*output*)	3	3,72	24,2%
TSG (*output*)	42,23	46,31	9,7%	TSG (*output*)	34,79	49,38	41,9%
UNIFEI (efficiency:0,979955)							
Variable	Current	Target	Target Variation x Current %				
CCAE (*input*)	12.933,35	12.933,35	0,0%				
ATIPE (*input*)	14,2	13,98	-1,5%				
ATIFE (*input*)	12,51	12,49	-0,2%				
IQCD (*input*)	4,41	4,41	0,0%				
CAPES (*output*)	3,5	3,57	2,0%				
TSG (*output*)	61	62,25	2,0%				

Source: Own elaboration based on SIAD data (2020).

It can also be seen in Table 7 that, the model proposed to all inefficient IFES, additions to all CAPES and TSG variables, which is the main objective of the output-oriented model. It is observed that, in all cases when recommending this reduction of inputs, the model may be demonstrating that these institutions presented difficulties in the optimization of their resources to maximize their products, since when calculating productivity and comparing them to their benchmarks failed to reach the efficiency frontier.

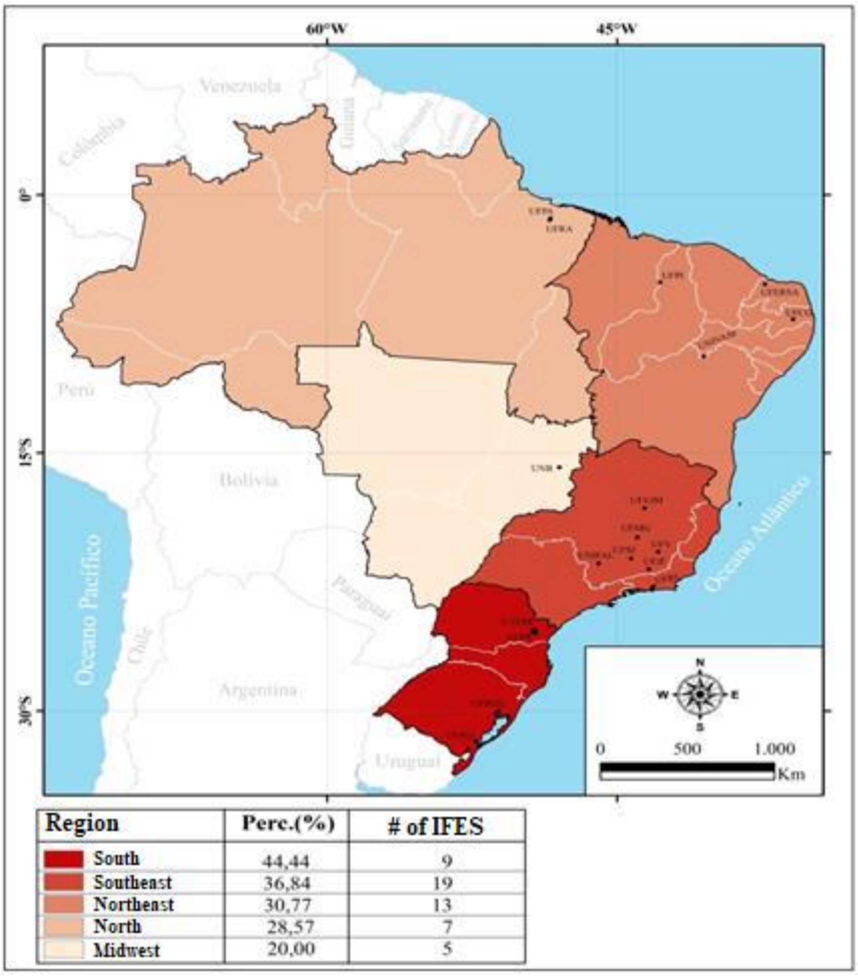
(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v11i5.28760

It can be inferred from these excesses of ATIFE and ATIPE as a model suggestion for the IFES to review their structures, that is, to analyze whether the student / teacher or student / employee relationship is compromising the result of their productivity. In the case of excess CCAE, that is, Student Cost can be interpreted as a recommendation of the method that IFES should review their priorities with public policies adopted to improve their productivity.

