Education Production Efficiency: Evidence from Brazilian Universities

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ABSTRACT

This paper investigates how efficient are the Higher Education Institutions (HEI) in Brazil, and which institution – public or private – is more efficient in the production of knowledge. In addition, it was also verified the determinants of performance of Brazilian students in Higher Education. We estimated a Stochastic Production Function of Education for the Brazilian HEI based on information from the Higher Education Census of 2006 and the National Examination of Performance Evaluation of Student (Enade) of 2007. By using the difference between the scores of first-year and last-year college students of National Examination of Performance Evaluation of Student (Enade) aggregated by HEI as a product in the Stochastic Production Function, it was possible to contribute with a new element to the literature devoted to the estimation of the Production Function of Education. The results show that the characteristics of institutions are the variables that best explain their performance. Additionally, public institutions are more inefficient than private ones.

Keywords: Aggregate Value, Higher Education**,** Standardized Tests **,** Stochastic Frontier Production Functions

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1. Introduction

The objective of this paper is to assess the determinants of performance of Higher Education Institutions (HEI) in Brazil, taking particularly into account the relative efficiency of public and private institutions on the application of their resources. There has been a remarkable increase in the demand for Higher Education in Brazil in the past two decades. This reflects the response of the labor market demand for better qualified professionals, and also the requirement that candidates for public office must have Higher Education to sit for competition exams. In addition, in this same period, the percentage of individuals who finished High School education has increased, which eventually boosted the demand for Higher Education.[5] Moreover, the Federal Government influenced the supply of vacancies in two ways. The first concerns the Federal Government's policy for the sector, which was apparently based on the supply of a larger number of vacancies through expansion of private organizations (Pinto, 2004). The second one is related to the "University Education for All" (ProUni), a program devised by the Brazilian Ministry of Education in 2004. This program grants low-income students from private HEI full-tuition or half-tuition scholarships.[6]

According to data of the 1987 and the 2007 Higher Education Census, the number of students enrolled in HEI more than tripled (a 231.9% increase). However, one should underscore that enrollments in private HEI were virtually three times greater than those in public institutions during the same period, increasing their share in the overall enrollment rate from 60.2 to 74.6% between 1987 and 2007. Regarding the overall enrollment rate in HEI, the change observed in this period was 167.41%. Additionally, the number of public HEI rose only 3.75% between 1987 and 2007, compared to 231.48% in private HEI.

The empirical literature that estimates production functions of K-12 Education developed independently from the literature on the efficiency of education provision. The ordinary least squares method (or any variant) was commonly used to plot a function through a series of points, and the residuals did not receive a special treatment. What actually mattered was the parameters of the production structure, not the individual deviations from the estimated function. This shows that the mean was considered more important than best practice.

The scores on standardized tests (known in Brazil as National Examination of Performance Evaluation of Student – ENADE) for Brazilian universities provide a widely accepted output measure and the possibility for direct estimation of an education production function. While qualitative indicators, such as occupation and remuneration in the long term, could better describe the contribution of education to human capital, an intermediate result as the score obtained on a standardized test can be regarded as one of the basic elements in human capital accumulation.[7]

Thus, the present paper estimates a stochastic production function for education, in which each university must cope with its own production frontier. This frontier is randomly dependent on the full set of stochastic elements that are deemed important but that cannot be controlled by the universities.

The available empirical literature on the efficiency of higher education uses mainly data envelopment analysis (DEA), which is usually applied in the estimation of cost functions of universities in an individual country in which the dependent variable generally captures the number of enrolled students or their level of achievement (master's degree, PhD, if financial support is granted, etc.).[8] Some recent references include

[5] The comparison of the Brazilian National Household Survey (PNAD) data for 1987 and 2007 shows that 4.66% of the Brazilian population aged 18 to 25 years attended higher education in 1987. In 2007, however, this rate amounted to 12.60%. Regarding high school education, according to PNAD data for 1987, 14.81% of Brazilian individuals had completed high school education by the age of 19. In 2007, this rate rose to 42.95%.

[6] Charnes and Cooper (2002) analyze different aspects regarding knowledge production by U.S. HEI, and one of their goals is to check the relative efficiency of public and private universities in the conferral of doctoral degrees.

[7] Sutherland, Price, Jourmad and Nicq (2007), to some extent, go in the same direction, using the scores of PISA in four academic disciplines as an intermediate result in order to evaluate the efficiency of basic education provision in OECD countries.

[8] Johnes, Oskrochi and Crouchley (2002) are an exception since they use the stochastic frontier method to estimate a cost function for UK higher education institutions.

