SEARCHING FOR THE LOST EFFICIENCY: A REVIEW ABOUT BRAZILIAN UNIVERSITY PERFORMANCE EVALUATION

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ABSTRACT

The recent context of fiscal stringency and contingency in Brazilian economy has highlighted the theme of efficiency in public services, including those provided by Federal Universities. Thus, after a brief review of the data envelopment analysis (DEA) framework, the literature about the application of DEA to Brazilian universities is analyzed following the guidances of Cook, Tone and Zhu (2014). It is the first work that critically analyses the literature about the application of DEA to Brazilian universities following those guidances. The results emphasize that the use of Tribunl de Contas da União (Federal Court of Audit - TCU) 'index values' results in a Multi Criteria Decision Making (MCDM) analysis of performance and not necessarily in efficiency measures. In order to calculate efficiency, the TCU 'raw values' variables are useful but not sufficient. Therefore, caution is required when using all these results in any policy context.
Key-words: Higuer Education. Efficiency. Performance. DEA, Brazil.

RESUMO

O recente contexto de contingência fiscal da economia brasileira tem ressaltado a importância da eficiência nos serviços públicos, incluindo os serviços educacionais prestados pelas universidades públicas. Assim, a literatura sobre aplicação the modelos DEA para instituições de ensino superior brasileiras é analisada seguindo as recomendações de Cook, Tone and Zhu (2014). Este é o primeiro trabalho que realiza este tipo de investigação seguindo tais recomendações. Como resultados tem-se que o uso de 'valores índices' do TCU resultam em medidas de análise multicritério de performance e não necessariamente em medidas de efficiência. Para calcular eficiência, os 'valores brutos' dos relatórios entregues ao TCU são úteis mas não suficientes. Deste modo, recomenda-se cuidado ao utilizar os resultados de tais modelos DEA para determinação políticas públicas.

Palavras chave: de três a cinco, devem aparecer logo abaixo do resumo.

1. INTRODUCTION

In the 21st century the Brazilian expenditures in public higher education has increased by a mean of 2.5% a year, representing approximately 0.8% of the GDP in each year and an equivalent value of USD $ 14 billion in 2016 (INEP, 2017). Despite the 200% increase of Brazilian higher education enrolments in the last two decades, in 2013 not more than 16% of the population between 25-34 years of age had an undergraduate degree and only 11% of the population between 55-64 had it (OCDE, 2015). In 2015 the Brazilian population was more than 200 million and the Brazilian higher education institutions (HEIs) overpassed the historic record of 8 million students enrolled (6 in private and 2 in public universities), the same size of the secondary courses system in that year (SAMPAIO, 2017, p. 28). In addition, only recently a great part of the Brazilian young population is taking a secondary course (IBGE, 2010) and potentially will be able to go to universities.

Inefficiency in higher education institutions raises a concern among policymakers and institutional administrators, as good performance in higher education is believed to produce growth effects (BLANCHARD, 2004). Also, its monetary and non-monetary benefits present strong externality effects overall the entire society (VILA, 2000). As the institutions can differ in their levels of efficiency, "it is important to study differences in efficiency because this offers lessons about good practice" which "can lead to improvements in the performance of the higher education system as a whole." (JOHNES; JOHNES, 2013, p. 5). Aleskerov, Belousova and Petruschenko (2017) present a review of empirical applications and systematize the results on efficiency studies applied to HEIs around the world. Their findings suggest that the major part of this type of research uses Data Envelopment Analysis (DEA).

The two terms, efficiency and performance, are commonly used as synonymous but in some cases each one assumes particular meanings. This distinction is specially important in DEA, which can be used to study both efficiency and performance. "While the DEA frontier can rightly be viewed as a production frontier", and used to measure relative efficiency, "it must be remembered that ultimately DEA is a method for performance evaluation and benchmarking against best-practice", and consequently also used as a multi criteria decision making (MCDM) tool (COOK; TONE; ZHU, 2014, p. 1).

In addition to the purpose of the measurement exercise, other important issues concerning the use of DEA are: model orientation (knowledge about the production process), inputs and outputs selection/definition, the use of mixed and raw data, and the number of inputs and outputs versus the number of DMUs (COOK; TONE; ZHU, 2014). As an example, Johnes and Tone (2017) realize a comparative exercise among three different DEA models using the same data from England HEIs. Their findings suggest that results are highly sensitive to the methodology chosen and that caution is required when applying the results in any policy context.

Therefore, the main objective of this work is to present and criticize, according to the guidance of Cook, Tone and Zhu (2014), the Brazilian literature about HEIs efficiency which uses DEA. In order to do it, this work is organized into five sections of which this introduction is the first. Section 2 presents the fundamentals of DEA framework. Section 3 is a critical analysis of Brazilian literature, while section 4 present the final remarks.

