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Departamento de Economía

Licenciatura en Economía

How good are you at producing PhD students? An efficiency analysis

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Abstract

We estimate the relative efficiency of economics departments around the world. Taking as output the students' placement in the Top 20 PhD programs in Economics in the United States, we estimate efficiency frontiers through non-parametric techniques (Data Envelopment Analysis, DEA) and parametric techniques (stochastic frontiers, SFA). As inputs, we include department size, journal article downloads, and number of citations. Results show that efficiency scores, rankings, and identifying the best and worst departments in terms of efficiency are significantly different between techniques.

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1. Introduction

One of the objectives of microeconomic theory is to understand and explain the behavior and functioning of firms. Of particular interest is whether these firms are productive and efficient in the process of producing goods and services. In this paper, we focus on institutions that produce human capital. In particular, we estimate the relative efficiency of economics departments from 174 universities around the world.

To estimate how efficient the universities are, i.e., how far they are from optimal production given the resources, we have to define the production function of each of the departments. As output, we use the placement in Top 20 PhD in Economics programs in the United States of students that were studying in 2020. As inputs in the production function, we use the size of the Economics department, the number of academic citations from faculty members, and the number of downloads of faculty members' articles. Additionally, as environmental variables, we include university's age and whether the university is public or private.

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To estimate relative efficiency, we resort to parametric and non-parametric techniques. First, we the efficiency frontier using Data Envelopment Analysis, a non-parametric approach that constructs the efficiency frontier and computes a relative efficiency score for each decision-making unit (DMU). We estimate two models: one with constant returns to scale, and the other one with variable returns to scale. Second, we estimate the efficiency frontier using a parametric stochastic frontier. We estimate three alternative production functions: linear, Cobb-Douglas, and translogarithmic.

Our results show large variability between the scores and rankings for each of the methodologies. For the DEA model with constant returns to scale, the average efficiency is

0.46, while, with variable returns, it is 0.64. In contrast, for the model with a linear production function, the average efficiency is 0.32; for the Cobb-Douglas function, it is 0.37, and for the translogarithmic, 0.38. We also conducted an internal consistency analysis of the results, which reveals that the efficiency scores, the rankings, and the identification of the most and least efficient departments are significantly different.

The structure is as follows. Section 2 presents related literature; Section 3 describes de data; Section 4 explains the methodology; Section 5 shows the results; and Section 6 concludes.

2. Related literature

The estimation of efficiency frontiers is a practice that has been done in multiple areas and services: internet companies (Serrano-Cinca, Fuertes-Callén, and Mar-Molinero, 2005), banks (Shahwan and Hassan, 2013), airlines (Lozano and Gutiérrez, 2014), insurance companies (Cimmins et al., 2010), electricity companies (Estache et al., 2004), natural gas distributions companies (Rossi, 2001). Another of the fields studied has been education institutions: multiple studies have examined the efficiency of primary schools, secondary schools, and, as in our case, universities.

This literature is already several years old since the first articles appeared in the 1980s (Ahn and Cooper (1988) and Tomkins and Green (1988)). After that, a large number of articles continued to use this methodology for analysis (Abbot and Coucouliagos, 2003; Madden and Savage, 1997; Sarafoglu and Haynes, 1996; McMillan and Datta, 1998; Johnes and Johnes, 1993). Johnes and Johnes (1993) estimated using DEA the research performance efficiency of UK economics departments. With the results of this paper, we can conclude that one of

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the trade-offs faced by researchers is whether to devote time to research or to devote time to teaching better classes. This is why we consider the variables that these authors have used for the estimation: the number of articles published in academic journals, articles in popular journals, published books, among other metrics. Likewise, using the same technique, Johnes (2006) measures teaching efficiency in UK universities.

Although they analyze the efficiency of universities, many of the works mentioned above take into account outputs other than the output with which we will be working. However, the paper by McMillan and Datta (1998) is an exception, as they estimate the relative efficiency of 45 Canadian universities using doctoral placement as output. This study found the average efficiency of these universities to be 94%, although, according to the authors, with only 45 observations, the estimate may be overestimated.

After the considerable development of the literature using non-parametric estimation methods, articles appeared that conducted the same analysis but used the stochastic frontier technique (parametric method). Among these articles, we can highlight Stevens (2001) and Izadi et al. (2002), who study the cost efficiency of universities, Chapple et al. (2005), who look at the efficiency of technology transfer offices of UK universities; Miranda, Gramani and Andrade (2012) who study the efficiency of business administrations courses and Zoghbi, Rocha and Mattos (2013) who analyze the efficiency of universities in Brazil as a function of student scores in a standardized test.

We consider important to mention that the paper by McMillan and Chan (2006) performs an analysis of university efficiency in which they estimate through stochastic and non-stochastic methods, as we will do. In their paper, they estimate frontiers using 45 universities in Canada and then perform a consistency analysis of the methods. They find that the different techniques achieve results that can be considered consistent.

3. Data

The objective of this paper is to construct efficiency frontiers to establish the relative efficiency of each DMU (university). As we mentioned in the previous section, we have to define the outputs and inputs for the analyses. As output, we use the placement in Top 20 PhD in Economics programs in the United States of students that were studying in 2020. The Top 20 ranking was retrieved from US News in January 2021 and is presented in Table A1 in the Appendix.

To construct this variable, we downloaded the list of doctoral students in each of the Top 20 universities, which generated a database with 2,518 students. Then, we searched each of them on LinkedIn and retrieved the last program in which they studied before starting their PhD. We found information on approximately 70% of all students (1754). With this database, we constructed the number of students each university placed in a Top 20 program. For this work, we will only use those universities that sent a total of two students or more. After this filter, our database consists of 184 universities from 34 countries.

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Table 1 shows the Top 30 economics departments ranked by the number of students sent to pursue a PhD. Table A2 in the Appendix shows the full ranking.

For each of the universities, we have considered some inputs that will be part of the production process for doctoral students. First, we have a measure that serves as a proxy for the size of the Economics department. What we will use is the number of members of each of the departments on the RePEc website. We believe that a larger department size can have more resources to generate better students who then enter a Top program.

Second, we use different departmental faculty performance metrics to incorporate teaching quality into our analysis. This is why we look for different metrics: the number of downloads of their academic articles on the RePEc website and the number of times their articles have been cited. It is worth noting that in order to construct each of these variables, we resorted to web scraping techniques. First, we assembled a list of all the members of the departments registered in RePEc. Then, we searched all the data for each of them, and then we took an average at the university level. The number of downloads has been obtained from the RePEc site while the remaining variables were obtained from the CitEc site, which is a service also provided by RePEc.

We believe that there are important reasons for including each of the variables we have mentioned. Firstly, the number of downloads of articles by members of the department provides an indication of the quality of the faculty. Secondly, the number of citations also refers to the quality of the faculty. Better individual performance metrics can have positive effects on students, as they surround themselves with better academics, or negative ones, as they, in order to improve their research output, do not maximize the quality of their classes.

In order to estimate our models, we have to incorporate environmental variables. The first variable we will include is whether the university is public or private. This allows us to control the nature of the university. Secondly, we will include the seniority of each university. This may be important because the older the university is, the greater the reputational effect that causes a greater number of students to enter good doctoral programs.

Table 2 shows descriptive statistics for the variables mentioned. Note that the table shows statistics for 174 departments instead of 184. This is because we deleted observations that we considered outliers. This is explained with detail in Section 4.1 of this paper.