Avkiran (2001) and Abbott and Doucouliagos (2003) for Australia, Salerno (2002) and Calhoun (2003) for the United States, Afonso and Santos (2004) for Portugal, Warning (2004) for Germany, Johnes (2005) for England, Jongbloed and Salerno (2003) and Chercye and Abeele (2005) for the Netherlands, and Castano and Cabanda (2007) for the Philippines. Joumady and Ris (2004) represent an exception as they work with a set of countries (Austria, Finland, France, Germany, Italy, Netherlands, Spain and the United Kingdom).[9] They also innovate by using the competence gained during the undergraduate years and the competence required by their current job as output measure. This information is obtained from a survey done with college students.[10]

Ferrari and Laureti (2004) and Laureti (2008) estimate a higher education production function in which the student is considered as the basic unit of production, using a model of homoskedastic (no explanation for the error terms) and heteroskedastic (some of the error terms are explained through other variables) stochastic frontier. As their studies assess a single university, the output measure is given by the mean score on the test. However, it is common knowledge that the tests made to be applied in the classroom by professors are not standardized. A standardized test is one that is administered, corrected (given a score) and interpreted in a standardized way. The objective of standardization is to ensure that all individuals who take the test are evaluated under the same conditions. In this case, no student will have any advantage over others. This way, there will be no differences in test application and the results will be comparable. Therefore, because ENADE is a standardized test, it provides a better output measure.

The paper is organized as follows. The output measure is discussed in Section 2. As the existence of standardized tests in HEI has not been described for other countries, the evaluation system used by Brazilian universities is carefully analyzed from its implementation to the current period. Section 3 briefly describes the inputs used. Section 4 presents the results and Section 5 discusses the robustness of these results. The last section summarizes the main conclusions.

2. Measuring the performance of higher education institutions: definition of output

As HEI produce a series of outputs, it is not easy to measure the results obtained by the universities. As illustrated by Salerno (2008, p. 25), suppose two institutions with the same number of students. Note, however, that one provides excellent education while the other one offers reasonable education. If the number of enrolled students were used as output measure, the institution with the largest number of students per professor would probably be considered more efficient, which is not necessarily true.

Although researchers suggest that an ideal estimation of education output attaches a "weight" to the number of students that an institution educates (Nelson and Hevert, 1992), the estimation difficulties make the task virtually impossible. Therefore, proxies in which education output is almost exclusively measured by enrollments or number of awarded diplomas are used, even though the limitations of disregarding quality are explicitly recognized.

Large-scale evaluations of higher education in Brazil have considerably improved in the past few years. To our knowledge, no other country uses an evaluation that is applied to students both at the beginning and at the end of their higher education courses. This allowed us to measure an output that takes into account the effort put into education of students and therefore may be more appropriate in an efficiency evaluation.

[9] Agastini (2008) also investigates several countries (Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Great Britain, Hungary, Ireland, Italy, Netherlands, Norway, Poland, Slovakia, Spain, Sweden, and Switzerland), and three outputs in order to calculate the frontier: rate of undergraduate students; rate of employability and of undergraduate students from abroad.

[10] Undergraduate students were asked to indicate to what extent they had acquired competence during their undergraduate years and to what extent this competence was required in the job they were holding at the time. To do that, the students used a scale between 1 (not at all) and 5 (to a very high extent), .

Higher education assessment was implemented in Brazil by Law 9.131 in 1995. This law established that a National Undergraduate Course Examination should be applied to all last-year college students in Brazil in previously chosen courses. This examination became known as "Provão."

The "Provão" consisted of a written examination applied annually and throughout the Brazilian territory. Students were obliged to participate, and those who did not take the exam could not obtain their diplomas. Decree no. 2.026/96 lays down the following as additional measures for higher education assessment: i) analysis of general performance indicators by state and by region, in accordance with the area of knowledge and the type of institution, based on Higher Education Census data[11]; ii) institutional assessment, based on information from the Census, but also on the reports of experts who visit the institutions in search of information in order to assess their administration, education, social integration and their technological, cultural and scientific products. The Decree maintained CAPES (Campaign for the Advanced Training of University-Level Personnel) in charge of assessing the graduate courses, as had been the case since 1976.