2. EFFICIENCY AND DATA ENVELOPMENT ANALYSIS BACKGROUND

Efficiency is generally understood as the use of the fewest inputs (resources) to produce the most outputs (services). More formally, considering two firms (x_1, y_1) and (x_2, y_2) which use resource x to product y, it can be said that firm 2 dominates or is more efficient than firm 1 if it uses no more inputs to produce no fewer outputs and is doing strictly better in at least one dimension. "In economics, the efficient firms are those that cannot be dominated by other firms" (BOGETOFT; OTTO, 2011, p. 23-24). Thus, to determine which firms are efficient, it is necessary to have a description of all possible firms (e.g., a listing or a technology set). Than, for a given technology set T, efficiency can be defined as:

Efficiency. (x, y) is efficient in T if and only if it cannot be dominated by some **(x', y') ϵ *T***

One strategy commonly used to measure relative efficiency among decision making units (DMUs) is DEA, which can be defined as "a mathematical programming based approach for measuring relative efficiency of DMUs that have multiple inputs and outputs" (CHARNES; COOPER; ROHDES, 1978 apud COOK; TONE; ZHU, 2014, p. 1). McMillan and Chan (2006) said that the essence of the DEA problem is to obtain efficiency measures based on the aggregated, or 'virtual', inputs and outputs. Tone (2001, p. 502) emphasizes that "the important characteristic of DEA is its dual side which links the efficiency evaluation with the economic interpretation", in the context of production process and production functions. On the other hand, considering practical implications, Johnes (2004, p. 663) presents DEA as a non-parametric technique which "can provide information on realistic targets for an inefficient institution", and also "information on a set of similar (in terms of input and output mix) but better-performing institutions whose practices the inefficient organization can realistically try to emulate."

The first DEA model developed was the CCR, originated and named after the work of Charnes, Cooper and Rhodes (1978). Banker, Charnes and Cooper (1984) relaxed the assumption of constant returns to scale (CRS) and modified the DEA model to incorporate variable returns to scale (VRS). This model was afterwards named BCC. The dual version of the problem cited above, both to output-oriented and to input-oriented are presented by Thanassoulis et al. (2011, p. 1297) as follows. In order to calculate the efficiency considering that the DMUs use *m* inputs to produce *h* outputs, under VRS, the following linear programming problem must be solved for each of the *n* DMUs (k = *1, …, n)*:

Output-oriented (VRS)	Input-oriented (VRS)
Maximise ϕ_k (Eq. A.1)	Minimise θ_k (Eq. A.2)
subject to	subject to
$\phi_k y_{rk} - \sum_{j=1}^{n} \lambda_j y_{rj} \leq 0$ for $r = 1, \ldots, h$	$y_{rk} - \sum_{j=1}^{n} \lambda_j y_{rj} \leq 0$ for $r = 1, \ldots, h$
$x_{ik} - \sum_{j=1}^{n} \lambda_j x_{ij} \geq 0$ for $i = 1, \ldots, m$	$\theta_k x_{ik} - \sum_{j=1}^{n} \lambda_j x_{ij} \geq 0$ for $i = 1, \ldots, m$
$\sum_{j=1}^{n} \lambda_j = 1$, $\lambda_j \geq 0$ $\forall_j = 1, \ldots, n$	$\sum_{j=1}^{n} \lambda_j = 1$, $\lambda_j \geq 0$ $\forall_j = 1, \ldots, n$

The overall efficiency of DMU *k* is measured by $E_k = 1/\phi_k$ in the output-oriented framework or $E_k = \theta_k$ in the input-oriented framework. The vector **λ** represents the weights to the convex combinations of the HEIs (considering the convexity assumption regarding the technology). The CRS efficiency score can be calculated simply by deleting the constraint $\Sigma \lambda_j = 1$ from the model.

McMillan and Chan (2006) clarify that the same weights (virtual multipliers) that maximize the ratio for DMUj are applied to the inputs and outputs of all DMUs in the solution to the problem for DMUj. This solution process is repeated for each DMU. Hence, because the weights can vary for each solution, the efficiency scores determined are those most favourable to each DMU (relative to the others DMUs).

Thanassoulis et al. (2011, p. 1297) interpret that "in practice, DMUs may produce many outputs from their resources, in which case programming techniques have to be used to identify the piecewise linear frontier joining up all efficient DMUs." Then the focus of one inefficient DMU will be to reach this frontier by: (i) reducing its inputs and maintaining its outputs (input-oriented approach); (ii) improve its outputs and maintaining its inputs (output-oriented approach); (iii) reducing its inputs and improving its outputs simultaneously.

It is important to highlight that the DEA models presented until here consider radial (proportional) variation in inputs and/or outputs to get the efficient production levels. In some cases this may not be the appropriate situation to the production function. In these cases an alternative is to work with slacks and calculate the variation in each input and/or output independently in order to achieve the efficiency production level. Johnes and Tone (2017, p. 195) affirm that non-radial measures are in many circumstances preferable to either an output or input-oriented approach. They state that "in particular, where decision making units are free to vary some inputs and outputs, but face constraints in their ability to vary others, it is appropriate to focus on the input and output specific slacks.".

