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# Technical efficiency of business administration courses: a simultaneous analysis using DEA and SFA

Rodrigo Miranda, Maria Cristina Gramani and Eduardo Andrade

*Business Department, Insper–Institute of Education and Research, Sao Paulo, Brazil*
*E-mail: rodrigoom1@al.insper.edu.br [Miranda]; mariacng@insper.edu.br [Gramani]; eduardo.andrade@insper.edu.br [Andrade]*

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**Abstract**

The aim of this study is to contribute to the existing literature on the efficiency of higher education institutions. The technical efficiency of higher education has been mostly studied using methods such as data envelopment analysis and stochastic frontier analysis. Many researchers compare either the efficiency among public education institutions or among departments in a university by using variables that give equal importance to teaching and research. In this paper, both these methodologies are applied to measure the efficiency of higher education courses, especially the business administration courses offered by private for-profit institutions that focus just on education and are located in the same geographical region. The variables selected covered the specific aspects of these courses and the results showed the complementarities of these two approaches.

*Keywords:* efficiency frontier; higher education; data envelopment analysis; stochastic

## 1. Introduction

Since the 1960s, many papers have addressed the performance measures and efficiency of higher education in various sectors and several countries (Salerno, 2003; Ehrenberg, 2004). Ehrenberg (2004) noted that higher education institutions (HEIs) are not in their production frontiers as they are not necessarily maximizing output, whereas some researchers have been analyzing the production functions of higher education through methods of frontier estimation. Stochastic frontier analysis (SFA) and data envelopment analysis (DEA) are the most commonly used methods for estimating frontiers in higher education.

There are several studies on the efficiency analysis of higher education in the literature; however, these studies either made a comparison among public educational institutions or among departments of the same institution (Fernando and Cabanda, 2007; Castano and Cabanda, 2007;

Ahn et al., 1988; Tomkins and Green, 1988; Beasley, 1990; Johnes and Johnes, 1993; Breu and Raab, 1994; Çokgezen, 2009).

The studies on the efficiency of educational institutions are mainly conducted in American (Ahn et al., 1988; Breu and Raab, 1994; Thursby and Kemp, 2002) and British universities (Tomkins and Green, 1988; Beasley, 1990; Johnes and Johnes, 1993). As these institutions are devoted to teaching and research, the variables used give equal importance to quality of both teaching and publication.

Working with educational institutions, research-oriented universities in China, for a different aspect, Feng et al. (2004) developed a tool for the estimating management performance in research and development activities. The tool was a combination of analysis hierarchical process and DEA. Yang et al. (2007) presented the DFX technique for creating a new department in a university of Taiwan and mentioned that educational institutions can learn about quality, low cost, and efficiency from private organizations. Recently, Tari (2008) concluded that HEIs in Spain can use management practices once such practices are modified as per their requirement. However, there are no studies in the literature regarding the efficiency of private for-profit educational institutions and focusing mainly on teaching.

This paper contributes to the existing literature on two aspects. First, the two techniques on efficiency analysis—DEA and SFA—are compared. DEA is a nonparametric and deterministic technique, whereas SFA is a parametric and stochastic technique. In Brazil, no study, comparing these two techniques, has been conducted to estimate the efficiency of higher education. In the second aspect, we apply these two approaches in higher education offered by the private sector, specifically business administration courses by private for-profit institutions located in the Brazilian State of São Paulo, which covers 25.8% of the business administration courses offered in Brazil.

This paper is organized as follows. In Section 2 some key features of the higher education sector in Brazil are compared with the higher education sector of the United States. Section 3 provides a literature review in which the aforementioned techniques are used for analyzing the efficiency of HEIs. Section 3 also details the methodology employed, including the techniques applied and the database (selection of productive units, input and output). The results are discussed in Section 4. Section 5 concludes the paper.

## 2. Brazilian higher education—a brief contextualization

On the basis of Andrade et al.'s (2009) study, some important features of the Brazilian higher education sector are compared with the higher education sector in the United States (the Brazilian data come from the National Institute of Educational Studies and Research Anísio Teixeira (INEP)—Sinopse Estatística da Educação Superior, 2007. Available at: http://www.inep.gov.br/superior/censosuperior/sinopse/).