In 2001, Decree no. 3.860 officially established the high-stakes evaluation system ("significant consequences for whom is being evaluated"), which should be used to guide decisions concerning the reaccreditation of institutions and the recognition and renewal of courses.[12]

The courses were classified according to the scores obtained on "Provão," that is, the average performance of the students was compared with the average performance of other courses in the same area of knowledge. As a minimum score that indicated proficiency in the course was not adopted, the results could not be directly used as a measure of teaching quality. This occurred only if, on average, a course had more or less prepared students than other courses in the same area of knowledge. In addition, the fact that the tests were not equivalent did not allow for the comparison of the results of different areas or of the same area over time. To make things worse, as the test was applied only to last-year students, the "Provão" could not identify the syllabuses that actually contributed to increasing the students' level of knowledge. Thus, institutions with a more rigorous admission process, usually had the best performance on "Provão." Special attention is given to public universities that tend to attract the best students. This is due to the fact that they enjoy excellent academic reputation, and are free of charge, even though the quality of these institutions is believed to have dropped recently because of budgetary problems and successive strikes.

Despite the expansion of "Provão" (from three areas tested in 1995 to 26 in 2003) and the reduction in the resistance to higher education assessment at the time of its implementation during the 2002 presidential campaign, various aspects of the test were discussed. Immediately after President Luiz Inacio Lula da Silva took office, a special committee was created for higher education assessment (CEA), whose objective was to suggest changes in the higher education evaluation system based on "Provão." In August 2003, the committee suggested a new system, which was formally established by federal law no.10.861 passed in April 2004. The Brazilian National Higher Education Evaluation System (SINAES) included a new approach for the evaluation of higher education courses, called Student Achievement Assessment Test (known in Brazil as ENADE).

ENADE maintained the approach of "Provão" by assessing courses separately, instead of evaluating the areas. However, both first-year and last-year students are now assessed, with the goal of determining to what extent the course contributes to learning, including an approximation of the concept of aggregate value

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[11] The following indicators, based on Decree no. 2.026/96, were used: gross and net rates of enrollment, availability of vacancies for new students, dropout and promotion rates, average time for course completion, level of qualification of professors, student to professor ratio, average number of students per class, cost per student, percentage of costs for higher education in relation to the overall public spending on education and percentage of GDP spent on higher education.

[12] In fact, only in extreme cases did institutions lose their accreditation. The Brazilian Ministry of Education needed to make some interventions in a few private institutions, but attempts to close courses and institutions whose performance was too poor were short-lived due to appeals filed with the judiciary, with the Brazilian National Council for Education or due to political pressure. The Brazilian Ministry of Education never made any intervention in any public institutions. The process of periodical reaccreditation did not come into force either.

in the results. This is known as performance indicator. The performance indicator would theoretically allow for two comparisons. The first would be the comparison between the averages obtained by last-year students and the averages obtained by first-year students in the same year. The problem is that the profile of students from a given course or institution may have changed during the course, and a selection effect may also occur as a result of students' promotion or retention, which tends to have a positive impact on the performance indicator.

The second would be the comparison of the results obtained by freshmen in the first year of the 3-year cycle of evaluation with those of last-year students in the third year of this same cycle. In this case, procedures that provide good performance indicators could be adopted. One could, for example, encourage first-year students to show poor performance, increase the rigor of tests during the course in order to retain students with the worst performance and promote only those students who do not compromise the results of the institution in ENADE. If the same students were evaluated in the first and last year, these problems would obviously be solved. Apart from the difficulties associated with obtaining such a panel, other problems could arise such as the provision of benefits so that poor performance could be improved.

Another difference between the "Provão" and ENADE concerns the fact that the latter proposes to establish minimum standards in different areas of knowledge, and to disperse the high-stakes system of "Provão" since ENADE takes into account other indicators and only by considering all of them one may take some regulatory decision and focus on general and specific knowledge. Finally, ENADE included the sampling procedure. A major criticism against the sampling approach is that it could lead to misrepresentations because the institutions could list only those candidates who were better prepared for the test. The score obtained in ENADE is recorded in the student's college transcript.

The test is composed of 40 questions, 10 related to general knowledge (25% of the score) and 30 related to specific knowledge in the area (75% of the score), both parts including open-ended and multiple choice questions. Last-year and first-year students are eligible to take the test , and only a share of these. students are selected at random. After a student is selected at random, he/she must take the test, otherwise he/she will have problems taking out the diploma and will need to provide justifications to the Brazilian Ministry of Education.

Table 1 shows the mean scores for ENADE general and specific tests applied in 2007 to first-year and last-year students from public and private higher education institutions.

Note that the scores obtained by first-year and last-year students are higher for those attending public universities than for those in private institutions, regardless of the region of the country. Thus, students who are better prepared are admitted to public universities (first-year students with the highest scores) and are better prepared when they leave these institutions (last-year students with the highest scores).

Given the aggregate value of knowledge, measured by the difference between the scores obtained by last-year and first-year students, one observes that the courses provide students with specific knowledge, other than general knowledge, as could be expected. In Brazil, general knowledge scores have shown an 11% improvement compared to 50% in specific knowledge scores.