This way, Tone (2001, p. 508) proposed a scalar measure (Slack Based Measure – SBM) of efficiency in DEA. This measure "deals directly with input excess and output shortfall" and contrasts with "the CCR and BCC measures which are based on the proportional reduction (enlargement) of input (output) vectors and which do not take account of slacks.". In addition, the SBM measure also "satisfies such properties as unit invariance and monotone with respect to slacks, and it is reference-set dependent", that is, "the measure is determined only by its reference set and not by statistics over the whole data set." (TONE, 2001, p. 508). Similar to the CCR model, the SBM model can be transformed into a linear program using the Charnes-Cooper transformation (TONE, 2001, p. 500) and it can also be modified to cope with input or output-orientation as special cases (TONE, 2001, p. 508). It was used by Costa, Ramos and Souza (2010) which calculated the output-oriented efficiency of Brazilian public federal HEIs using the following equation:

$$\text{Minimise} \quad \rho_k = \frac{1}{1+\left(\frac{1}{h}\right)\cdot\sum_{r=1}^{h} s_r^+ / y_{rk}}$$

$$\text{subject to} \qquad \text{(Eq. 3)}$$

$$x_k = \lambda_j x_{ij} \quad \text{for} \quad i=1,\dots,m$$

$$y_k = \lambda_j y_{rj} + s_{rj}^+ \quad \text{for} \quad r=1,\dots,h$$

$$\lambda_j \geq 0 \quad , \quad s_{rj}^+ \geq 0$$

The vector $\boldsymbol{\rho}$ represents the relative efficiency of the DMUs and the vectors $\boldsymbol{s}^+$ indicate the the output shortfall and are called slacks. The value of the objective function will be $0 \leq \boldsymbol{\rho} \leq 1$ and will decrease with increases in $\boldsymbol{s}^+_{rj}$, *coeteris paribus.*

Nevertheless, considering the empirical application of DEA and based on their experience as paper referees, Cook, Tone and Zhu (2014, p. 4) observe that "despite the many applications of DEA that have been advanced in the literature, it would appear that in many cases little attention is paid to a number of important modeling issues". They address important key issues and recommendations related to the use of DEA:

- clearly specifying the purpose of the analysis (and the production process);
- deciding on inputs and outputs;
- choosing a model orientation;
- paying attention to the type of data involved, whether ratio versus raw data.

These key issues and recommendations are the base to the analysis of the Brazilian empirical uses of DEA to HEIs to be presented in the following section. The analysis naturally includes the description of the available data and its evolution *pari passu* the increase of the preoccupation about accountability which occurred in the last decades.

3. ANALYSING EMPIRICAL APPLICATIONS OF DEA TO BRAZILIAN HEIS

This part of the work realises a critical evaluation of some existent empirical uses of DEA to Brazilian HEIs. As a preamble, it is briefly presented the evolution of earlier performance evaluations and the availability of useful data.

Belloni (2000) presents a brief history of Brazilian HEIs evaluation and diagnoses that, even having started in the 1950s decade, it was only in 1990s that its principles and characteristics were established. This is synthesized in two reports: the Proposta de Avaliação Institucional da Associação Nacional dos Dirigentes das Instituições de Ensino Superior – ANDIFES (ANDIFES, 1993); and the Documento Básico do PAIUB (MEC/PAIUB, 1994).

In addition, Belloni (2000, p. 27-28) emphasizes some common principles between both reports: i) globality, the HEIs should be evaluated in a global way, not only analysing the characteristics individually, but considering simultaneously the dimensions – teaching, research, services and management; and ii) respect of institutional identity, the particular characteristics of each institution should be respected, thus, two HEIs could give a different importance to a same dimension or academic activity. The current Brazilian higher education evaluation system (Sistema Nacional de Avaliação da Educação Superior - SINAES) follows similar principles. It is important to highlight that these principles are respected by DEA modeling and that is just one of its advantages in relation to other evaluation models. The indicators suggested by ANDIFES (1993) and MEC/PAIUB (1994), even trying to consider those principles, are partially efficiency ones, derived from a ratio between two diverse quantities (there are only two exceptions: the professor quality index and the courses quality index). Because of this, their methodologies do not handle so well the analysis of multiple inputs to produce multiple outputs such as the case of HEIs.

As a result, already with data from the year of 1994, studies which applied DEA to evaluate HEIs performance by using these indicators started. The first work known to do that is Marinho, Resende and Façanha (1997), by considering VRS and using Principal Component analysis (PCA) to identify common dimensions and to allow a reduction on the number of variables (three factors as input and three factors as outputs were used). The work just criticizes the MEC-ANDIFES evaluation model to funding the Brazilian federal HEIs and considers that DEA provides useful insights into critical resource allocation and management problems that constrain the HEIs.

If until 2001 the researchers of public HEIs had difficulties with available data, after this time it can be considered that the difficulty moved into selecting the correct data for analysis using DEA. After the development of Higher Education Census from the National Institute of Teaching and Educational Research – Ministry of Education (INEP/MEC), the quantitative data became more available. In 2018 there are available microdata by year from 1995 until now. This information can be visualized and dowloaded through INEP (2018).