On the one hand, the most favorable regional economic conditions are expected to play a part in the efficiency standards of universities in Brazil. For example, it is a plausible hypothesis to suppose that the IFES in the center of southern Brazil are more "efficient" than universities located in the North and Northeast of Brazil. However, there may be successful higher education institutions due to their management and the contingent conditions that surround them.

As shown in Figure 2, the results of this research demonstrate that in relative terms the largest number of efficient universities is concentrated in the South Region, that is, of the total of 9 (nine) of IFES that are in the South Region, 44.44% were considered efficient. Next is the Southeast Region, which out of a total of 19 (nineteen) Federal Institutions of Higher Education 36.84% were defined as efficient by the standard result. In the Northeast Region, 30.77% of the total of 13 (thirteen) IFES was efficient, while in the North Region, of the total of 07 (seven) IFES, also 28.57% was efficient. Finally, in the Midwest, 20% of the total of 05 (five) IFES was considered efficient.

Figure 2 - Percentage of Efficient Universities by Brazilian Region.



Source: Research Data (2020).

Another issue to consider when analyzing Figure 1 is that with the process of regional deconcentration of higher education, in the last fifteen years, many medium-sized universities have excelled in terms of efficiency and resource optimization. As was shown in the research among the IFES considered efficient, UFERSA and UNIVASF are in cities far from large urban centers in the Northeast Region, with UFERSA headquartered in Mossoró-RN, and UNIVASF in the city of Petrolina-PE. In the Southeast Region, the UFVJM universities that have headquarters in the city of Diamantina, UNIFAL, in Alfenas and UFSJ in São João Del Rei, all in the state of Minas Gerais, stand out. All these institutions, which according to the study analyzed, were efficient in their management, especially regarding good rates in graduate school, considering the local reality of each one.

What can be inferred from this, is that in Brazil when universities were created or only campuses in regions with good demographic density, but with low university coverage, it is evident that, even in cities with less purchasing power or with less favorable socioeconomic indexes, it was possible to result in good institutions of higher education.

4. Final Considerations

The objective of this research was to analyze the efficiency level of Brazilian Federal Universities. For this, a sample with 53 IFES was used. The applied methodology was the Data Envelopment Analysis, CCR model (constant scale returns) and the cluster analysis. To homogenize the sample, it was divided into two groups, the first group with the highest rates in research and graduate studies and the second group focusing more on teaching. The indicators chosen for the survey were recommended by the Federal Court of Accounts, with four inputs (CCAE, ATIPE, ATIFE, IQCD) and two outputs (CAPES, TSG).

The results of the standard efficiency found showed that in Group 1 the model presented 11 (eleven) efficient IFES. In Group 2, it resulted in 07 (seven) efficient Universities. In Group 1, the institutions considered efficient were UFMG, UFCG, UFPR, UFRJ, UFRGS, UFV, UNB, UFJF, UFPEL, UTFPR and UFPA representing 35.48% of the total group. In Group 2, the ones considered efficient were UFPI, UFERSA, UFVJM, UNIVASF, UFRA, UFSJ and UNIFAL, which represents 31.82% of the total of Group 2. In the normalized compound efficiency, UFMG was considered highly efficient in Group 1 when obtaining score 1, and in Group 2 UFPI also obtained this score and it is also delimited with high efficiency.

Also, according to the DEA-CCR model, the standard frontier, efficient Universities with a score of 1 became possible benchmarks for inefficient IFES. According to Group 1, UFPEL was considered a reference for 18 (eighteen) non-efficient units, while UFMG was an excellent partner for 16 (sixteen) inefficient units and UFRGS for 09 (nine) IFES, which can be explained by the high indexes Capes Concept and Graduation Success Rate of these institutions. In Group 2, the IFES considered benchmarks for the other inefficient ones were UFERSA being a reference for 15 (fifteen) inefficient units, UFPI considered a benchmark for 10 (ten) units and UFVJM an excellent partner for 7 (seven) inefficient IFES.

Regarding the goals or targets that the DEA-CCR model suggested to inefficient institutions that, to reach the production frontier, they should in all cases increase their Capes Concept and the Graduation Success Rate, varying according to each IFES in relation to comparison with its benchmarks. Result that can contribute to the management of these universities to evaluate their actions and improve their planning and thus increase the efficiency of their bodies.