The most important difference is that in Brazil students choose the subject of their bachelor degree before taking admission in an HEI. For example, if they want to obtain their undergraduate degree in business administration, they have to apply for programs specialized in business administration. In the United States, a student takes core courses common to all students in the first two years and then chooses the fields he/she wants to specialize in. For this reason, the focus of the analysis in this paper is in one particular undergraduate course.

In 2006–2007 academic years, there were 4,314 American HEIs. Almost 40% of them were public and only 22% (986 institutions) were for-profit institutions. Taking into consideration the number of enrolled students, for-profit and private institutions were even less significant: only 5.7% of 17.5 million students took courses in for-profit institutions, whereas the whole private system corresponded to 25.5%.

The scenario in Brazil is quite different. In 2006, of 2,281 institutions, more than 89% were private and about 74.6% of students were enrolled in these private institutions. In the same year, approximately 52% of the private institutions were for-profit, which means that there were more than 1,000 for-profit colleges or universities. The majority of these private HEIs is not involved in research activities.

As mentioned in the Introduction, the focus of the analysis is on undergraduate business administration courses in the State of São Paulo. This strategy allows us to narrow the investigation without deviating too much from the main features of the Brazilian higher education system. The higher education system in São Paulo city is very similar to the national system, given that almost one-fourth (24.1%) of the existing courses in Brazil are located in the State of São Paulo. While 89.1% of the institutions are private in the national system, private institutions represent 90.1% of the total in São Paulo. The business administration courses are the main courses, not only in terms of number of courses (7.6%) but also in number of student enrolled (13.9%).

To summarize, private (and for-profit) colleges and universities in Brazil have a significant market share and the revenue coming from tuitions is a key aspect. Consequently, a large part of the Brazilian higher education system is formed by institutions whose objectives do not go beyond selling educational services for undergraduate students.

## 3. Methodology

Although the efficiency is a topic well developed within the higher education literature, there is a high degree of diversity regarding the methodologies used to estimate the efficiencies and their results (Salerno, 2003). Only few have combined the two most popular techniques—DEA and SFA. Some of these works are shown in Table 1.

It is interesting to mention the complementarity of both techniques. Salerno (2003) pointed out that the weakness of one technique is the strength of the other technique and therefore the use of both can help to validate the results of one another, offering different points of view to measure the same phenomenon: the technical efficiency. The best advantage of DEA is that it requires no assumptions about the functional form and allows for multiple outputs, which is hardly achieved in SFA. At the same time, the best advantage of SFA is that once it is set as the functional form and the distribution of the error term, the significance of the components of the model can be tested, which is not possible in DEA (Pozo, 2002). In this paper, the two techniques will be applied to compare the efficiency of the HEIs and the main features of each are discussed further.

Table 1
Papers that used DEA and SFA techniques to measure efficiency in higher education

| Year | Author(s) | Work |
|---|---|---|
| 2002 | Pozo | He measured the efficiency of 34 teaching and research departments at the Polytechnic University of Cataluña |
| 2005 | Chapple et al. | They evaluated the performance of the technology transfer offices of 50 British universities |
| 2005 | Kuo et al. | They compared 53 public and private universities in Taiwan, setting the variables by SFA and calculating the efficiency with DEA |
| 2006 | Glass et al. | They combined the two techniques to calculate the profit efficiency of 98 public universities in England |
| 2006 | McMillan and Chan | They compared the results of efficiency of 45 Canadian universities by examining the rankings formed by the two frontiers |
| 2007 | Castano and Cabanda | They evaluated the performance of 30 private higher education institutions in the Philippines and used SFA to find out whether age, ownership structure, and autonomy had a significant effect on technical efficiency of private institutions, finally using DEA to compare the relative efficiency between them |

Source: authors.

### *3.1. Data envelopment analysis*

DEA allows obtaining a degree of efficiency for each unit of observation, which is called decision-making unit (DMU). The efficiency of the DMUs is measured and their efficiencies are evaluated relative to the units identified as efficient, i.e. those in the efficient frontier (Charnes et al., 1978).

DEA is a nonparametric and deterministic approach, that is, it assumes that all deviations from the frontier are due to inefficiency, without considering stochastic errors. In DEA, the DMUs are units that have similar activities, operate under the same conditions, and distinguish themselves by the quantities of inputs consumed and the outputs produced.