A limitation of this census to HEIs efficiency analysis is the fact that it contains no information about postgraduate courses, as well as secondary courses supplied by some HEIs. Regarding the case of postgraduate information, it is necessary to access the data from the Improvement Coordination of People of Higher Education (CAPES). CAPES evaluates postgraduate programs and provides information by program to the trienniums 2004-2006, 2007-2009 and 2010-2012 (CAPES, 2018) and to each year of the 2013-2016 period (CAPES, 2018b).

Another relevant case is the information which became available in the management reports presented annually to the Federal Court of Audit (Tribunal de Contas da União – TCU) by federal public HEIs. It resulted from the 408/2002 TCU decision. Since 2002, the TCU starts demanding specific information about performance indicators from Brazilian public federal HEIs (TCU, 2002). In 2010 the TCU also starts demanding the raw values used to calculate those indicators. Since then, the HEIs should present the respective year values as well as the historic values to the four past years, considering both raw values and indices values (named indicators by TCU). The detailed criteria and methodology developed by TCU to orient the HEIs in the calculus of the values are presented in TCU (2010) and are synthesized in the Appendices A and B.

Then, since 2010 it became possible to use these raw values to calculate global efficiency. Despite that, until the year 2016 none of the works had done it. Table 1 presents a synthesis of the principal works which focus on Brazilian HEIs' performance. It shows the intended purpose of each work, the model specification and orientation, the number of DMUs, inputs and outputs, the type of HEIs analysed and the year considered. The rest of this section is dedicated to analyse and criticize these works. In general, all presented works explicitly intend to measure efficiency, but a great part is actually about performance evaluation as a MCDM tool. In Table 1, these works are identified by the lines 4, 7, 8, 9, 10, 11, 12.

Paredes (1999) uses data from 1993 and presents initially 36 potential variables as inputs and outputs to 33 Brazilian public federal HEIs. After the application of two different procedures to select the variables (factor analysis and the Norman and Stoker iterative procedure), its final DEA model uses 3 variables as inputs and 3 as outputs. It concludes that both procedures of variables selection present similar results. In the same way, Belloni (2000) uses data from 1994 to also select the relevant variables as input and output to 33 Brazilian public federal HEIs. It starts from about 30 variables to, at the end, identify 4 trustworthy and relevant ones: total number of professors as input, and, as outputs, number of undergraduate degrees, number of papers published, and undergraduate courses quality index.

Corbucci (2000) is an example of using only partial indicators to analyse the HEIs; the limitations of its approach is just one of the motivations to use DEA which allows to access the efficiency information globally by considering simultaneously all variables. On the other hand, Façanha and Marinho (2001) present a type of macro analysis considering all Brazilian HEIs to 1995 and 1998. It is done by calculating each HEI's efficiency and then grouping these efficiencies by geographic regions, by administrative category (public or private) and by knowledge area. The analysis permits to compare the performance among the diverse groups and use it in order to provide some policy recommendation. Even so, the analyses are done first to the graduate level and after to the postgraduate level, not considering that, for example, the input professor is disputed by both undergraduate and postgraduate courses. This type of limitation was overcome by Alencastro and Fochezatto (2006) in an example of DEA applied to a private institution. The work analyses the courses of one HEI considering, among other aspects, the hours of work from teachers with doctorate degree, from teachers with master degree and from teachers without these degrees. In this case, each course was considered one DMU and, by using the strategy of considering teachers' work hours, the problem of one professor working in more than one course was solved.

The first work identified as using TCU indicators was Oliveira and Turrioni (2006), with data from year 2004. However, the work considered only 19 from a total of about 50 existing HEIs, according the authors due to having only these data available online in their sites. Also, the work uses the TCU efficiency and productivity indicators in the same DEA model. It could be said that the work uses partial performance indicators (including efficiency and productivity ones) with the intention to calculate a global indicator of efficiency. This strategy can hinder the analysis as well as the results' validity. According to Cook, Tone and Zhu's (2014, p. 2) guidances, this use of DEA could be considered as a MCDM tool, a situation in which "DEA can be viewed as a multi-criteria evaluation methodology where DMUs are alternatives, and DEA inputs and output are two sets of performance criteria.". Thus, the use of partial indicators in the DEA model results in a type of performance measure, but that could not be considered efficiency.