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On average, the 174 universities in our database have sent 8.52 students to pursue a PhD at a Top 20 program in the United States between 2015 and 2020. The university that has sent the most students was The London School of Economics and Political Science (72), as we saw earlier. The average number of downloads of published articles from the RePEc site is 172, with a minimum of 2.71 and a maximum of 501.67. Then, the number of citations has considerable variability: the average number of citations is 824, with a maximum of 7,879 and a minimum of 19.

Regarding the two environmental variables, 49% of the universities are private, and the average age is 160 years.

4. Methodology

In order to calculate the efficiency of each of the economics departments, we use two different approaches. First, we estimate the efficiency frontier through a non-parametric method, DEA. Second, we will estimate the efficiency frontier through the SFA method.

Before explaining each of the methodologies in detail, we believe it is important to introduce terminology that will help to understand the results of this work. In microeconomic theory, firms are treated as entities whose purpose is to transform inputs into outputs. A natural and reasonable question is whether firms are good at that process, and this is why we need metrics to evaluate performance. The most traditional way is measuring productivity, this is, how many outputs are produced for each unit of input. In a context where we have a firm that produces a single output with a single input, productivity is the ratio between them. In a context where we have more than one input and more than one output, a more general

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term is defined as total factor productivity. This measure calculates productivity taking into account all factors of production.

As mentioned by Coelli et al. (2005), the terms "productivity" and "efficiency" have been used as synonyms, when in fact they are very different concepts. Productivity is, as we said, the ratio between input and output. The production frontier is a function that represents the maximum amount of output that can be achieved for a given level of input. When the firm operates above this frontier, we say that it is technically efficient. When it is below it, we say that it is technically inefficient. In other words, efficiency compares what is actually produced with the optimal value of production.

Our interest is focused on wanting to estimate the relative efficiency of the 174 departments of economics. In the following two subsections, we will explain the two methodologies we will use.

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4.1. Data Envelopment Analysis (DEA)

The Data Envelopment Analysis, a procedure developed by Charnes, Cooper, and Rhodes (1978), constructs a non-parametric frontier over the data through linear programming methods. To explain it, we believe it is convenient to introduce some notation. Suppose we have data from N inputs an M outputs for each of the I firms. These inputs and outputs, for the i-th firm, are represented as $\boldsymbol{x}_i$ and $\boldsymbol{q}_i$, respectively. The $\boldsymbol{X}$ input matrix has dimension $N \times I$, and the output matrix, $\boldsymbol{Q}$, $M \times I$.

This method aims to obtain an efficiency measure for each Data Management Unit (DMU). In order to achieve this, assuming that all firms have constant returns to scale (CRS), the mathematical problem is the following:

$$
\min_{\theta,\lambda} \ \theta \quad st. \quad \begin{array}{c} -\boldsymbol{q}_i + \boldsymbol{Q}\lambda \geq 0, \\ \theta \boldsymbol{x}_i - \boldsymbol{X}\lambda \geq 0, \\ \boldsymbol{\lambda} \geq 0 \end{array}
$$

where θ is a scalar and λ is a $I \times 1$ vector of scalars. The value of θ resulting from this problem is the efficiency score for the i-th firm. According to Farrell (1957), this parameter satisfies $\theta \leq 1$. It takes the unit value in case the i-th firm is technically efficient, i.e., it is on the frontier. Note that to retrieve the score for each firm, the problem has to be solved I times.

It may not be true that firms are operating at an optimal scale. Therefore, the assumption that they have constant returns to scale might not be realistic. If not all firms are operating at an optimal scale, technical efficiency is confounded by scale efficiency. This is why Seiford & Thrall (1990) have modified the model so it can capture variable returns to scale (VRS). The solution consists in including a convexity constraint to the original problem. The new linear programming problem is the following:

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$$
\min_{\theta,\lambda} \ \theta \quad st. \quad \begin{array}{c} -\boldsymbol{q}_i + \boldsymbol{Q}\lambda \geq 0, \\ \theta \boldsymbol{x}_i - \boldsymbol{X}\lambda \geq 0, \\ \boldsymbol{I1}'\lambda = 1 \\ \lambda \geq 0 \end{array}
$$

Where $I1$ is a vector of ones of dimension $I \times 1$.

Computing both CRS and VRS technical efficiency measures, scale efficiency can be obtained. With these two scores, technical efficiency from the CRS model can be decomposed into one component, that is, scale inefficiency and one due to "pure" technical inefficiency. Naturally, if both scores are different, this means that scale inefficiencies are present in the firm. Having estimated both efficiencies scores, scale efficiency can be calculated as the ratio between technical efficiency in the constant returns to scale model and technical efficiency in the variable returns to scale model. Formally,

$$SE = \frac{TE_{CRS}}{TE_{VRS}}$$

Until now, we have been dealing with input-oriented DEA models, this is models that identify technical inefficiency as the proportional reduction of input keeping output constant. Some industries might have fixed quantities of resources, and their objective is to maximize output: this is why output-oriented models have been developed. A very important comment made by Coelli et al. (2005) is both input and output-oriented DEA models will estimate the same frontier, and the same firms will be the efficient ones. What varies along these models is the efficiency metric. In this paper, we are going to use the input-oriented models due to the fact that we do not believe that universities have fixed quantities of resources in terms of the inputs we include in the models.

Finally, it is very important in the DEA model to take into account environmental variables, this is, variables that the firm cannot control and influence the firms in a similar manner. There are various alternatives to include these environmental variables (see Coelli et al. (2005)). In this paper, we are going to adopt a straightforward method in which we include these variables into the DEA problem.

As we have mentioned, DEA computes the efficiency of the i-th DMU relative to the others. Therefore, the existence of outliers is a problem (Wilson, 1993) given that one outlier can distort the measure of the efficiency of all DMUs. This is why we calculated some statistics in order to identify outliers in our sample. We begin constructing a variable that is the output divided by each of the inputs. Then, we identified and dropped the universities above or below the 99^{th} and 1^{st} percentile of each ratio. We ended up deleting Barcelona Graduate School of Economics, Central University of Finance & Economics, Higher School of Economics, Keio University, Sharif University of Technology, UC Berkeley, UC San Diego, UC Santa Barbara, and The University of Naples Federico II. For our estimations, we use the 174 departments left.

4.2. Stochastic frontiers

The other methodology we will be using in this paper is the stochastic frontier analysis (SFA) which estimates the efficiency frontier parametrically[1]. This parametric estimation results from a key assumption we have to make: the functional form that relates input with output. We define a general SFA production function:

$$\mathrm{Y_i} = f(X_i; \beta) + \varepsilon_i$$

Where Y_i is the output, X_i a matrix of inputs, and β are the technological parameters to be estimated. The error term, ε_i, can be decomposed into two components: $\varepsilon_i = \nu_i - \mu_i$. We assume that ν_i are independent and identically distributed random errors with a normal distribution centered in zero and variance σ_ν^2 that represents noise, and μ_i are non-negative random variables that represent technical efficiency.

As we have seen, the error term of the model includes two random components. In order to estimate these models, it is common to assume the distribution of the random terms and estimate the parameters through Maximum Likelihood. The best-known models are those that assume that the efficiency term follows a half-normal, exponential, or truncated normal distribution. Coelli et. al. (2005) mentions that the problem with using Ordinary Least Squares for these estimations is that the intercept coefficients are downwards biased. In spite of this issue, we will use OLS for the estimation, given that the intercept parameters are

[1] See Rossi (2015) for a more detailed explanation of this methodology.