This paper uses the output orientation due the characteristics of the problem. According to Alencastro (2006), services such as education—as well as health and social benefits concessions, among others—have the nature of public service, must seek to maximize social welfare, i.e. maximize the product is more interesting. Another way to see the product orientation is that the main input in an educational institution is the teacher, and a decrease in their number would not be congruent (Alencastro, 2006). That is, using the cost function that minimizes the inputs would not be consistent. Moreover, since the production function maximizes the products of the SFA because the HEIs are on the frontier or below it, this study the compares these two techniques (DEA and SFA) so it is more consistent to use the same orientation.

When using DEA, it is also important to define what kind of return to scale the HEI presents. In this work, to define the returns of scale we used the empirical test proposed by Johnes and Johnes (1993). This test involves checking whether there is a significant covariance between the results of the technical efficiency produced by the constant scales effects and the size of the HEI course. Also, it is applied that the sum of the number of professors and the number of technical and administrative staff of the course is a proxy for the size of the course. The test results in low correlation and covariance, both positive, in the model. This shows that the effects of scale are too small to be taken into consideration. Thus, we have kept returns of scale constant.

DEA is often used with weight restrictions or "assurance regions" in studies of HEI efficiency (Beasley, 1990; Athanassopoulos and Shale, 1997; Köksal and Nalçaci, 2006). However, these restrictions are based on the evaluator's perception of the relative importance of the different variables or other managerial judgments, such as monetary values (Podinovski, 2007). Nevertheless, the resulting efficiency of DEA with restricted weights gives no basis for knowing how the efficiency can be improved because it does not allow the results of the efficiency evaluation to be interpreted as a radial improvement factor (Podinovski, 2007). As the technical efficiency of the HEIs is being evaluated in this study, weight restrictions are not used.

### 3.2. *Stochastic frontier analysis*

SFA is a technique that allows the measurement of inefficiency and stochastic errors, which are inevitable in any set of experimental data. In other words, they incorporate random problems in data, function, restrictions, or in any other probabilistic element.

As previously noted, the DEA technique extracts information from the sample of observations and optimize (maximization of outputs or minimization of inputs) each individual observation aiming the measurement of a specific frontier by the efficiency of the DMUs. In contrast, the approach of the parametric method is to optimize a single regression plan through the data. Therefore, one single regression equation is applied for all DMUs. Unlike DEA, which reveals the behavior of each DMU, the parametric approach reveals the behavior of an "average" DMU.

Due to the separation of the component of inefficiency and statistical noise, the parametric approach requires the use of a specific functional form (e.g. a regression equation or a production function) that relates the dependent and independent variables. This functional form requires specific assumptions about the statistical distribution of the error terms (normal distribution, exponential etc.).

In this work, we have used a Cobb–Douglas production function because the sample is small and this function saves degrees of freedom (Cubbin and Zaman, 1996; Wang, 2001). SFA is calculated using the maximum likelihood estimator as described in Kumbhakar and Lovell (2003), the distribution of the idiosyncratic error term is normal and the distribution of the inefficiency term is half-normal, which is widespread in empirical applications (Gong and Sickles, 1992). Greene (1990) reports that the relative position of the HEI is not very sensitive to the distribution of the inefficiency term and thus the data can be trusted.

To complete the parametric frontier analysis, similar to DEA analysis, we tested the null hypothesis that the DMUs employ constant returns of scale using Wald test (Kmenta, 1990) to test the hypothesis that the sum of production factors elasticities is equal to 1 (testing restriction $\sum_{k=1}^{m} \beta_k = 1$). This shows that the hypothesis cannot be rejected at 95% confidence level. In this work, the constant returns of scale are utilized.

### 3.3. *The selection of HEIs*

The HEIs analyzed in this research are private, for-profit, institutions with business administration courses located in the State of São Paulo. The following factors were considered while choosing these HEIs. First, the selection of institutions was made as homogeneous as possible. The lack of homogeneity is a problem in studies that used institutions with more than one output (research and teaching) or with different objectives (for-profit and nonprofit) or with different nature (public and private) or located in different regions.

Second, another methodological problem was avoided by taking into account the quality of inputs. The quality was measured through questions asked to students concerning the assessment to the physical facilities and to the computers and library collection of their institution. Professors were also categorized by their title and types of employment contract, portraying the different qualities of this important input. The lack of quality control reduces the institutional comparability because the differences in technical efficiencies can be attributed to the quality (Salerno, 2003). Hence, institutions with consistent data were used.