Table 1 – Works which analyse the Brazilian HEIs efficiency/performance

id	Author and year	Intended purpose	Model specification and orientation	DMUs		nr. of inputs				nr. of outputs				Type of institutions studied	Analised year	Benchmarks (efficient DMUs)	Proportion of efficient DMUs (%)	mean efficiency of DMUs
				Nr of DMUs	Characteristics of the sample of the subsets of DMUs group	all	raw	ratio	index	all	raw	ratio	index					
1	Marinho, Resende, and Façanha (1997)	efficiency	VRS input	38	38 of 52	3			3	3			3	Public federal	1994	16	42.11	93.00
2	Paredes (1999)	efficiency	VRS input	33	33 of 37	3	3			3	3			public federal	1993	16	48.48	84.32
						2	2			3	3					13	39.39	83.01
3	Belloni (2000)	efficiency	VRS output	33	33 of 37	1	1			3	2		1	Public federal	1994	6	18,18	83,54
4	Corbucci (2000)	efficiency and productivity	ratio between indicators	35	35 of 37	7		7		7		7		Public federal	1995 to 1998	x	x	x
5	Façanha and Marinho (2001)	efficiency	VRS Input and output	894	210 public; 684 private	4	4			11	11			HEIs without postgraduate programs	1995-1998	grouped results(geographical regions, public and private organizations and areas of study)		
				973	209 public; 764 private													
				349	grouped by postgraduate program areas and HEIs	2	2			6	6			postgraduate programs	1997			
6	Alencastro and Fochezato (2006)	efficiency	CRS input	30	30	5	4	1		3	3			courses from a private HEI	2000	16	53.33	91.51
				34	34										2004	19	55.8	93.41
7	Oliveira and Turrioni (2006)	efficiency	CRS input and CRS output	19	19 of 55	7		5	2	2		1	1	Public federal	2004	14	73.68	99.65
8	Costa, Ramos and Souza (2010)	efficiency		49	49 of 55	4		3	1	2		1	1	public federal	2004-2008	x	x	x
			SBM output	28	with research (static)											15	53.57	94.57
			DSBM output	28	with research (dynamic)											18	64.28	95.42
			SBM output	21	low research (static)											8	38.09	94.19
			DSBM output	21	low research (dynamic)											16	76.19	97.52
9	Costa, Souza, Ramos and Silva (2012)	efficiency	SBM output	49	idem											Idem		
10	Costa, Ramos and Souza (2014)	efficiency	SBM output and DSBM output	49	idem													
11	Costa, Ramos, Souza and Sampaio (2015)	efficiency	DSBM output	49	idem													
12	Furtado and Campos (2015)	efficiency	VRS output	19	19 de 38	3		2	1	1		1		IFETS (federal public institutions of technlogy education – HE and tech high school)	2012-2013	6	31.58	84.40
13	Duenhas, França and Rolim (2013, 2015)	efficiency	SBM	75	75 of ??	2	2			4	3		1	federal public universities	2007-2008	x	x	x
				18	large											12	66.67	94.28
				22	medium											12	54.54	85.86
				35	small											28	80.00	97.00
14	Bittencourt et al. (2016)	efficiency	VRS input	81	81 of 98	6	6			7	7			Selected public universities	2014	x	x	x
				45	large											31	68.89	97.70
				30	medium											24	80.00	96.73
				6	small											6	100.00	100.00
15	Letti and Bittencourt (2017)	efficiency	VRS input	221	221 (total)	5	5			4	4			public HEIs	2012	49	21.87	62.00
				51	large											33	64.71	96.00
				70	medium											29	41.43	84.00
				103	small											22	21.36	50.00
16	Letti and Bittencourt (2018)	efficiency	VRS input	97	97 of 97	1	1			7	7			public universities	2010	22	22.68	60.00
				97	97 of ??	3	3								2016	33	34.02	80.00

Source: research results

In the same way, Costa, Ramos and Souza (2010) (prized by the National Treasury Department Award in 2010), Costa, Souza, Ramos and Silva (2012), Costa, Ramos and Souza (2014) and Costa, Ramos, Souza and Sampaio (2015) realize similar works with the same data from TCU to the years of the period 2004-2008. All of them explicitly declare that the main purpose was to measure the relative efficiency of Brazilian public federal HEIs. The analysis is in the tradition of DEA method using SBM and considering also the evolution of efficiencies along the time (Malmquist's (1953) index and Dynamic SBM - DSBM). However, the DEA models used consider some of the 'TCU indices' and not the 'TCU raw values'. More specifically, they use 2 indicators as outputs: i) rate of undergraduate degrees by freshmen undergraduate students; ii) quality index of postgraduate courses; and 4 indicators as inputs: i) rate of current expenditures by equivalent student; ii) rate of full time student by equivalent professor; iii) rate of full time student by equivalent non academic staff; iv) quality index of academic staff. In that sense, these works can also be considered MCDM. But, even so, according to Cook, Tone and Zhu (2014, p. 2) in these cases the input variables will be "the-less-the-better" type of performance measures and the outputs will be "the-more-the-better". Hence, the use of the quality index of academic staff as input could be criticised and an alternative could be a transformation such as, for example, using '100 – quality index' to 'convert' it in a 'the-less-the-better' variable. The chosen alternative strategy in the four cited works was to use output-orientation, and consequently to consider the inputs as non-discretionary variables by the managers. Furthermore, to the case of variables that use financial values to do an analysis through time, these values should have been deflated to a common reference year. That is because a simple variation of nominal values, but not necessarily a real variation, could be interpreted as a real increase in expenditures and, consequently, compromise or bias the frontier comparisons among the years.