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neither different nor statistically different if we compare them with the Maximum-Likelihood estimation using half-normal and truncated normal distributions for the inefficiency term.

The function $f(\cdot)$ can now take different functional forms to estimate the efficiency frontier. In this paper, we will estimate the frontier using the functional forms most commonly used in this type of empirical work: linear function, Cobb-Douglas, and translogarithmic.

First, to estimate the linear production function, we will use the following equation:

$$Placement_i = \beta_0 + \beta_1 FacultySize_i + \beta_2 Downloads_i + \beta_3 Citations_i + \beta_4 Private_i + \beta_5 Established_i + \nu_i - \mu_i$$

Where $Placement_i$ is the number of students sent to pursue their PhD, $FacultySize_i$ is the proxy for department size, $Downloads_i$ is the number of article downloads from RePEc, $Citations_i$ the number of citations, $Private_i$ is a binary variable that takes value 1 if the university is private and $Established_i$ is a variable indicating the years of seniority of the university. Finally, ε_i represents the unobserved heterogeneity.

Second, to estimate the Cobb-Douglas production function, we are going to estimate the following equation by Ordinary Least Squares:

$$\ln(Placement_i) = \beta_0 + \beta_1 FacultySize_i + \beta_2 Downloads_i + \beta_3 Citations_i + \beta_4 Private_i + \beta_5 Established_i + \nu_i - \mu_i$$

Where $ln\ (Placement_i)$ is the natural logarithm of the number of students sent to pursue a PhD, the regressors are the same as in the previous model.

Finally, the equation to estimate the translogarithmic production function:

$$
\begin{aligned}
\ln(Placement_{\mathrm{i}}) &= \beta_0 + \beta_1 \ln(FacultySize_i) + \beta_2 \ln(Downloads_i) + \beta_3 \ln(Citations_i) \\
&+ \beta_4 \ln(FacultySize)^2 + \beta_5 \ln(Downloads_i)^2 \\
&+ \beta_6 \ln(Citations_i)^2 + \beta_7 \ln(FacultySize_i) \times \ln(Downloads_i) \\
&+ \beta_8 \ln(FacultySize_i) \times \ln(Citations_i) \\
&+ \beta_9 \ln(Dowloads_i) \times \ln(Citations_i) + \beta_{10}\ \mathrm{Private_i} \\
&+ \beta_{11} \ln(Established_i) + \nu_i - \mu_i
\end{aligned}
$$

Again, for the estimation we use Ordinary Least Squares.

With each of these production functions, we will make a prediction of the residuals, which will be our efficiency metrics. The farther the observation is from the prediction made by the model (i.e., the larger the residual), the more efficient we say that the university is.

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5. Results

5.1. Data Envelopment Analysis

In this work, we estimated a two-stage DEA model with constant returns to scale (DEA-CRS) and a model with variable returns to scale (DEA-VRS). These two stages are used to identify the input and output slacks. The estimation results are in Tables A2 and A3 in the Appendix. For the 174 departments with which we estimated the model, the average technical efficiency is 0.46, with a standard deviation of 0.29, a minimum of 0.06, and a maximum of 1. The ranking reported by this estimation is presented in section 5.3, together with the other rankings.

To interpret the results, we will focus on the three Argentine universities: Universidad Torctuato di Tella, Universidad Nacional de La Plata and Universidad de San Andrés. The

Universidad Torcuato di Tella has an efficiency score of 0.08 and is ranked 170th in the ranking. The fact that the efficiency score is 0.08 means that this university can decrease its inputs by 92% and still maintain the same level of output. In addition to this decrease, it can decrease its faculty by 52 people and reduce the number of citations by 596 and still maintain the output. The efficient point on the frontier for this university is composed by a linear combination that is 0.3845 of California Institute of Technology and 0.6154 of Ludwig Maximilian University of Munich. Finally, it should be noted that the score using the VRS model is identical to the CRS model, so we cannot say anything about the returns to scale.

As for the Universidad Nacional de La Plata, we can say that it is ranked 119th with an efficiency score of 0.30. In words, this university can decrease its inputs by 70% and maintain the same level of output. The point on the frontier for this university is composed of a linear combination between Ludwig Maximilian University of Munich and Maastricht University School of Business and Economics. The efficiency score for the VRS model is 0.50, which indicates that the university has increasing returns to scale.

Finally, the Universidad de San Andrés is in position 171 of the ranking, with an efficiency score of 0.08, which says that it can decrease its inputs by 92% and still keep the output level fixed. Additionally, it can decrease the downloads of articles by 7 units and the number of citations by 1075 units. The universities that construct the point on the efficient frontier are California Institute of Technology and Maastricht University School of Business and Economics, as for Universidad Torcuato di Tella. In this case, we cannot make comments on the returns to scale, given that the efficiency scores are identical.

5.2. Stochastic Frontiers

All the production functions were estimated as described in the previous section of this paper. The results of the three regressions are in Table 3.

With regards to the linear and Cobb-Douglas production functions, all variables have a positive sign, i.e., the correlation between the inputs (faculty size, the number of article downloads, and citations) with the number of students is positive. For faculty size and citations, the relationships are significant at 1%, while they are not significant at traditional levels for the number of downloads. A joint significance test was conducted for the two environment variables, which showed that the variables are jointly significant at 1% in explaining university placement. This validates the inclusion of these variables in our model.

We mentioned earlier that one of the problems with estimating stochastic frontiers through OLS is that the intercept estimator is downward biased. Tables A4, A5, and A6 in the Appendix show the production functions estimated through Maximum-Likelihood. Column (1) shows the same model already presented that was estimated by OLS, Column (2) shows the estimation assuming that the technical inefficiency term has half-normal distribution, and Column (3) assumes that the term has truncated normal distribution. In these three tables, there are no significant differences in the intercept estimators, so we are validating the use of OLS for the estimations.

To do the efficiency analysis, as explained above, we made the prediction of the residuals for each of the models and then standardized them so that they are bounded between zero and one. The results we arrived at are that the average efficiency for the linear production function is 0.32, for the Cobb-Douglas 0.37, and for the translogarithmic, 0.38. In the next section, we will compare these results with the non-parametric estimates.

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We will now analyze the rankings produced by each of the estimates. These results are in Table A7 in the Appendix. At first glance, we observe that the positions in the rankings are not correlated. For example, Harvard University is ranked 131 with the DEA-CRS model, 1 with the DEA-VRS, 54 with the linear production function, 161 with Cobb-Douglas, and 65 with translog. Another example is the University of San Andres, which is ranked 171 and 172 in the DEA-CRS and DEA-VRS models, respectively, and 7, 3, and 4 in the estimations with linear, Cobb-Douglas, and translog functions. With these two brief examples, we can see that there are cases in which the correlation between techniques does not seem to exist. We want to rigorously test if this absence of correlation is systematic for all the universities. This is why we will pose a series of tests and statistical comparisons in the next section.

5.3. Consistency of results

So far, we have shown the results of the different techniques and specifications for estimating the efficiency of economics departments in terms of placement of PhD students in the Top 20 universities in the United States. All the techniques and specifications used were defined with the same output (placement), the same inputs (faculty size, downloads of published articles, and the number of citations), and the same environment variables (whether the university is public or private and years of seniority).

In this section of the paper, we want to test if the different efficiency metrics generated by the different techniques have internal consistency. In other words, we to see if the results are similar in terms of efficiency levels, rankings, and identification of the best and worst performing departments.