Finally, the focus on the HEIs with courses in business administration is due to the importance of this area. The number of enrollments in HEIs has grown year after year, but this increase has not been equally distributed. The increase in the number of students in courses in the area of business administration is enhanced and the presence of such courses at the HEIs in several countries, particularly in Brazil, is significant. This can be explained partially as these courses are relatively inexpensive when compared with courses such as engineering and medicine, among others (Engwall, 2007). Thus, of the 105 HEIs counted initially had a final number of 78 observations due to some missing information on some of the databases used.

### *3.4. The database*

The selection of the outputs and inputs to be used in the evaluation of the efficiency is a very important step, because there is a large number of existing variables and the DEA technique is especially sensitive to the amount of those used in the analysis (Johnes, 2006). Much of the empirical studies about efficiency in higher education used the number of students enrolled or the number of credits as an indicator for education output (Pozo, 2002; Salerno, 2003). Abbott and Doucouliagos (2003, 2009) utilized the number of students enrolled as an output because they believed this number better captures the learning aspects of an institution, which is the strategy employed in this work. The single output (or dependent variable) considered in this analysis is *NSE*, which is the number of students enrolled in the business administration course at the HEI.

Following the literature, the physical inputs, human or infrastructure, are frequently used in the analysis of technical efficiency (Pozo, 2002; Salerno, 2003; Chen, 1997), i.e. they are some of the model's explanatory variables. In this work, all the factors are random because the researchers were interested in quantifying how much of the overall variation to attribute to a factor and they also would like to generalize the conclusions about this factor to the whole population (Grace-Martin, 2003).

In this work, two sets of variables regarding human inputs are used. The first one relates to the number of technical and administrative staff represented by *TAS*. This input was utilized because technical and administrative staff is an operating part of the infrastructure and the resources of the institution. The second group of variables is related to the size and quality of the faculty members of the institution. To take into consideration not only the number of professors but also their quality, the categories of professors are separated in different variables. It would be possible to aggregate the categories of professors into a single category with all the professors, but their experience and their level of education—important aspects of a professor and the most important input in an HEI—would be lost in the assessment. Accordingly, the variables *FMSG*, *FMM*, and *FMD* represent the number of professors with specialization, master's degree, and doctorate, respectively. Finally, the explanatory variable PROF corresponds to the weighted number of professors by the type of employment contract. This variable is used especially because when it comes to teaching in the classroom all professors have the same importance. However, it is believed that the greater the professors' dedication to the institution, including extra-class activities, the more positively to the institution they contribute (Calderón, 2000). Again, the professors, $F =$ faculty members in full-time, part-time and hourly contract, respectively, receive an importance equals to 3, 2, and 1. So, it is expected that both the quantity of members and the quality measured by their title or their employment contract type influence positively the number of enrolled students, the dependent variable.

Concerning the infrastructure inputs the variables used represent the infrastructure of the institution for the use and support of the student, such as the number of computers for academic purposes (*COMP_ACAD*) and for administrative purposes (*COMP_ADM*) and the number of books in the library (*LIB*). Not many studies utilized the quantities of physical inputs. In this work, it is believed that these physical quantities are intrinsic part of the HEI infrastructure and they affect directly and positively the number of enrolled students.

To avoid the methodological problem of institutional lack of comparability, which may affect the technical efficiency as proved in many estimates of the production function, the quality of the infrastructure is taken into account. As pointed out by Salerno (2003), not measuring the quality of an input is the major weakness of the studies of higher education production. Therefore, we used the results of a survey conducted among seniors and first-year students of the business administration course of each HEI, concerning the quality of the physical facilities (*E48M*), the access to computers to meet the needs of the course (*E53M*) and library collection, concerning the updates, according to the needs of the course (*E54M*). The value of each of these variables was also used as explanatory variables, ranging from 0 (minimum quality) to 5 (maximum quality) and reflects the average of responses from students. Those qualitative variables could also be aggregated into a single one, but again, in doing so the quality and greater detail of the infrastructure inputs are not addressed.

The explanatory variable *TCH* was also added, which corresponds to the number of total course hours. This variable represents the duration for which the institution's resources are used, or how much of the infrastructure available is used for academic purposes. Finally, the variables related to the amount of funding (*FUND*) and scholarships (*SCHOL*) granted by the HEI were also considered, because the institutions that make use of these resources are benefiting from filling their idle vacancies without increasing their costs proportionally. Regarding the variable *FUND*, the weights given to nonrefundable financing, mixed, and repayable financing are, respectively, equal to 3, 2, and 1. For the *SCHOL*, the weights depend on the type of scholarship, ranging from a weight equals to 5 for full scholarships, to a weight 1 for scholarships between 10% and 19% of the total. Obviously, nonrefundable funding and full scholarships have a higher weight, as these factors make the HEI a more attractive institution for students.