Freire, Crisóstomo and Castro (2007), Barbosa, Freire and Crisóstomo (2011), Cohen, Paixão and Oliveira (2018) are not presented in Table 1 but they also use the TCU indicators with the same characteristics and limitations in relation to DEA being used as MCDM but without recognizing it explicitly. Casado and Siluk's (2011) work is a good example of misunderstanding because its objective is specifically to verify if the TCU indicators can be used to calculate efficiency. It could be considered that the using of these indicators, at minimum, adds a lot of difficulties to the analysis and interpretation of results. The use of DEA for efficiency analysis is hampered because of the mixing of the indicators with different denominators and, moreover, because of the mixing of the rates with index indicators without considering to which variables the manager has direct control over. It may be that, at the time when the first of these works was done, the raw values that originated the indicators were not available. This could be a justification to use the indicators. If this was the case, then the authors should have cited it in the texts, which did not happen.

More recently, Oliveira et al. (2014) and Siqueira (2015) also used 'TCU indicators' with an intention to measure HEIs' efficiency (they are not present in Table 1 neither). Both have the special goal to evaluate a Federal Program named Program to Support the Restructuring and Expansion of Federal Universities (REUNI), implemented in 2008. They compare results of DEA models applied to data from years 2007 to 2012. According to them, the increase in funds from the new policies of Reuni (2008-2012) did not change the level of efficiency of the HEIs in the way expected. Nevertheless, it is important to highlight that these conclusions are done by using partial performance indicators from TCU and considering that the results represent efficiency. The development of DEA and posterior methodologies in its tradition (Malmquist index, SBM, DSBM, and others) has occurred precisely to overcome the difficulties in analysing simultaneously various partial indicators of efficiency and productivity.

Furtado and Campos (2015) carry out an investigation about the efficiency of the Federal Education Institutions - IFETS (which offers diverse courses both in technical and undergraduate levels). It also uses some of the TCU indicators and suffers the same 'indices problem' by using expenditures by students and students by professor as inputs, and undergraduate degrees by student enrolled as outputs. In this specific case, another limitation is the fact that the IFETS offer different course levels and this should be taken under consideration (for example, by differentiating the outputs from each type of the course).

The work of Duenhas, França and Rolim (2015) analyse 62 Brazilian public HEIs by using SBM models and Malmquist index. The HEIs were grouped by size in big (18), medium (22) and small (22) and then the efficiencies were calculated. They come back to the use of data from INEP and CAPES, and not data from TCU. They consider four outputs (number of total students both in under and postgraduate courses, number of services activities, number of theses and dissertations summed up, and a quality index of the courses valid to under and postgraduate courses simultaneously) and two inputs (total income and full time equivalent professor). Nevertheless, the actual values used in the calculus were previously divided by the number of students (except to the quality index); then the efficiency measure is done considering the values by student. This issue/consideration could be thought in details with more attention to its implications in a future study. It could be considered that the work presents some advantages in relation to the others. First, by using practically only absolute values (or better, ratios with the same denominator) the analysis, interpretation and management recommendations are facilitated. In addition, by using one variable from dimension services (third mission) the results become more realistic with the HEIs activities. Second, by considering all dimensions simultaneously, each DMU has 'virtual freedom to choose' its combination of inputs and outputs to maximize efficiency. Furthermore, the methodology applied allows the DMUs to aim for efficiency in an easier way (reducing some inputs or improving some outputs, without proportionality). In this specific case, a lot of caution should be taken, especially about those inputs and outputs which are actually controllable by the managers and policymakers and those that are not, but this was not considered in the work. Third, the work analyses and compares the efficiencies between two years, adding to the analysis some dynamic traits, but not so much considering the time required for any change in the HEIs production. It is important to stress that, even considering two consecutive years, this work corrected the nominal financial values to the same moment in time. Finally, Duenhas, França and Rolim (2015) conclude that the Brazilian public universities are inefficient, especially the small and medium ones. Also, they state that small and medium groups increased their productivity among these years. These results differ from the other studies here presented both in terms of static and dynamic analysis. As a conclusion, their findings suggested that if there were improvements in the management of HEIs, it would be possible to increase the number of students without increasing the expenditures.

Regardless of the positive aspects presented, there are some things that could be improved in the Duenhas, França and Rolim (2015) analysis. First, there are indications that the information about HEIs' income is not so trustworthy; therefore, it should be compared with other information sources (for example, with TCU reports data to the case of public federal HEIs). Also, the income information could be disaggregated and it could allow the manager policymaker to reallocate the budget among groups of expenses. Furthermore, the consideration of one undergraduate student as equivalent to one doctorate student is a little complicated. Actually, comparing some undergraduate courses among each other is already complicated. For example, the structure and process required to 'produce' a medical degree is very different from that of a pedagogical degree or of an engineering degree. The TCU 'student equivalent' tries to overcome this limitation. Still, there are other outputs that could be considered, for example the innovation of the HEIs due to its crucial importance for the economic models of development. Also, as the global process of one HEI does not change considerably from one year to another, a period of more years could be more advantageous for a dynamic analysis. According to Cook, Tone and Zhu (2014, p. 1) "in any study of organizational efficiency it is necessary to have a clear understanding of the 'process' being evaluated" and consequently "a clear specification of the function to be studied will drive the choice of inputs and outputs to be examined".