We begin comparing the efficiency levels for each of the models. Table 4 shows descriptive statistics of the efficiency scores for each of the estimated models. As a result, we can see that average efficiency is higher when estimating the DEA models, although they have more variability than the linear models.

We also proceeded to test whether the distribution of the efficiency scores is similar or not. For this, we performed the Kruskal-Wallis non-parametric test. Under the null hypothesis, the five models generate the same distribution of our metric. The result is that we reject the hypothesis at 1%. This result is not unusual, as it is common for the results to be similar within techniques (only varying specifications) but very different across methodologies. For example, in this case, we only reject at 10% the null hypothesis of the Kruskal-Wallis test taking into account the scores of the linear models.

Since the results do not show consistency in terms of efficiency scores, what we will do next is to establish if they generate similar rankings. For this purpose, we will calculate the Spearman correlation for each pair of techniques. Recall that what this correlation coefficient does is to test non-parametrically the strength and direction between two variables that are categorical. Table 5 is a matrix of Spearman correlations between the rankings.

The relationship between the rankings made within each of the techniques is high: the rankings of the two models estimated with DEA are similar (the correlation is 0.72 and statistically significant at 1%), and the rankings of the three models estimated by OLS are similar (the correlation is 0.81 between the linear and translog production function, 0.96 between translog and Cobb-Douglas, and 0.78 between linear and Cobb-Douglas. All statistically significant at 1%). Now, the disparity occurs when we compare between the techniques. Here what we can see is that the correlations are high and significant, but negative. Again, we conclude that the models yield results that are inconsistent with each other. Finally, we will assess whether we can use the models to identify the best and worst performing economics departments. In order to be able to make a comparison, we will divide the rankings into quartiles and see what proportion of the universities are simultaneously identified in the first and last quartile for each model. The results can be found in Table 6.

The upper triangle in Table 6 shows the proportion of universities that are simultaneously identified in the fourth quartile, while the lower triangle shows those that are identified in the first quartile. As we have shown so far, there are similarities between the models estimated through the same strategy, but they are different between strategies. For example, between the DEA model with constant returns to scale and variable returns to scale, the fourth quartiles share 63% of the universities and the first quartiles 91%. In contrast, the DEA with constant returns to scale and the Cobb-Douglas production function model do not share any universities in either the first or the last quartile. This shows that the third consistency condition is not met.

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6. Conclusions

In this paper, we used parametric and non-parametric techniques to estimate the relative efficiency of 174 economics departments around the world, using as output the placement in Top 20 PhD in Economics programs in the United States. We use as inputs the number of members on the department's RePEc site, the number of downloads from published articles on the RePEc website, and the number of citations of each paper. Additionally, we include as environmental variables the age of the university and whether it is public or private.

To estimate each of the efficiency scores, we use Data Envelopment Analysis, an approach that, through mathematical programming, constructs an efficient frontier and then calculates the radial distance of each of the universities to the frontier, thus giving an efficiency metric. From this model, we estimate two specifications: the first uses constant returns to scale and the second uses variable returns to scale. Then, we use the efficient frontier method to estimate three different production functions (linear, Cobb-Douglas and translogarithmic) through Ordinary Least Squares.

The ranking produced by each of the methodologies differs significantly from the others. For example, for the Argentine universities, Universidad de San Andrés, Universidad Torcuato di Tella and Universidad Nacional de La Plata, the DEA-CRS model reports that they are ranked 172, 171 and 119, respectively. On the other hand, according to the linear production function model, the positions are 3, 2, and 89 for San Andrés, di Tella, and La Plata, respectively.

For the five estimated models, the average efficiency is below 0.40, indicating that there are inefficiencies in the sector. Finally, we conducted a consistency analysis of the results of the methodologies, in which we concluded that there is no significant correlation between the efficiency scores and the rankings. In addition, we did not find that the methodologies simultaneously rank the most and least efficient departments.

Several conclusions can be drawn from this work. The first is that the measurement of relative efficiency is not trivial. This requires an analysis of each of the techniques along with their potential advantages, disadvantages, or potential problems. In particular, we consider that in our work, the estimates using DEA may not be accurate since the variables used as inputs may present certain measurement errors. One of the shortcomings of this method is that it is very sensitive to outliers and measurement errors. For this reason, we finally ended up preferring the results of the linear models since they are less sensitive to outliers, given that an estimate is made on average.

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For future lines of research, we consider that we could improve the quality of inputs from the universities, i.e., we could look for information that does not contain measurement errors. In addition, variables that reflect other areas of the productive process of doctoral students could be used instead of only variables that show the quality of the department members, such as the number of students per cohort.

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Table 1: Ranking by placement

University	Placed students
London School of Economics and Political Science	72
The University of Chicago	63
Bocconi University	57
Harvard University	45
University of California, Berkeley	37
Oxford University	34
University of Wisconsin-Madison	34
Yale University	31
Columbia University in the City of New York	30
Princeton University	30
Seoul National University	29
Peking University	28
Getulio Vargas Foundation	27
Massachusetts Institute of Technology	25
Universidad Torcuato di Tella	25
Universidad de San Andrés	25
Stanford University	24
Duke University	22
New Economic School	22
Cambridge University	20

Source: own elaboration

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Table 2: Summary statistics

Variable name	Obs	Mean	SD	Minimum	Maximum
Placement	174	8.52	10.77	2.00	72.00
Faculty size	174	44.86	44.69	1.00	360.00
Article Downloads	174	172.22	95.50	2.71	501.67
Citations	174	823.89	1,059.45	18.67	7,879.33
Private university	173	0.49	0.50	0.00	1.00
Years from establishment	174	160.83	137.62	12.00	934.00

Table 3: Production functions estimations

VARIABLES	(1) Placement	(2) ln(Placement)	(3) ln(Placement)
ln(Faculty)			-0.759
			(0.611)
ln(ArticleDownloads)			1.006
			(1.083)
ln(Citations)			-0.181
			(0.559)
ln(Faculty)²			0.0699
			(0.0560)
ln(Faculty)* ln(ArticleDownloads)			0.0391
			(0.0899)
ln(Faculty)* ln(Citations)			0.0594
			(0.0866)
ln(ArticleDownloads)²			-0.00381
			(0.0834)
ln(Citations)* ln(ArticleDownloads)			-0.155*
			(0.0923)
ln(Citations)²			0.0835*
			(0.0424)
ln(Years from establishment)			0.0317
			(0.0789)
Private university	4.126***	0.396***	0.395***
	(1.262)	(0.113)	(0.120)
Faculty	0.107***	0.00618***	
	(0.0143)	(0.00128)	
ArticleDownloads	0.00703	0.000723	
	(0.00669)	(0.000598)	
Citations	0.00411***	0.000363***	
	(0.000634)	(5.66e-05)	
Years from establishment	0.00393	0.000372	
	(0.00451)	(0.000403)	
Constant	-3.515*	0.717***	-1.250
	(1.902)	(0.170)	(3.655)
Production function	Linear	Cobb-Douglas	Translog
Observations	174	174	174
R-squared	0.466	0.385	0.364

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

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Table 4: summary statistics of efficiency scores

	Obs	Mean	SD	Minimum	Maximum
DEA-CRS	174	0.46	0.29	0.06	1.00
DEA-VRS	174	0.64	0.31	0.07	1.00
Linear	174	0.32	0.14	0.00	1.00
Cobb-Douglas	174	0.37	0.21	0.00	1.00
Translog	174	0.38	0.21	0.00	1.00