With regard to the aggregate value of specific and general knowledge, the scores vary markedly from region to region and also depend on whether the institution is public or privately-owned.

For example, for the North and Northeast regions of Brazil, the aggregate value of specific knowledge in private institutions exceeds that of public institutions (56 and 61% for private institutions against 44 and 56% for the public ones, respectively). However, in the Southeast and South regions of Brazil, there are no differences in the improvement rate of specific knowledge between public and private HEI. Only in the Central West region of Brazil is the percentage gain concerning specific knowledge higher in public HEI.

Nevertheless, in the Northeast, Southeast and South, private HEI provide more general knowledge in percentage values than public HEI. All in all, the Northeast was the region with the greatest percentage increase in aggregate value of knowledge (44%) followed by the North (41%) and South (37%). These data suggest that, in terms of aggregate value, we must take into account the following: 1) whether the institutions

are public or private; 2) the regions where HEI are located, and 3) the different components of the test (general or specific knowledge), as they may influence the results when one estimates the factors that determine the performance of HEI.

Table 1 – Average score in ENADE 2007 for first-year and last-year students in public and private institutions

		General		***Public***		***Private***	
		First-year	Last-year	First-year	Last-year	First-year	Last-year
Brazil	General knowledge	44.67 (21.96)	49.59 (21.78)	47.41 (24.21)	54.61 (25.14)	42.53 (20.32)	46.48 (18.96)
	Specific knowledge	31.35 (16.29)	47.21 (20.11)	32.61 (17.26)	50.94 (22.72)	30.17 (15.68)	44.70 (18.13)
	General and Specific knowledge	34.69 (16.12)	47.81 (19.26)	36.33 (17.45)	51.87 (22.25)	33.27 (15.18)	45.16 (16.88)
North	General knowledge	42.06 (19.25)	50.68 (22.71)	42.07 (19.26)	51.90 (23.55)	40.20 (19.00)	44.73 (18.56)
	Specific knowledge	31.12 (14.08)	44.94 (20.46)	31.19 (14.06)	45.13 (21.28)	27.88 (14.69)	43.68 (17.34)
	General and Specific knowledge	33.87 (13.90)	46.38 (19.71)	33.92 (13.89)	46.84 (20.61)	30.98 (14.05)	43.95 (15.91)
Northeast	General knowledge	45.49 (26.09)	49.24 (24.98)	47.18 (28.04)	50.36 (25.81)	41.55 (21.22)	45.84 (21.17)
	Specific knowledge	29.88 (18,41)	47.13 (22.50)	30.13 (19.58)	47.30 (23.14)	28.59 (15.54)	46.26 (19.57)
	General and Specific knowledge	33.80 (18.86)	47.67 (22.02)	34.40 (20.28)	48.07 (22.76)	31.84 (15.31)	46.16 (18.65)
Southeast	General knowledge	44.52 (21.87)	48.54 (21.31)	54.99 (26.80)	57.37 (26.43)	42.16 (20.34)	46.09 (19.08)
	Specific knowledge	30.68 (16.47)	45.85 (19.81)	35.22 (18.97)	52.99 (23.59)	29.44 (15.92)	43.67 (18.29)
	General and Specific knowledge	34.15 (16.21)	46.54 (18.88)	40.17 (19.33)	54.10 (23.28)	32.63 (15.37)	44.29 (17.04)
South	General knowledge	45.45 (22.03)	51.00 (20.73)	50.62 (25.38)	55.03 (23.98)	43.13 (20.37)	47.96 (17.88)
	Specific knowledge	33.42 (16.55)	50.14 (19.10)	35.62 (19.22)	53.01 (21.98)	32.25 (15.43)	47.94 (16.91)
	General and Specific knowledge	36.44 (16.30)	50.37 (18.20)	39.38 (19.19)	53.53 (21.39)	34.98 (14.99)	47.96 (15.61)
Central West	General knowledge	47.45 (20.93)	52.18 (21.08)	53.14 (22.78)	58.99 (21.43)	44.06 (19.39)	46.53 (19.13)
	Specific knowledge	31.62 (15.37)	49.01 (19.44)	33.99 (16.92)	54.79 (19.63)	30.03 (14.44)	43.92 (18.04)
	General and Specific knowledge	35.59 (15.03)	49.82 (18.62)	38.79 (16.41)	55.85 (18.89)	33.55 (14.06)	44.58 (16.97

Source: Standard deviations are shown in parentheses.