In short, an attempt was made to include missing attributes in past researches: the failure to consider the quality of the variables and more detail of inputs used in the HEI. Both attributes can increase the accuracy of performance measures (Kuo et al., 2005). In addition, the large number of variables is important for structuring an appropriate model. The efficiency frontier techniques used allow variables to be tested, altering and removing variables that are not significant, without harming the process (Bandeira et al., 2001).

Table 2 shows the variables considered in this work, its definition, and the source of information. It is important to note that all variables were obtained from official information from the Ministry of Education of Brazil for the year 2006, through different databases: the Census of Higher Education, Portal of SINAES and Enade (http://www.inep.gov.br). Finally, it was not possible to obtain data on some variables specifically for the business administration course, only through HEI. In this case, they were considered in the proportion of the business administration students with respect to all students of the HEI. These variables are *PROF*, *TAS*, *LIB*, *COMP_ACAD*, *COMP_ADM*, *FUND*, and *SCHOL*.

## 4. Results

The model with the variables, inputs, and outputs described above was evaluated using both techniques—DEA and SFA. The software Frontier Analyst version 4.0 was used for DEA implementation and to obtain results of SFA the software STATA version 10 was used. In order to verify the importance of the variables in the calculation of the model, initially an investigation of atypical observations existence was made, which may hinder the analysis of the results of both DEA and SFA. Then, the resulting weights for each variable using both techniques will be presented and the results of institutions' efficiency will be discussed, indicating the complementarity of the two techniques.

### *4.1. Existence of atypical observations*

There are two common explanations for the existence of atypical observations: the error and presence of institutions with characteristics that are very different from other institutions in the sample (Fiorentino et al., 2006). As it is expected that errors may occur randomly, the stochastic method can reduce this problem. This is not the case when DEA is used, especially because one of the negative factors of this methodology is its sensitivity to extreme values (Pozo, 2002).

The efficiencies were evaluated using 78 institutions in order to verify the existence of atypical observations. Later, the institutions that met the two criteria were withdrawn: (i) should belong to the efficient frontier, and (ii) should be a reference to more than 20 other institutions. Thus, three data observations were eliminated and then the efficiencies for DEA and SFA were recalculated. Taking into consideration that only three institutions were excluded, the increase in average efficiency of DEA and SFA was significant, DEA being higher. At the same time, it is possible to verify that the variance of the efficiencies dropped to less than half for DEA. Hereafter, only the sample of 75 HEIs is used. Table 3 presents the descriptive statistics for the efficiencies before and after the institutions with extreme values were excluded from it.

Table 2
Definition of inputs and outputs

| Code | Definition | Source |
|---|---|---|
| *TCH* | It takes into account the number of total course hours | Census of Higher Education 2006 |
| *FMSG* | It takes into account the number of professors with specialization or graduation for the course | Portal of SINAES |
| *FMM* | It takes into account the number of professors with Master's degree for the course | Portal of SINAES |
| *FMD* | It takes into account the number of professors with Doctorates or higher grade for the course | Portal of SINAES |
| *PROF* | It takes into account the number of professors for type of employment contract, according to the formula and their weights in proportion to the students of the course<br>Formula: [3 × (full-time professors) + 2 × (part-time professors) + 1 × (hourly contracted professors)] × (students enrolled in the course) / (students enrolled in the HEI) | Census of Higher Education 2006 |
| *TAS* | It takes into account the number of technical and administrative staff in accordance with the formula and their weights in proportion to the students of the course<br>Formula: (staff of the HEI) × (students enrolled in the course) / (students enrolled in the HEI) | Census of Higher Education 2006 |
| *LIB* | It takes into account the total print collection according to the formula and their weights in proportion to the students of the course<br>Formula: (HEI books') × (students enrolled in the course) / (students enrolled in the HEI) | Census of Higher Education 2006 |
| *COMP_ACAD* | It takes into account the number of computers for academic purposes, in proportion to the students of the course<br>Formula: (HEI academic computers') × (students enrolled in the course) / (students enrolled in the HEI) | Census of Higher Education 2006 |
| *COMP_ADM* | It takes into account the number of computers for administrative purposes, in proportion to the students of the course<br>Formula: (HEI administrative computers') × (students enrolled in the course) / (students enrolled in the HEI) | Census of Higher Education 2006 |
| *E48M* | It takes into account the issue of Enade (2006) concerning physical facilities used in the course. The data refer to the average of the responses of freshmen and seniors when both answered the questionnaire and only the freshmen when there were no seniors responding to the questionnaire. The data are consistent with the formula and their weights<br>Formula: (freshmen + seniors) / 2 for complete HEI and freshman for HEI with only freshmen responding | Enade 2006 |
| *E53M* | It takes into account the issue of Enade (2006) relating to the access to computers that meet the needs of the course. The data refer to the average of the responses of freshmen and seniors when both answered the questionnaire and only the freshmen when there were no seniors responding to the questionnaire. The data are consistent with the formula and their weights<br>Formula: (freshmen + seniors) / 2 for complete HEI and freshman for HEI with only freshmen responding | Enade 2006 |