Table 5: Spearman correlation between pairs of models

	DEA-CRS	DEA-VRS	Linear	Cobb-Douglas	Translog
DEA-CRS	1.00				
DEA-VRS	0.72	1.00			
Linear	-0.72	-0.54	1.00		
Cobb-Douglas	-0.92	-0.82	0.78	1.00	
Translog	-0.92	-0.75	0.81	0.96	1.00

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Table 6: Consistency of best and worst performers identification

	DEA-CRS	DEA-VRS	Linear	Cobb-Douglas	Translog
DEA-CRS		0.63	0.02	0.00	0.00
DEA-VRS	0.91		0.05	0.00	0.00
Linear	0.00	0.16		0.58	0.67
Cobb-Douglas	0.00	0.09	0.86		0.84
Translog	0.02	0.11	0.86	0.93	

8. Appendix

Table A1. Best Economics Schools as January 2021

Ranking	PhD program
1	Harvard University
2	MIT
3	Princeton University
4	Stanford University
5	University of California - Berkley
6	Yale University
7	Northwestern University
8	University of Chicago
9	Columbia University
10	University of Pennsylvania
11	New York University
12	University of California - Los Angeles
13	University of California - San Diego
14	University of Michigan - Ann Arbor
15	University of Wisconsin - Madison
16	Cornell University
17	Duke University
18	University of Minnesota - Twin Cities
19	Brown University
20	Carnegie Mellon University

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Table A2: DEA-CRS results

tdmu	university	rank	theta	ref_Univ3	ref_Univ15	ref_Univ19	ref_Univ41	ref_Univ57	ref_Univ59	ref_Univ99	ref_Univ144	ref_Univ171	ref_Univ180	ref_Univ181	ref_Univ182	ref_Univ183	ref_Univ184	is_sentstudents	os_faculty	os_down_journal	os_citations	os_private	os_yearsestablished
Univ 1	American University	49	0,667		0,780			0,220												33,878	1002,328		93,976
Univ 2	Amherst College	44	0,667			0,335		0,665											56,230		248,768		181,685
Univ 3	Arizona State University	1	1,000	1,000				0,000				0,000											0,000
Univ 4	Athens University of Economics and Business	27	0,865					0,172	0,693											0,000	262,325	0,000	24,559
Univ 5	Australian National University	91	0,374	0,436	0,000		0,275	0,224														0,000	138,490
Univ 7	Bilkent University	47	0,667			0,074		0,926											59,076		249,806		474,975
Univ 8	Bocconi University	173	0,073		0,312			1,774												241,742	710,793		896,475
Univ 9	Bogazici University	140	0,193					0,250			0,136								0,885		35,185	0,000	
Univ 10	Boston College	59	0,526		0,653			0,662												148,901	537,489		290,906
Univ 11	Boston University	31	0,770		0,842			0,698												236,888	41,830		311,451
Univ 12	Brandeis University	105	0,338		0,212			0,801											46,934		237,009		394,408
Univ 13	Brigham Young University	157	0,125		0,386			0,614											44,343		535,445		241,243
Univ 14	Brown University	132	0,221	0,101	1,046			0,089				0,308										0,046	
Univ 15	California Institute of Technology	1	1,000		1,000																		
Univ 16	Cambridge University	149	0,152		0,055			1,465											80,497	284,468	0,000	0,055	
Univ 17	Carleton College	110	0,333		0,434			0,566											54,392		970,228		212,050
Univ 18	Carnegie Mellon University	62	0,500		0,651	0,113		0,236											19,570				98,676
Univ 19	Catolica Lisbon School of Business and Economics	1	1,000		0,000	1,000		0,000											0,000				0,000
Univ 20	Central European University	103	0,341			0,031		0,993											61,900		171,902		516,574
Univ 22	Centro de Estudios Monetarios y Financieros	145	0,160			0,000	0,343				0,057										92,641	0,000	13,502
Univ 23	Centro de Investigación y Docencia Económica	85	0,394				0,427	0,164											0,000		206,908	0,000	91,129
Univ 24	Claremont McKenna College	80	0,400		0,306			0,694											48,923		564,929		324,862

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Univ 25	Colby College	45	0,667			0,256		0,744			65,498		431,109		212,864
Univ 26	Collegio Carlo Alberto	56	0,597		0,415			0,779			19,404		665,562		464,990
Univ 27	Columbia University in the City of New York	152	0,141	0,000	1,908					0,200		50,995		0,908	19,874
Univ 28	Cornell University	121	0,278		1,240					0,288		7,653		0,240	59,909
Univ 29	Dartmouth College	90	0,376		2,255						6,599	119,660	0,000	1,255	42,467
Univ 30	Davidson College	66	0,500		0,654			0,346			40,365		1229,022		90,940
Univ 31	Delhi School of Economics	164	0,104				0,526	0,048					60,723	0,000	13,873
Univ 32	Dickinson College	21	1,000		0,742			0,258			36,136	102,695	1319,138		
Univ 33	Duke University	159	0,118	0,139	0,866			0,298				49,776			112,207
Univ 34	ENSAE Paris	143	0,180		0,007		0,150	0,112			15,272			0,007	
Univ 35	Ecole Normale Superieure	88	0,384					0,273	0,495		28,719		83,896		
Univ 36	Ecole Polytechnique	109	0,333		0,435			0,565			36,363		915,348		139,903
Univ 37	Fudan University	82	0,400		0,561			0,439				79,948	1016,565		197,951
Univ 38	Georgetown University	148	0,153		0,822			0,402				155,648	338,288		95,803
Univ 39	Getulio Vargas Foundation	168	0,086		0,471			0,695				115,206	909,049		366,062
Univ 40	Grinnell College	20	1,000		0,893			0,107			24,807	58,187	1352,488		
Univ 41	HEC Montreal	1	1,000		0,000	0,000	1,000	0,000			0,000				0,000
Univ 42	Harvard University	131	0,222		4,987						8,774	353,204	0,000	3,987	267,355
Univ 43	Haverford College	46	0,667			0,203		0,797			76,775		418,765		259,595
Univ 44	Heidelberg University	13	1,000		0,631			0,369			20,277		555,726		113,710
Univ 46	Indian Institute of Technology	113	0,327			0,000	0,215	0,060	0,052		0,000		103,555		
Univ 47	Indian Statistical Instititute	158	0,123			0,377	0,216	0,086	0,000		7,083			0,377	
Univ 48	Indiana University Bloomington	102	0,344		0,266		0,583	0,182			16,797			0,266	
Univ 49	Instituto Tecnologico Autonomo de Mexico	163	0,105		0,926			0,074			18,069		1380,939		86,010
Univ 50	KTH Royal Institute of Technology	43	0,667		0,339		0,069	0,259			15,220			0,339	0,000
Univ 52	Korea University	11	1,000		0,163			0,837			56,644		4,691		364,752