Thus, it was possible to use the difference between the general knowledge scores obtained by last-year and first-year students as output measure.[13] This allowed us to analyze the effects of inputs on how much students' knowledge changed throughout their graduate course. In addition, when we used the difference between scores, we removed the possible effect of best (worst) scores luring the best (worst) students, that is, those who obtain the highest scores as first-year students.

The information used herein was obtained from Microdata of the Higher Education Census 2006 and from ENADE 2007.

3. Measuring the performance of higher education institutions: definition of inputs

The following variables were used as HEI inputs obtained from Higher Education Census microdata:

1) Total number of professors per enrolled students as a measure of labor input;
2) Total number of computers per enrolled students as a measure of capital input;
3) Existence of a complete teaching plan as proxy for technology; [14]
4) Expenditures on professors (disregarding inactive ones) per student;
5) Capital expenditure per student;
6) Expenditures on other factors (maintenance, cleaning etc) per student.[15]

In addition, we included explanatory variables that indicate family background and students' inherent characteristics. This information is given in percentage values per type of HEI, as follows:

1) If the student works more than 20 hours per week;
2) Dummy equal to 1 if the student is non-white and 0, otherwise;
3) Maternal education. It has been a fundamental factor for students' performance in works that assess the determinants of K-12 education,[16] which suggests that it can also occur with higher education. Therefore, this variable was used as input for the stochastic frontier production function.

Table 2 presents some descriptive statistics of the inputs, classified according to the type of HEI (public or private), contemplating all Brazilian regions.

Table 2 – Inputs based on the information provided by students and categorized by type of HEI

Region	**North**		**Northeast**		**Southeast**		**South**		**Central West**	
Type of HEI	*Private*	*Public*	*Private*	*Public*	*Private*	*Public*	*Private*	*Public*	*Private*	*Public*
Professor to student ratio	0.0225	0.0306	0.0218	0.0391	0.0293	0.0602	0.0126	0.0042	0.0318	0.0378
Total number of computers per student	0.0759	0.0346	0.0425	0.0619	0.0549	0.2503	0.073	0.131	0.0636	0.0754
Complete teaching plan of the HEI (%)	61.89	40.28	63.47	47.54	61.02	49.64	63.3	52.43	63.02	48.12
Expenditure on professors per student	1,374	2,385	1,381	4,750	1,775	7,902	1,679	3,125	1,719	2,945
Capital expenditure per student	200	408	350	1,365	300	825	357	412	432	413
Other expenditures per student	2,028	2,059	1,885	6,641	2,551	10,519	2,284	4,099	1,518	2,341
Student working 20 hours or more (%)	28.49	28.5	28.2	23.64	49.21	21.97	45.7	29.44	37.71	25.65
Maternal schooling – higher education (%)	21.91	17.15	28.87	27.19	21.99	31.98	21.84	32.18	23.19	29.86
Non-white student (%)	44.16	37.03	36.51	36.22	21.26	20.28	9.03	7.59	28.54	23.98

Source: Created by the authors based on INEP (Brazilian National Institute for Studies and Research) data.

[13] The inputs derived from the ENADE questionnaire were aggregated to last-year and first-year HEI students.

[14] A complete teaching plan includes the following aspects: objectives, teaching and evaluation procedures, syllabus and related bibliography.

[15] The expenditures are established in R$1,000.00.

[16] Barros et al. (2001) and among other authors, indicate the family as the primary determinant of children's educational results, which are influenced mainly by their parents' education.

Note that public HEI have a larger number of professors per student than private HEI, except for the southern region. With respect to the variable used as proxy for capital, that is, the total number of computers per student, there is a higher value for public HEI in four of the five regions. In fact, in the southeastern region, the value found for public HEI is approximately five times greater than that observed in private HEI. However, the opposite was noted for the northern region, in which private HEI had a larger number of computers per student than public HEI.

In regard to the variable "complete teaching plan," note that a higher percentage of students from private institutions, comparatively to those from public institutions, gave a positive reply. As to the expenditures per enrolled student incurred by the HEI, public HEI spend more than private institutions. The expenditures on professors, capital expenditures, and other expenses may be fourfold larger in public HEI than in private ones. However, this difference varies across regions.

With respect to students' characteristics, the percentage of students who work 20 hours or more per week is higher in private institutions. In the south and southeast regions, this percentage is about two times larger than in public institutions.

Among public HEI in the southeast, south and central west regions of Brazil, the percentage of students whose mothers have college education is larger in public institutions. In the north and northeast regions, this percentage is higher among private HEI.[17]

Finally, there is a higher percentage of non-white students in private institutions than in public ones. This higher rate shows a perverse characteristic of the Brazilian higher education system, in which students of a more vulnerable socioeconomic background who wish to pursue higher education are forced to pay for it.