Table 2
Continued

| Code | Definition | Source |
|---|---|---|
| *E54M* | It takes into account the issue of Enade (2006) relating to library collection, regarding the update on the needs of the course. The data refer to the average of the responses of freshmen and seniors when both answered the questionnaire and only the freshmen when there were no seniors responding to the questionnaire. The data are consistent with the formula and their weights<br>Formula: (freshmen + seniors) / 2 for complete HEI and freshman for HEI with only freshmen responding | Enade 2006 |
| *FUND* | It takes into account the funding provided to students, according to the formula and their weights in proportion to the students of the course<br>Formula: [3 × (students with nonrefundable funding) + 2 × (students with mixed funding) + 1 × (students with refundable funding)] × (students enrolled in the course) / (students enrolled in the HEI) | Census of Higher Education 2006 |
| *SCHOL* | It takes into account the scholarships offered to students, according to the formula and their weights in proportion to the students of the course<br>Formula: [5 × (students with full scholarship) + 4 × (students with scholarships of 70–99%) + 3 × (students with scholarships from 50–69%) + 2 × (students with scholarships from 20–49%) + 1 × (students with scholarship from 10–19%)] × (students enrolled in the course) / (students enrolled in the HEI) | Census of Higher Education 2006 |
| *NSE* | It takes into account the number of students enrolled in the course | Census of Higher Education 2006 |

Source: authors.

Table 3
Sensitivity of efficiencies to the extreme values

| | DEA | | SFA | |
|---|---|---|---|---|
| | Before | After | Before | After |
| Average | 91.208 | 96.055 | 0.595 | 0.614 |
| Standard error | 0.463 | 0.328 | 0.022 | 0.022 |
| Median | 90.370 | 95.650 | 0.638 | 0.663 |
| Standard deviation | 4.087 | 2.836 | 0.197 | 0.188 |
| Variance | 16.701 | 8.045 | 0.039 | 0.035 |
| Kurtosis | 0.403 | −1.120 | −0.612 | −0.265 |
| Asymmetry | 0.744 | 0.052 | −0.501 | −0.718 |
| Range | 18.690 | 10.270 | 0.757 | 0.767 |
| Minimum | 81.310 | 89.730 | 0.148 | 0.143 |
| Maximum | 100.000 | 100.000 | 0.905 | 0.910 |
| Observations | 78 | 75 | 78 | 75 |

Source: authors.

Table 4
DEA average weights

| Variables | Weights |
|---|---|
| *TCH* | 0.712 |
| *FMSG* | 20.864 |
| *FMM* | 6.659 |
| *FMD* | 3.735 |
| *PROF* | 0.000 |
| *TAS* | 12.995 |
| *LIB* | 10.796 |
| *COMP_ACAD* | 2.653 |
| *COMP_ADM* | 9.649 |
| *E48M* | 2.769 |
| *E53M* | 0.205 |
| *E54M* | 0.443 |
| *FUND* | 26.713 |
| *SCHOL* | 1.791 |

Source: authors.

### 4.2. Weight analysis (DEA) and coefficients (SFA)

To calculate the levels of efficiency, DEA provides the weights that were used in the evaluation of the variables for each institution. These weights are provided in Table 4. It is worth highlighting three findings. First, the weights of the numbers of professors with Master's Degree and Doctorate (variables *FMM* and *FMD*) are relatively small, especially when compared with the number of professors with post graduation (*FMSG*). This result can be explained by the fact that these HEIs do not have their focus on research.