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Univ 53	Koç Üniversitesi	138	0,200			0,033		0,967				78,344		90,492		504,398
Univ 54	Lahore University of Management Sciences	23	1,000		1,000							6,000	39,249	1553,924	0,000	93,000
Univ 55	Lewis And Clark College	17	1,000			0,062		0,938				93,025		535,207		363,909
Univ 56	London School of Economics and Political Science	169	0,085					0,000	3,051				472,820	273,797		13,339
Univ 57	Ludwig Maximilian University of Munich	1	1,000					1,000					0,000	0,000	0,000	
Univ 58	Luiss Guido Carli University	141	0,185		0,060		0,066	0,059				9,025			0,060	0,000
Univ 59	Maastricht University School of Business and Economics	1	1,000					0,000	1,000					0,000	0,000	0,000
Univ 60	Macalester College	81	0,400		0,694			0,306				35,105		1020,360		111,279
Univ 61	Massachusetts Institute of Technology	118	0,309		3,861							2,489	338,292	0,000	2,861	344,729
Univ 62	McGill University	99	0,351	0,000	0,382			0,251			0,068		22,764		0,382	
Univ 63	Miami University	12	1,000		0,019			0,981				84,463		124,070		329,145
Univ 64	Michigan State University	100	0,350	1,005	0,031		0,183	0,008							0,031	0,000
Univ 65	Middlebury College	63	0,500			0,145		0,855				66,401		101,535		255,504
Univ 66	Mount Holyoke College	65	0,500			0,211		0,789				80,093		476,193		259,334
Univ 67	National Taiwan University	153	0,138		0,015		0,237	0,300				10,124			0,015	
Univ 68	National University of Singapore	125	0,238	0,172			0,144	0,280							0,000	73,778
Univ 69	Nazarbayev University	123	0,263			0,000	0,099			0,164				12,237		25,138
Univ 70	New Economic School	167	0,091		0,659			0,341					76,427	784,586		244,073
Univ 71	New York University	73	0,435	0,000	1,779						0,398		112,958		0,779	117,210
Univ 72	New York University Abu Dhabi	79	0,400		0,817			0,183					99,983	554,972		195,646
Univ 73	Northeastern University	15	1,000			0,171		0,829				70,281		327,382		430,259
Univ 74	Northwestern University	136	0,201		1,773						0,137		30,372		0,773	87,073
Univ 75	Nova School of Business and	42	0,673	0,032	0,000		0,034	0,607							0,000	297,964

	Economics																
Univ 76	Occidental College	48	0,667			0,212		0,788					79,059		530,284		309,121
Univ 77	Oxford University	161	0,113					1,663	0,252					337,700	79,914		
Univ 78	Paris School of Economics	89	0,381					0,000	2,475					67,095	1186,127		79,831
Univ 79	Peking University	174	0,060			0,080	0,000				0,764		0,657		14,390	0,080	
Univ 80	Penn State University	51	0,623	0,000	1,040							0,207		5,144		1,040	8,326
Univ 81	Pomona College	124	0,250			0,473		0,527					51,184		324,003		178,650
Univ 82	Pompeu Fabra University	133	0,212	0,000	0,064							0,999		1,548		0,064	165,094
Univ 83	Pontifica Universidad Catolica de Chile	156	0,128		0,374			0,713					20,076		858,884		307,387
Univ 84	Pontifical Catholic University of Rio de Janeiro	165	0,100		0,034	0,180		0,787					60,870				365,095
Univ 85	Princeton University	134	0,211		3,161							0,001		121,433		2,161	138,269
Univ 86	Queen's University	98	0,351	0,369				0,249				0,083					22,293
Univ 87	Renmin University of China	146	0,158			0,429	0,000	0,113			0,010		8,051			0,429	
Univ 88	Rice University	107	0,333		0,963			0,037						38,861	745,165		36,329
Univ 89	Rutgers University	112	0,331					0,254			0,739		27,969		44,572		
Univ 90	Sabanci University	50	0,667		0,663			0,337					41,609		1158,933		244,075
Univ 91	Sant'Anna School of Advanced Studies	39	0,703	0,415	0,000		0,178	0,110								0,000	102,747
Univ 92	Science Po	117	0,314		0,521			1,046						57,983	781,661		493,687
Univ 95	Smith College	14	1,000			0,231		0,769					74,496		409,475		287,350
Univ 96	Sogang University	18	1,000		0,379			0,621					45,935		681,534		329,264
Univ 97	Stanford University	139	0,200	0,000	2,095							0,304		164,982		1,095	194,835
Univ 98	Stony Brook University	70	0,464	0,299			0,148	0,018								0,000	2,637
Univ 99	Sungkyunkwan University	1	1,000					0,000		1,000			0,000	0,000			
Univ 100	Swarthmore College	151	0,143		0,221			0,779					67,840		724,267		299,205
Univ 101	Tel Aviv University	127	0,231		0,925								15,657	87,029	0,000	0,925	55,229
Univ 102	Texas A&M University	53	0,615			0,000	0,064	0,550					0,000		143,681		164,137
Univ 103	The Chinese University of Hong Kong	130	0,223	0,345	0,094		0,008									0,094	1,434
Univ 104	The College of William and Mary	126	0,236			0,000	0,000	0,554			0,154		30,660		87,377		

Univ 105	The George Washington University	58	0,539		0,504			0,843				9,407		816,786		328,872
Univ 106	The Hebrew University of Jerusalem	129	0,224	0,209	0,351						0,225		0,000		0,351	13,136
Univ 107	The Hong Kong University of Science and Technology	69	0,487		0,150	0,015	0,565								0,165	54,383
Univ 108	The John Hopkins University	114	0,325		1,162						0,137		86,701		0,162	32,057
Univ 109	The Ohio State University	60	0,525	0,066	0,286		0,639	0,058							0,286	0,000
Univ 110	The University of British Columbia	104	0,339	0,000	0,709						0,478		32,537		0,709	69,237
Univ 111	The University of Chicago	172	0,076		1,855						0,550		144,817		0,855	214,910
Univ 112	The University of Edinburgh	26	0,868		0,092			0,776				34,281	68,915		0,092	
Univ 113	The University of Kansas	40	0,701		0,209		0,323	0,168				19,435			0,209	0,000
Univ 114	The University of Oslo	29	0,819	0,090	0,291		0,184	0,253							0,291	0,000
Univ 115	The University of Queensland	25	0,877					0,377	0,395		0,105					132,204
Univ 116	Tilburg University	67	0,498		0,086		0,328	0,084				20,989			0,086	
Univ 117	Toulouse School of Economics	55	0,614						0,918		0,618		54,065		0,000	144,029
Univ 118	Trinity College Dublin	30	0,780		0,573			0,597					67,471	873,642		204,337
Univ 119	Tsinghua University	142	0,181			0,942		0,070		0,162		18,232		173,852		
Univ 120	Tufts University	77	0,408		0,171			0,849				58,011		19,869		319,548
Univ 121	UNSW Australia	61	0,513	0,535				0,228			0,007					127,126
Univ 122	Univerisidad Nacional de La Plata	119	0,300					0,329	0,272				0,000	228,217	0,000	76,277
Univ 123	Universidad EAFIT	19	1,000		0,451			0,549					82,447	1033,742		298,939
Univ 124	Universidad Torcuato di Tella	170	0,080		0,385			0,615				52,469		595,729		357,882
Univ 125	Universidad de Chile	166	0,093					0,404	0,045		0,200				0,000	81,880
Univ 126	Universidad de Los Andes	97	0,354		0,450			0,789					66,299	1048,965		418,885
Univ 127	Universidad de Montevideo	83	0,400		0,882			0,118				14,663		1345,793		144,378