It is important to note that, in the total of 53 Universities surveyed, 35 IFES, according to the standard frontier, were defined as inefficient, that is, those that did not reach score 1. One of the ways that can lead to improving the indexes of these institutions is to increase the Graduation Success Rates, which includes training in teaching, and the Capes Concept, which evaluates graduate studies and research. It is suggested that there is an internal evaluation of these indexes and that they be invested in public policies aimed at improving these indicators, mainly in the case of TSG, in which, one of the problems of this indicator is due to the high rate of dropout and retention in Higher Education Institutions, that is, many students drop out or fail during their undergraduate periods.

Regarding the result of university performance by region, it was found that the largest number of efficient universities is in the South and Southeast. However, one should not disregard the fact that some universities considered to be medium-sized have excelled in optimizing their resources even though they are in areas with lower socioeconomic indexes such as UFERSA located in Mossoró-RN, or UFVJM in Diamantina-MG.

In this context, it is essential that federal educational institutions find optimizing strategies in the management of undergraduate and graduate courses with a view to increasing their productivity, according to the regional vocations of each institution and its region of coverage. Also, is suggested that new research could consider expanding this study by including input data over the years, allowing to compare the growth between the universities and show which are the variables that can contribute more to the have better efficiency.

References

Amaral, O. D. S. (1999). Avaliação da eficiência produtiva das unidades acadêmicas da universidade do amazonas, nos anos de 1994 e 1995, empregando análise Envoltória de Dados. *Master's dissertation*.

Brasil. (2002). Tribunal de Contas da União - TCU. *Decisão nº408* - Plenário. Relatório Consolidado de Auditoria Operacional. Ata nº 13 – Plenário. Brasília, DF, 24 de abril de 2002. Disponível em: http://portal2.tcu.gov.br/portal/pls/portal/docs/1/ 2045500.PDF.

Brasil. (2004). *Lei n. 10.861*, de 14 de abril de 2004. Institui o Sistema Nacional de Avaliação da Educação Superior-SINAES.

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European journal of operational research*, *2*(6), 429-444.

Charnes, A., Cooper, W., Lewin, A. Y., & Seiford, L. M. (1997). Data envelopment analysis theory, methodology and applications. *Journal of the Operational Research society*, *48*(3), 332-333.

Costa, E. M., Souza, H. R. D., Ramos, F. D. S., & Silva, J. L. M. D. (2012). Eficiência e desempenho no ensino superior: uma análise da fronteira de produção educacional das IFES brasileiras. *Revista de Economia Contemporânea*, 16(3), 415-440.

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

Ferreira, C. M. C. F. & Gomes, A. P. (2009). *Introdução à análise envoltória de dados: teoria, modelos e aplicações*. UFV editora.

Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (2009). *Análise multivariada de dados*. Bookman editora.

Hsu, F. M., & Hsueh, C. C. (2009). Measuring relative efficiency of government-sponsored R&D projects: A three-stage approach. *Evaluation and program planning*, *32*(2), 178-186.

Irina-Ștefana, C. (2014). Development And Efficiency Of Budget Of Public Institutions By The Method Based On Performance. *Management Strategies Journal*, *26*(4), 334-337.

Megginson, L. C., Mosley, D. C., & Pietri, P. H. (1998). *Administração: conceitos e aplicações*. Harba editora.

Mello, J. C. C. B. S., Gomes, E. G., Meza, L. A., & Leta, F. R. (2008). DEA advanced models for geometric evaluation of used lathes. *WSEAS Transactions on Systems*, 7(5), 510-520.

Mello, J. C. C. B. S., Meza, L. A., Gomes, E. G., & Neto, L. B. (2005). Curso de análise de envoltória de dados. *XXXVII Simpósio brasileiro de pesquisa operacional*, 20520-2547.

Meza, L. A., Biondi Neto, L., Mello, J. C. C. B. S. D., & Gomes, E. G. (2005). ISYDS-Integrated System for Decision Support (SIAD-Sistema Integrado de Apoio à Decisão): a software package for data envelopment analysis model. *Pesquisa Operacional*, *25*(3), 493-503.

Revilla, E., Sarkis, J., & Modrego, A. (2003). Evaluating performance of public–private research collaborations: A DEA analysis. *Journal of the Operational Research Society*, *54*(2), 165-174.

Tupy, O., Yamaguchi, L. C. T. (1998). Eficiência e produtividade: conceitos e medição. *Embrapa Pecuária Sudeste-Artigo em periódico indexado (ALICE)*.