4. Results

As previously mentioned, the stochastic frontier production method is used to estimate the level of inefficiency of HEI. The specification for cross-sectional data is the following:

$$\ln y_i = \beta_0 + f(\beta_k, x_i^k) + v_i - u_i, \quad i = 1,\ldots,I;\ k = 1,\ldots,n, \ (1)$$

where $\ln y_i$ is the logarithm of the output of university *i*; β_0 is the intercept of the equation; $f(\beta_k, x_i^k)$ is the appropriate functional form; β_k is the vector of technological coefficients; x_i^k is the vector of inputs used for production by university *i*; v_i is the (idiosyncratic) random shock uncorrelated with x_i^k and u_i, with an $N(0,\sigma_v^2)$ distribution; and u_i is the nonnegative term that captures the inefficiency of university *i* also uncorrelated with x_i^k.

For the estimation of the technological coefficients of the stochastic frontier production function, we use maximum likelihood estimators.[18] It is necessary to make distributional assumptions about the term of

[17] By separately calculating the percentage of students whose mothers pursued higher education for first-year and last-year students, one observes an increase in public HEI in the past 5 years. This is possible to verify by comparing this rate between last-year students (admitted 4 or 5 years ago) and first-year students. Among private HEI, there is a contrary trend, that is, a reduction in this percentage over time, which indicates an increase in the demand for higher education among students with poorer family background.

[18] Other estimators may be used to calculate the coefficients. Maximum likelihood was used here because it is a consolidated method literature on technical inefficiency and also because it has interesting properties that other estimators do not appear to have. As the detailed description of the various possible methodologies for the estimation of stochastic frontiers is not within the scope of this work, we suggest that the readers see Kumbhakar and Lovell (2000).

inefficiency u_i. Various asymmetric distributions may be used for the term u_i, and in the present work, we assume that the inefficiency component of the model's error has an exponential distribution.[19]

One of the main disadvantages of the stochastic frontier method is the arbitrary choice for the efficiency distribution. However, there is evidence that the relative position of the decision-making units (DMUs) in the ranking of efficiencies is not very sensitive to the distributional form assumed by DMUs, as shown by Greene (1990). Thus, we believe that the obtained results can be deemed reliable.

Although HEI are the subject of analysis, only universities are considered. Other academic organizations (university center, colleges, etc) were not included in the sample. The reason for including only universities is that this academic category has a larger number of courses than other categories.[20] As our analysis includes a set of courses for each institution, we needed a more homogeneous sample with respect to the total number of courses offered by each HEI, and a sample that could represent the highest possible number of courses evaluated by ENADE. A total of 164 universities were assessed.

We decided to evaluate the efficiency of HEI using the difference between the general knowledge scores of last-year and first-year students as output variable, which allowed us to assess the effects of inputs on how much knowledge the HEI provided students with. Another reason for using the difference between the scores of last-year and first-year students as output variable is that private HEI, in general, proportionally provide more general knowledge than do public HEI (Table 2). However, the latter show the highest degree of proficiency, thus rendering this analysis highly interesting.

Table 3 presents the results of the stochastic frontier estimations. Two estimations were used for each model. The first specification identifies whether the inefficiency component of the model (u_i) is different from zero. This is necessary because otherwise the model could be estimated by OLS. The second specification includes additional information to explain the inefficiency of the model, if the component is different from zero. According to Siegel, Waldman and Link (2003), the variables that explain the deviations associated with relative inefficiency of the production function include environmental and institutional characteristics that lie beyond the control of production units.

In model 1, traditional variables, namely, capital and labor, are considered as input. The total number of professors per enrolled student was used as a measure of labor input whereas the total number of computers per enrolled student measured capital input. Furthermore, it was used a variable to indicate whether the HEI has a complete teaching plan in an attempt to determine the "quality" of the institution and its effect on productivity. [21]

In model 2, the input variables that were measured physically, are now replaced with their monetary compensation. Thus, expenditures on professors (disregarding inactive ones) per student, capital expenditures per student and other expenditures per student are used as inputs.

In model 1, note that the larger the total number of professors per student the lesser the difference between the scores of last-year and first-year students in both specifications (1.1 and 1.2, elasticity of approximately -1). This result demonstrates that this type of input is not a decisive determinant of aggregate knowledge.