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Univ 128	Universidad de Piura	22	1,000		1,000								0,000	1,824	1543,208	0,000	78,000
Univ 129	Universidad de San Andres	171	0,080		0,817			0,183						7,380	1075,620		173,646
Univ 130	Universidad del Pacifico	95	0,361		0,383			0,701					16,997		884,761		375,734
Univ 131	Universidade de Brasilia	96	0,359					0,239	0,119						50,222	0,000	76,984
Univ 132	Universitat Autonoma de Barcelona	41	0,677				0,591				0,086				48,966	0,000	27,503
Univ 133	University College London	120	0,282	0,310	0,662							0,437				0,662	15,889
Univ 134	University Of Nevada, Reno	71	0,464				0,227	0,123			0,345				77,577	0,000	
Univ 135	University of Alabama	87	0,390		0,193		0,114	0,278					6,470			0,193	0,000
Univ 136	University of Arizona	34	0,734			0,190	0,000	0,107			0,437		8,678			0,190	
Univ 137	University of Bologna	33	0,748							1,497			4,936	208,375	325,082	1,497	
Univ 139	University of California, Los Angeles	128	0,228	0,000	0,826							0,428		1,043		0,826	86,219
Univ 142	University of Illinois at Urbana-Champaing	94	0,366		0,672		0,386	0,041					17,961			0,672	
Univ 143	University of International Business and Economics	54	0,615					0,085	0,530					13,852	228,612		0,000
Univ 144	University of Kentuky	1	1,000			0,000		0,000			1,000		0,000		0,000		
Univ 145	University of Lausanne	10	1,000		0,155			0,845					58,279	76,358	163,448	0,155	
Univ 146	University of Mannheim	84	0,399					0,099	0,438			0,062					10,090
Univ 147	University of Maryland Baltimore County	36	0,713		0,011	0,402	0,300						1,024			0,413	0,000
Univ 148	University of Maryland College Park	101	0,348	0,576	0,527		0,102	0,011								0,527	0,000
Univ 149	University of Melbourne	116	0,315					0,256	0,690						232,842	0,000	3,293
Univ 150	University of Michigan - Ann Arbor	150	0,149	0,268	0,603			0,041				0,352		0,000		0,603	
Univ 151	University of Minnesota - Twin Cities	147	0,154		0,173		0,416	0,183					20,534			0,173	0,000
Univ 152	University of	32	0,751		0,322		0,692	0,111					21,768			0,322	0,000

	Missouri-Columbia																
Univ 153	University of North Carolina at Chapel Hill	106	0,336		0,222		0,740	0,216					48,631			0,222	
Univ 154	University of Notre Dame	86	0,391		0,747			0,426						58,702	460,564		151,905
Univ 155	University of Oregon	24	0,951		0,346		0,534	0,071					10,935			0,346	
Univ 156	University of Pennsylvania	135	0,208		1,548			0,105				0,113		125,127		0,548	
Univ 157	University of Pittsburgh	75	0,417	0,000	0,227			0,360				0,038		58,664		0,227	
Univ 158	University of Rochester	64	0,500		0,854			0,146						65,025	637,386		20,317
Univ 159	University of Southern California	38	0,705		0,830			0,581						197,345	102,189		286,047
Univ 160	University of St. Gallen	74	0,435					0,501	0,151					0,000	111,507		158,710
Univ 161	University of Sydney	78	0,400		0,538			0,462					21,855		511,986		152,427
Univ 162	University of Texas at Austin	93	0,369	0,578			0,228	0,117									30,863
Univ 163	University of Tokyo	160	0,118		0,205		0,881	0,031					5,282			0,205	0,000
Univ 164	University of Toronto	144	0,170	0,187	0,094			0,093				0,561				0,094	
Univ 165	University of Utah	52	0,616					0,192			0,425		10,069		119,543		
Univ 166	University of Virginia	92	0,370	0,170	0,716		0,086	0,138								0,716	
Univ 167	University of Warwick	35	0,734	0,348				0,158				0,595				0,000	190,086
Univ 168	University of Washington	72	0,450		1,320							0,032		13,574		1,320	17,818
Univ 169	University of Wisconsin-Madison	162	0,106	0,000	1,694							0,112		99,651		1,694	69,046
Univ 170	University of Wyoming	28	0,830		0,398		0,353	0,079					12,274			0,398	0,000
Univ 171	University of Zurich	1	1,000					0,000	0,000			1,000				0,000	0,000
Univ 173	Università degli Studi di Torino	68	0,495					0,000		0,990			7,808	26,267	199,178	0,990	
Univ 174	Vanderbilt University	37	0,712		0,791			0,278						1,356	495,167		107,317
Univ 175	Vassar College	108	0,333		0,793			0,207					23,969		952,076		56,708
Univ 176	Washington University in St. Louis	115	0,318		0,955			0,158						52,568	63,470		43,064
Univ 177	Wellesley College	137	0,200		0,167			0,833					67,323		22,820		333,114
Univ 178	Wesleyan University	16	1,000			0,052		0,948					79,855		463,502		333,097
Univ 179	Western University	57	0,591	0,319	0,000		0,394	0,173								0,000	40,258

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Univ 180	Williams College	154	0,134		0,407	0,593	0,015	0,262			15,128				0,000
Univ 181	Wuhan University	76	0,409			0,000	0,378	0,236			0,000		222,603		44,400
Univ 182	Yale University	155	0,129	0,000	1,708			0,114		0,183		193,024		0,708	
Univ 183	Yonsei University	111	0,333		0,986			0,014			12,174	13,063	1521,637		
Univ 184	Zhejiang University	122	0,271					0,223	0,048			15,197	144,040	0,000	0,000

Table A3: DEA-VRS results

dmu	university	CRS_TE	VRS_TE	SCALE	RTS
Univ1	American University	0,6667	0,6667	1,0000	-
Univ2	Amherst College	0,6667	0,6667	1,0000	-
Univ3	Arizona State University	1,0000	1,0000	1,0000	-
Univ4	Athens University of Economics and Business	0,8652	1,0000	0,8652	irs
Univ5	Australian National University	0,3738	0,4000	0,9344	irs
Univ7	Bilkent University	0,6667	0,6667	1,0000	-
Univ8	Bocconi University	0,0732	1,0000	0,0732	drs
Univ9	Bogazici University	0,1930	0,5000	0,3861	irs
Univ10	Boston College	0,5263	0,7071	0,7443	drs
Univ11	Boston University	0,7703	1,0000	0,7703	drs
Univ12	Brandeis University	0,3376	0,3446	0,9797	drs
Univ13	Brigham Young University	0,1250	0,1250	1,0000	-
Univ14	Brown University	0,2206	0,5788	0,3811	drs
Univ15	California Institute of Technology	1,0000	1,0000	1,0000	-
Univ16	Cambridge University	0,1520	0,5617	0,2706	drs
Univ17	Carleton College	0,3333	0,3333	1,0000	-
Univ18	Carnegie Mellon University	0,5000	0,5000	1,0000	-
Univ19	Catolica Lisbon School of Business and Economics	1,0000	1,0000	1,0000	-
Univ20	Central European University	0,3413	0,3544	0,9633	drs
Univ22	Centro de Estudios Monetarios y Financieros	0,1603	0,4000	0,4008	irs
Univ23	Centro de Investigación y Docencia Económica	0,3936	0,6667	0,5904	irs
Univ24	Claremont McKenna College	0,4000	0,4000	1,0000	-
Univ25	Colby College	0,6667	0,6667	1,0000	-
Univ26	Collegio Carlo Alberto	0,5970	0,8917	0,6695	drs
Univ27	Columbia University in the City of New York	0,1406	0,4370	0,3217	drs
Univ28	Cornell University	0,2779	0,5647	0,4921	drs
Univ29	Dartmouth College	0,3759	1,0000	0,3759	drs
Univ30	Davidson College	0,5000	0,5000	1,0000	-
Univ31	Delhi School of Economics	0,1044	0,1818	0,5742	irs
Univ32	Dickinson College	1,0000	1,0000	1,0000	-
Univ33	Duke University	0,1184	0,2129	0,5563	drs
Univ34	ENSAE Paris	0,1798	0,6667	0,2697	irs
Univ35	Ecole Normale Superieure	0,3842	0,5000	0,7683	irs
Univ36	Ecole Polytechnique	0,3333	0,3333	1,0000	-
Univ37	Fudan University	0,4000	0,4000	1,0000	-
Univ38	Georgetown University	0,1530	0,1822	0,8396	drs
Univ39	Getulio Vargas Foundation	0,0864	0,1348	0,6409	drs
Univ40	Grinnell College	1,0000	1,0000	1,0000	-
Univ41	HEC Montreal	1,0000	1,0000	1,0000	-
Univ42	Harvard University	0,2217	1,0000	0,2217	drs