Second, the variable related to funding (*FUND*) has a great weight, even higher than the faculty members or other resources of educational institutions. Finally, a somewhat surprising result is that the weights for the qualitative variables (variables *E48M*, *E53M*, *E54M*) are almost negligible. It probably happened because these qualitative tests are new and students are still not used to utilizing them when choosing their college.

Table 5 shows the results of SFA, that is, the coefficients of the inputs used and also their *p*-values are given in parentheses. The resulting coefficients deserve to be highlighted. To a great extent, it is observed that with few exceptions, the variables whose coefficients are significant in the analysis of SFA are those that have high weights in the analysis of DEA: *TAS*, *LIB*, *COMP_ADM*, *FUND*, and *FMSG*. At the same time, in general, the variables whose coefficients are statistically insignificant in explaining the output in the SFA analysis have low weights in the analysis of DEA: *TCH*, *FMM*, *FMD*, *COMP_ACAD*, *E48M*, *E53M*, *E54M*, and *SCHOL*.

An exception was made to the fact that the *PROF*, which corresponds to the weighted number of faculty members related by type of employment contract, has a significant coefficient in analyzing SFA and was not relevant in DEA. At the same time, it was expected that its coefficient would be positive, since the larger this variable, the more time the professor will spend at the institution, i.e. the greater the dedication of professor. Finally, it is worth noting that as in the case of DEA and unlike expected, the coefficients of the qualitative variables (*E48M*, *E53M*, *E54M*) were not significant in

Table 5
Coefficients calculated by SFA

| Variables | Coefficients[1] |
|---|---|
| *TCH* | – 0.232 |
| | (0.772) |
| *FMSG* | 0.131 |
| | (0.072)* |
| *FMM* | 0.028 |
| | (0.754) |
| *FMD* | – 0.033 |
| | (0.788) |
| *PROF* | – 0.274 |
| | (0.023)** |
| *TAS* | 0.426 |
| | (0.000)*** |
| *LIB* | 0.177 |
| | (0.043)** |
| *COMP_ACAD* | 0.015 |
| | (0.742) |
| *COMP_ADM* | 0.176 |
| | (0.028)** |
| *E48M* | 0.687 |
| | (0.511) |
| *E53M* | – 1.336 |
| | (0.321) |
| *E54M* | 0.277 |
| | (0.790) |
| *FUND* | 0.079 |
| | (0.095)* |
| *SCHOL* | 0.030 |
| | (0.430) |
| *CONSTANTE* | 6.419 |
| | (0.383) |
| $\sigma_v$ | 0.261 |
| | [0.075] |
| $\sigma_u$ | 0.731 |
| | [0.122] |
| $\sigma$*** | 0.602 |
| | [0.154] |
| Λ | 2.802 |
| | [0.182] |
| Log Likelihood | – 53.407 |
| *LR* test | 3.700 |
| $(\sigma_u = 0)$ | (0.027)** |
| Wald $\chi$*** | 219.690 |
| | (0.000)*** |

Source: authors.
[1] *p*-values are given in parentheses and the standard errors are given in square brackets.
*Coefficient significant at 0.10 level of significance.
**Coefficient significant at 0.05 level of significance.
***Coefficient significant at 0.01 level of significance.

SFA. In short, it is possible to observe that the analysis of results of DEA and SFA indicate many similarities between the variables to explain the output *NSE*, i.e. the number of students enrolled in the HEIs of the sample.

### *4.3. Analysis of efficiency using DEA and SFA*

Table 6 shows the ranking of efficiency calculated by DEA and SFA. The first and the last 20 HEIs in the ranking of efficiencies are listed. Additionally, some HEIs were present in the first or last 20 positions in both methodologies, and these are denoted in bold. In case of a technical analysis of DEA, the HEIs considered efficient attained 100% efficiency. In the case of SFA, as it is possible to calculate the distance of maximum possible efficiency, it was observed that there is no HEI that reached the maximum efficiency (all are below 100%).