Moreover, Bittencourt et al. (2016) and Letti and Bittencourt (2017) present some contribution due to using information about registered patents as outputs. However, some limitations from these works are the use of plenty of inputs and outputs to few HEIs (resulted from grouping by size) and the consideration of 'very young' HEIs (lower than 5 years of implementation). Letti, Vila and Bittencourt (2018) partially overcame it. Nevertheless, the work could be complemented by considering additionally information from TCU reports, specially the monetary ones.

As a synthesis, the studies here reviewed about Brazilian HEIs can be classified, according to the data used, in three groups:

- before TCU indicators;
- after TCU indicators and using them;
- after TCU indicators but not using them.

In general, the works reviewed consider in some aspect the importance of using adequate inputs and outputs variables, but a lot of them do not explicitly justify how/why the variables are chosen and, most importantly, what the relation is of a given variable with the production process and, consequently, with the DEA framework.

The first group of studies had difficulties with useful and reliable data and with the challenge of this 'new type' of evaluation to Brazilian institutions, with multi-inputs, multi-products and heterogeneous contexts (size, age, regions, demographic variables, etc.). In the case of those works which use TCU indicators, starting by Oliveira e Turrioni (2006), some make explicit the fact that these indicators are not the best ones, but they are the ones available. However, a lot of studies were done considering these indicators, including the ones evaluating the government programs (such as REUNI) and orienting the decisions of policymakers without emphasizing this limitation and without suggesting better indicators. Special attention should be given to the case of the Costa, Ramos and Souza's (2010) work, which received a prize by the National Treasury Department Award, and other 3 sequential works from the same group of authors. And, still, other sequential investigations from different authors which were inspired by those ones. For instance, one from the UNB-UFPB-UFRN Accounting postgraduate program work (SIQUEIRA, 2015), one from the UFPR Accounting postgraduate program (OLIVEIRA et al., 2014) and another from UFTO Regional Development master program (COHEN; PAIXÃO; OLIVEIRA, 2018).

4. FINAL REMARKS

Following the guidances of Cook, Tone and Zhu (2014) for doing DEA analysis, the findings of the present investigation show that the empirical works regarding Brazilian public HEIs using DEA present differences in terms of: a) purposes; b) model orientation; c) selection and number of inputs and outputs variables; as well as d) the use of mixed or raw data; and e) data sources.

Due to law enforcement, Brazilian public federal HEIs should present annually a report describing some specific performance information to the Brazilian Federal Court of Audit (Tribunal de Contas da União – TCU). The report should contain 'performance indices' as well as the 'raw values' used to calculate those indices. The 'raw values' are very useful (though not sufficient) to the objectives of measuring efficiency. The 'indices values' permit the realization of a Multi Criteria Decison Making (MCDM) analysis.

A great majority of recent works declare using DEA to measure the efficiency of HEIs; however, what they do, in fact, is to perform a MCDM analysis using just these 'performance indices' from the TCU reports. It is important to remember that the works which use some of these indicators, in general did not use the most adequate indicators to their declared objectives of efficiency analyses. For example, the information about the total expenditures and the absolute number of students (or equivalent students) and professors (or equivalent professors) are available, but the works used some ratio values as expenditures by student, or student by professors. This option could hinder the analysis of results and make it difficult for interpretation and comparisons.

In the particular case studied here, it is difficult to carry out this comparative exercise among results of models which use ‘indices values’ and models which use ‘raw values’ due to their different focus. The former results in targets in relation to ratios of variables, and the latter results in targets about raw values; consequently, as suggested by Johnes and Tone (2017), caution is required when using these results in any policy context.

Considering suggestions for future research, it would be important to use the results from this work to analyze the evolution of the HEIs efficiency after 2007, as well as to consider information from other sources than the TCU reports to complement the DEA models. In that sense, specific information about postgraduate programs should be considered, as well as information about registered patents (as proxy to innovation) and about third mission activities. A curious exercise could also be to compare the financial information from TCU reports (available only to Federal Public Universities) with the financial information from the Higher Education INEP Census and then to validate or not the use of the available INEP financial information to the other HEIs (public state and municipal universities).