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[19] When choosing an econometric method, it is necessary to evaluate the existing advantages between the choice made and the possible alternatives. The first question that arises is: why not use ordinary least squares (OLS)? As pointed out by Kumbhakar and Lovell (2000), the ordinary least squares estimator, albeit unbiased for the vector of technological coefficients, is biased for the intercept of the equation to be estimated. Furthermore, this method does not allow for the existence of technical inefficiency, attributing all the variation in production that can be explained by the variation in inputs to random shocks. In this situation, if inefficiency is not present, OLS is the most appropriate estimator for the production function. Thus, OLS assumes fully efficient states, while the stochastic frontier method does not.

[20] According to the statistical summaries of the 2007 Higher Education Census, universities have, on average, seven times more courses than other types of academic institutions.

[21] A complete teaching plan covers the following aspects: objectives, teaching and evaluation procedures, syllabuses and related bibliography.

As to the total number of computers per student, there is a positive and statistically significant effect on the difference between the scores (elasticity 0.4). This shows that by investing in capital, the HEI can aggregate more knowledge.

With regard to the variable "complete teaching plan," the greater the percentage of students who replied that the course had a complete teaching plan the smaller the difference between the scores of last-year and first-year students (elasticity -1.73). It should be underscored that this characteristic had a higher percentage among private institutions (Table 2).

The negative sign associated with the coefficients of the variables "professor" and "teaching plan" is unusual since a positive effect should be expected from both variables on the output. Two new stochastic frontier models were then estimated: one with only the scores of first-year students as output, and one with only the scores of last-year students as output. In the model with the scores of first-year students, both coefficients (professor and teaching plan variables) were positive; however, the same does not apply to the model with the scores of last-year students. Therefore, it seems that the best universities lure the best students, and consequently their characteristics are positively correlated with the scores of first-year students.

Table 3 – Stochastic frontier estimations with the difference in score between last-year and first-year students (inputs: characteristics of the HEI)

	Model 1		Model 2	
	Model l.1	Model l.2	Model 2.1	Model .2.2
professor to student ratio	-99.30*** (31.92)	-87.88*** (32.44)		
total number of computers per student	16.55*** (4.69)	16.80*** (4.82)		
complete teaching plan of the HEI	-8.43*** (3.19)	-10.05*** (3.25)		
Expenditures on professor per student			-0.17 (0.00)	-0.13 (0.00)
Capital expenditures per student			0.28 (0.00)	0.29 (0.00)
Other expenditures per student			0.06 (0.00)	0.06 (0.00)
Student working 20 hours or more				
Non-white student				
Maternal schooling – higher education				
Constant	14.75*** (2.51)	14.74*** (2.53)	7.61*** (1.04)	7.25*** (1.05)
Explaining inefficiency				
Public HEI		1.51* (0.81)		0.99 (0.67)
Constant	2.10*** (0.42)	1.05 (0.91)	2.12*** (0.52)	1.52** (0.76)
N	164	164	155	155
Dummies of Regions	yes	yes	yes	yes
LR test for null inefficiency component ($p>\chi^2$)	6.88	-	3.13	-

Source: Robust standard deviations are shown in parentheses. *p<0.10, ** p<0.05, *** p<0.01.

In the first model, to explain the inefficiency (specification 1.2), a dummy indicating whether the institution is public or private is used. The positive coefficient indicates that the public institution is more

inefficient than the private one. In model 2, in which the labor and capital variables are measured in monetary units, the coefficients of the three expenditure variables were not statistically significant. Moreover, by explaining inefficiency based on information of whether HEI are public or private, one observes that the coefficient of this variable, albeit positive, was not statistically significant.

These results corroborate what was demonstrated by the previously mentioned literature, according to which physical inputs determine the contribution of the HEI to the production and/or aggregation of knowledge.

However, another strand of the literature argues that the results of standardized tests such as ENADE reflect mainly the socioeconomic status of students, rather than the value added by schools (Mizala et al. 2007; Chay, Mcewan and Urquiola, 2005).

In order to verify whether the obtained results were not contaminated by the effect of variables related to students and their families, three variables that characterize the students were included in the production function, namely: a dummy variable indicating whether the student works more than 20 hours per week; maternal schooling, and a dummy variable for race.[22]

In model 3, only the students' characteristics are included to explain the output. Model 4, on the other hand, included the students' characteristics and inputs of the university measured in physical units. Finally, model 5 included the students' characteristics and the expenditures of the universities.

Regarding model 3, only the variable "mother's education" proved to be statistically significant and negative. Thus, the higher the percentage of students in HEI whose mothers pursued higher education, the smaller the difference between the scores of last-year and first-year students. This result seems to indicate that HEI aggregate less knowledge the better the family background.