Additionally, some HEIs were present in the first or last 20 positions in both methodologies. As seen in Table 6 in the first cases are the HEIs E, Y, AF, AI, AO, AP, BA, BG, BM, AS, R, V, O, and BP. The second cases are the HEIs M, AK, BW, P, Q, D, G, L, BX, W, AA, H, and BU. This may indicate the robustness of the choice of variables and that the methodologies are complementary to each other. At first, there is no reason to favor one technique over another. Consequently, it is reasonable to analyze the efficiency using different techniques to cross-check the results (Stone, 2002).

The estimates of efficiency obtained should be used as indicators for deeper analysis. According to Jacobs et al. (2006), the comparison between SFA and DEA allows institutions to be divided into three groups: (a) a group sensitive to the choice of methodologies, (b) a group efficient in both methodologies, and (c) a group where institutions appear inefficient in both methodologies. It is not advisable to draw conclusions about the level of efficiency of the institutions in the first group. The second group is more informative. And finally, the third group is the one that deserves more investigation by the institution, so it is clear that its technical efficiency is inferior to its competitors in both approaches. The results can provide important information about benchmarking, potential improvements for each variable, besides identifying which input most affects the efficiency of the institution.

## 5. Concluding remarks

This study aimed to measure the efficiency of a fairly homogeneous group of an HEI: private institutions with business administration courses, for-profit, and located in the same geographic region (the State of São Paulo, Brazil). Two important results emerge from the analysis performed with both techniques (DEA and SFA). On the one hand, both identified with few exceptions, the same explanatory variables (or inputs) as significant in explaining the level of output (in this case, the number of students enrolled). On the other hand, both techniques could identify to a large extent, the same HEIs as the best and worst in terms of efficiency. In other words, both methodologies identify the HEIs that had consistent extreme results. These similar results are achieved from different techniques, are somewhat complementary, and suggest a robustness of the results. Therefore, the efficiency estimates obtained can be used at least to improve the performance of those HEIs that appear as inefficient in both methodologies. It is worth mentioning that the results should work as a support for the HEIs' managers to determine the sources of inefficiency and the priority variables to improve the productive performance of their institutions.

Table 6
Rankings of average efficiencies

| DEA | | SFA | |
|---|---|---|---|
| HEI | Efficiency (%) | HEI | Efficiency (%) |
| **E** | 100.00 | **BP** | 0.910 |
| **Y** | 100.00 | **BG** | 0.897 |
| **AF** | 100.00 | **V** | 0.878 |
| **AI** | 100.00 | BF | 0.869 |
| AJ | 100.00 | **BA** | 0.860 |
| **AO** | 100.00 | **AS** | 0.843 |
| **AP** | 100.00 | **O** | 0.820 |
| AX | 100.00 | **R** | 0.818 |
| **BA** | 100.00 | **AF** | 0.815 |
| **BG** | 100.00 | **E** | 0.805 |
| BH | 100.00 | **AP** | 0.804 |
| BJ | 100.00 | **Y** | 0.793 |
| BK | 100.00 | X | 0.790 |
| **BM** | 100.00 | **AI** | 0.783 |
| BN | 100.00 | AD | 0.776 |
| **AS** | 99.85 | **BM** | 0.767 |
| **R** | 99.46 | **AO** | 0.766 |
| **V** | 99.33 | AC | 0.757 |
| **O** | 99.07 | AZ | 0.756 |
| **BP** | 98.89 | AY | 0.754 |
| ... | ... | | |
| BE | 93.82 | **D** | 0.518 |
| **M** | 93.78 | BJ | 0.504 |
| BQ | 93.61 | AH | 0.478 |
| B | 93.61 | **BW** | 0.467 |
| **AK** | 93.61 | **G** | 0.452 |
| **BW** | 93.55 | BO | 0.447 |
| **P** | 93.52 | AQ | 0.420 |
| AL | 93.47 | **AA** | 0.413 |
| **Q** | 93.21 | **P** | 0.378 |
| Z | 93.09 | **M** | 0.375 |
| BD | 92.93 | AR | 0.350 |
| AY | 92.80 | **BX** | 0.350 |
| **D** | 92.40 | **Q** | 0.319 |
| **G** | 92.38 | T | 0.311 |
| **L** | 92.15 | **AK** | 0.282 |
| **BX** | 91.98 | AM | 0.240 |
| **W** | 91.87 | **L** | 0.231 |
| **AA** | 91.85 | **H** | 0.206 |
| **H** | 90.94 | **BU** | 0.192 |
| **BU** | 89.73 | **W** | 0.143 |

Source: authors.

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