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Appendix A

Synthesis of TCU (2010) orientations about the definitions and calculus of the indices and its raw values.

	acronym	Raw values	definition
1	CCCHU	current cost with HU (university hospitals);	current expenditures of HEI add with 35% of the university hospital expenditures (not consider pensions, judicial sentences and not active staff)
2	CCSHU	current cost without HU;	idem but not adding the 35% of HU
3	PE	number of full time equivalent professors;	permanent professors, substitute professor, visiting professors (consider only active ones) – calculated by time of work proportionaly to a one professional which work 40h/week
4	FECHU	number of full time equivalent employees with HU;	permanent employees not professors, temporary contract employees not professors, include all employees from HU (consider only active ones) - calculated by time of work proportionaly to a one professional which work 40h/week
5	FESHU	number of full time equivalent employees without HU;	idem but excluding that ones working exclusively to HU
6	AG	Number of enrolled students in undergraduate courses	total of enrolled undergraduate students – not consider participants of third missions activities, not consider students in non-presencial courses
7	APG	number of enrolled students in postgraduate courses (master and doctorate)	total of enrolled postgraduate students (only master and doctorate courses)
8	AR	number of intern students (medical residence);	total of undergraduate students enrolled as intern
9	AGTI	number or full time undergraduate students;	sum of all courses value according the equation: { (NDI*DPC) * (1 + [retention factor]) + (((NI – NDI)/4)*DPC)} In which: NDI = number of undergraduate degrees in the year; DPC = standard course duration (in years); (see Appendix B); NI = number of fresh undergraduate students in the years; Retention factor = factor calculated by HE governamental office (see Appendix B)
10	AGE	number of undergraduate students equivalent	= AGTI * [course group weight]; (see Appendix B)
11	APGTI	number of full time equivalent postgraduate students;	= APG * 2
12	ARTI	number of full time equivalent intern (medical residence).	= AR *2

	acronym	Indicators	definition
1	CCCHUAE	current cost with HU by equivalent student;	= CCCHU / (AGE + APGTI + ARTI)
2	CCSHUAE	current cost without HU by equivalent student	= CCSHU / (AGE + APGTI + ARTI)
3	ATIPE	full time student by equivalent professor;	= (AGTI + APGTI + ARTI) / PE
4	ATIFECHU	full time student by equivalent employees with HU;	= (AGTI + APGTI + ARTI) / FECHU
5	ATIFESHU	full time student by equivalent employees without HU;	= (AGTI + APGTI + ARTI) / FESHU
6	FECHUPE	equivalent employees with HU by equivalent professors;	= FECHU / PE
7	FESHUPE	equivalent employees without HU by equivalent professors	= FESHU / PE
8	GPE	index of students participation;	= AGTI / AG
9	GEPG	ratio of postgraduate students;	= APG / (AG + APG)
10	TSG	students degrees by registered students;	= [nr. of undergraduate degrees in the year] / [nr. of fresh undergraduate students in the respective cohort considering the standar duration of the course]
11	IQCD	qualification of teaching staff index	= (5*D + 3*M + 2*E + 1*G) / (D + M + E + G), In which: D is the number of professors with doctorate degree; M is the number of professors with master degree; E is the number of professors with especialization degree; G is the number of professors with undergraduate degree.
12	CCAPES	quality index of postgraduation (concept of Coordination for Enhancement of Higher Education Personel for Post-Graduation Progams)	= [sum of the CAPES quality index of each postgraduate program from the HEI] / [number of postgraduate programs from the HEI]

Source: adapted TCU (2010) SESu/MEC (2018)

Appendix B

Informations to calculate the number of full time equivalent students and undergraduate students equivalent from Appendix A

MINISTÉRIO DA EDUCAÇÃO
SECRETARIA DE EDUCAÇÃO SUPERIOR

Tabela Para Cálculo dos Indicadores de Desempenho das IFES, Conforme Solicitação do TCU
(fator de retenção e duração média padrão das áreas de conhecimento)

Área	Descrição da Área	Fator de Retenção	Duração Média	Grupo	Peso do Grupo
A	Artes	0,1150	4	A3	1,5
CA	Ciências Agrárias	0,0500	5	A2	2,0
CB	Ciências Biológicas	0,1250	4	A2	2,0
CET	Ciências Exatas e da Terra	0,1325	4	A2	2,0
CH	Ciências Humanas	0,1000	4	A4	1,0
CH1	Psicologia	0,1000	5	A4	1,0
CS1	Medicina	0,0650	6	A1	4,5
CS2	Veterinária, Odontologia, Zootecnia	0,0650	5	A1	4,5
CS3	Nutricao, Farmácia	0,0660	5	A2	2,0
CS4	Enfermagem, Fiso, Fono, Ed Física	0,0660	5	A3	1,5
CSA	Ciências Sociais Aplicadas	0,1200	4	A4	1,0
CSB	Direito	0,1200	5	A4	1,0
ENG	Engenharias	0,0820	5	A2	2,0
LL	Linguística e Letras	0,1150	4	A4	1,0
M	Música	0,1150	4	A3	1,5
TEC	Tecnologos	0,0820	3	A2	2,0
CET	Ciências Exatas - Mat, Comp, Est	0,1325	4	A3	1,5
CSC	Arquitetura/Urbanismo	0,1200	4	A3	1,5
CH2	Formação de Professor	0,1000	4	A4	1,0

Note:
fator de retenção in Appendix B is the **retention factor** of the Appendix A
duração média in Appendix B is the **standard duration** of the Appendix A
peso do grupo in Appendix B is the **course group weight** of the Appendix A

Source: ANDIFES (2018)