In model 4 (Table 4), in both specifications (4.1 and 4.2), none of the information about the students appears as statistically significant. On the other hand, the characteristics of the institutions showed, in general, similar signs and magnitudes to those observed in model 1.

In addition, in specification 4.1, the null hypothesis that there is no technical inefficiency in the model is rejected by means of the Wald test and the likelihood ratio test. By explaining this inefficiency based on the information of whether the HEI are public or private (specification 4.2), the fact that HEI are public increases inefficiency in similar magnitude as verified in model 1.

In model 5 (Table 4), note that expenditures continue with statistically nonsignificant coefficients and that only the variable "student working 20 hours or more" has a negative and significant effect. In addition, whether the institution is public or private is important to explain inefficiency.

[22] Dummy equal to 1 if the student is non-white and 0, otherwise.

Table 4 – Stochastic frontier estimations with difference in scores between last-year and first-year students (inputs: characteristics of the HEI)

	Model 3		Model 4		Model 5	
	Model 3.1	Model 3.2	Model 4.1	Model 4.2	Model 5.1	Model 5.2
professor to student ratio			-92.99*** (34.63)	-90.99*** (34.92)		
total number of computers per student			16.41*** (4.75)	17.03*** (4.87)		
complete teaching plan of the HEI			-6.70 (4.69)	-9.22* (4.71)		
Expenditures on professors per student					-0.17 (0.00)	-0.15 (0.00)
Capital expenditures per student					0.20 (0.00)	0.22 (0.00)
Other expenditures per student					0.08 (0.00)	0.09 (0.00)
Other expenditures per student	-3.37 (3.47)	-5.46 (3.50)	-1.30 (4.35)	-2.19 (4.26)	-4.37 (3.56)	-6.05* (3.56)
Student working 20 hours or more	-2.65 (4.96)	-1.47 (4.91)	0.36 (4.95)	2.16 (4.88)	0.35 (5.29)	1.10 (5.14)
Non-white student	-7.66* (4.43)	-6.86 (4.44)	-3.98 (5.55)	-1.47 (5.63)	-7.20 (4.76)	-6.79 (4.75)
Maternal schooling – higher education	11.12*** (2.38)	11.30*** (2.34)	15.00*** (2.75)	15.41*** (2.77)	11.34*** (2.42)	11.46*** (2.37)
Explaining the inefficiency						
Public HEI		1.18* (0.70)		1.54* (0.85)		1.10* (0.65)
Constant	2.16*** (0.48)	1.41* (0.79)	2.11*** (0.42)	1.05 (0.94)	2.28*** (0.46)	1.61** (0.70)
N	164	164	164	164	155	155
Dummies of Regions	yes	yes	yes	yes	yes	yes
LR test for null inefficiency component ($p>\chi^2$)	3.61	-	6.66	-	3.99	-

Source: Robust standard deviations are shown in parentheses. *p<0.10, ** p<0.05, *** p<0.01.

5. Conclusions

The objective of this work is to assess the determinants of performance of HEI in Brazil, taking into account the relative efficiency of public and private institutions on the application of their resources. The difference between the scores of last-year and first-year students in ENADE is used to measure performance.

The main results indicate that:

1. Labor input (professor per student) negatively affects the difference in ENADE scores, which in principle would be counterintuitive. The separate estimation, however, using the score of first-year students and that of last-year students as output indicates that labor input affects the former but not the latter. This indicates that HEI attract the best students, which explains the impact on the score of first-year students. However, because

they attract the best students, they end up adding little value, which leads to a negative impact of professors on the score of last-year students and on the difference in scores.

2. Capital input positively affects the difference in ENADE scores, as expected.

3. The existence of a research plan negatively affects the difference in ENADE scores and the reasons for that are the same ones associated with the negative effect of professor per student.

4. Inefficiency increases if the university is public.

5. The socioeconomic characteristics of students are not important to explain the results, except in the case in which maternal schooling and the student's working status negatively affect the difference in ENADE scores.

An attempt to complement the existing literature is made by estimating education production functions as control for inputs is exercised. The availability of scores in standardized tests for Brazilian universities helps a lot with this task since they provide a widely accepted output measure. In the absence of qualitative indicators such as occupation and long-term remuneration that could more adequately describe the contribution of education towards human capital, an intermediate result such as the score on a standardized test can be seen as a good approximation. Moreover, one replaces the traditional use of DEA with the stochastic frontier method.

If other studies firmly attest to the result that public HEI are more inefficient, linking the transfer of resources from the Government to the performance of these HEI could be an effective strategy. Therefore, only public universities with a score greater than a certain threshold and/or with improved performance over the time would be entitled to receive resources.

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