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Univ43	Haverford College	0,6667	0,6667	1,0000	-
Univ44	Heidelberg University	1,0000	1,0000	1,0000	-
Univ46	Indian Institute of Technology	0,3275	1,0000	0,3275	irs
Univ47	Indian Statistical Instititute	0,1235	0,1818	0,6792	irs
Univ48	Indiana University Bloomington	0,3435	0,3738	0,9190	drs
Univ49	Instituto Tecnologico Autonomo de Mexico	0,1053	0,1053	1,0000	-
Univ50	KTH Royal Institute of Technology	0,6674	1,0000	0,6674	irs
Univ52	Korea University	1,0000	1,0000	1,0000	-
Univ53	Koç Üniversitesi	0,2000	0,2000	1,0000	-
Univ54	Lahore University of Management Sciences	1,0000	1,0000	1,0000	-
Univ55	Lewis And Clark College	1,0000	1,0000	1,0000	-
Univ56	London School of Economics and Political Science	0,0847	1,0000	0,0847	drs
Univ57	Ludwig Maximilian University of Munich	1,0000	1,0000	1,0000	-
Univ58	Luiss Guido Carli University	0,1848	1,0000	0,1848	irs
Univ59	Maastricht University School of Business and Economics	1,0000	1,0000	1,0000	-
Univ60	Macalester College	0,4000	0,4000	1,0000	-
Univ61	Massachusetts Institute of Technology	0,3088	1,0000	0,3088	drs
Univ62	McGill University	0,3508	0,5000	0,7015	irs
Univ63	Miami University	1,0000	1,0000	1,0000	-
Univ64	Michigan State University	0,3504	0,6429	0,5451	drs
Univ65	Middlebury College	0,5000	0,5000	1,0000	-
Univ66	Mount Holyoke College	0,5000	0,5000	1,0000	-
Univ67	National Taiwan University	0,1378	0,2500	0,5511	irs
Univ68	National University of Singapore	0,2379	0,4000	0,5948	irs
Univ69	Nazarbayev University	0,2630	1,0000	0,2630	irs
Univ70	New Economic School	0,0909	0,0909	1,0000	-
Univ71	New York University	0,4353	1,0000	0,4353	drs
Univ72	New York University Abu Dhabi	0,4000	0,4000	1,0000	-
Univ73	Northeastern University	1,0000	1,0000	1,0000	-
Univ74	Northwestern University	0,2010	0,5209	0,3858	drs
Univ75	Nova School of Business and Economics	0,6729	1,0000	0,6729	irs
Univ76	Occidental College	0,6667	0,6667	1,0000	-
Univ77	Oxford University	0,1126	1,0000	0,1126	drs
Univ78	Paris School of Economics	0,3807	1,0000	0,3807	drs
Univ79	Peking University	0,0603	0,0714	0,8447	irs
Univ80	Penn State University	0,6235	0,9231	0,6754	drs
Univ81	Pomona College	0,2500	0,2500	1,0000	-
Univ82	Pompeu Fabra University	0,2125	0,2335	0,9099	drs
Univ83	Pontifica Universidad Catolica de Chile	0,1279	0,1616	0,7917	drs
Univ84	Pontifical Catholic University of Rio de Janeiro	0,1000	0,1000	1,0000	-
Univ85	Princeton University	0,2108	0,8740	0,2412	drs
Univ86	Queen's University	0,3508	0,5000	0,7016	irs
Univ87	Renmin University of China	0,1576	0,2857	0,5517	irs

Univ88	Rice University	0,3333	0,3333	1,0000	-
Univ89	Rutgers University	0,3312	0,3333	0,9936	irs
Univ90	Sabanci University	0,6667	0,6667	1,0000	-
Univ91	Sant'Anna School of Advanced Studies	0,7029	1,0000	0,7029	irs
Univ92	Science Po	0,3135	1,0000	0,3135	drs
Univ95	Smith College	1,0000	1,0000	1,0000	-
Univ96	Sogang University	1,0000	1,0000	1,0000	-
Univ97	Stanford University	0,1999	0,5052	0,3957	drs
Univ98	Stony Brook University	0,4644	1,0000	0,4644	irs
Univ99	Sungkyunkwan University	1,0000	1,0000	1,0000	-
Univ100	Swarthmore College	0,1429	0,1429	1,0000	-
Univ101	Tel Aviv University	0,2314	0,2500	0,9254	irs
Univ102	Texas A&M University	0,6147	1,0000	0,6147	irs
Univ103	The Chinese University of Hong Kong	0,2232	0,5000	0,4465	irs
Univ104	The College of William and Mary	0,2360	0,3333	0,7079	irs
Univ105	The George Washington University	0,5390	1,0000	0,5390	drs
Univ106	The Hebrew University of Jerusalem	0,2243	0,2857	0,7849	irs
Univ107	The Hong Kong University of Science and Technology	0,4867	0,6667	0,7300	irs
Univ108	The John Hopkins University	0,3247	0,4962	0,6543	drs
Univ109	The Ohio State University	0,5248	0,6141	0,8546	drs
Univ110	The University of British Columbia	0,3392	0,4098	0,8278	drs
Univ111	The University of Chicago	0,0763	0,2720	0,2807	drs
Univ112	The University of Edinburgh	0,8685	1,0000	0,8685	irs
Univ113	The University of Kansas	0,7006	1,0000	0,7006	irs
Univ114	The University of Oslo	0,8187	1,0000	0,8187	irs
Univ115	The University of Queensland	0,8767	1,0000	0,8767	irs
Univ116	Tilburg University	0,4975	1,0000	0,4975	irs
Univ117	Toulouse School of Economics	0,6145	1,0000	0,6145	drs
Univ118	Trinity College Dublin	0,7799	1,0000	0,7799	drs
Univ119	Tsinghua University	0,1807	1,0000	0,1807	drs
Univ120	Tufts University	0,4083	0,4256	0,9594	drs
Univ121	UNSW Australia	0,5132	0,6667	0,7699	irs
Univ122	Universidad Nacional de La Plata	0,3005	0,5000	0,6010	irs
Univ123	Universidad EAFIT	1,0000	1,0000	1,0000	-
Univ124	Universidad Torcuato di Tella	0,0800	0,0800	1,0000	-
Univ125	Universidad de Chile	0,0927	0,1429	0,6486	irs
Univ126	Universidad de Los Andes	0,3539	0,7271	0,4867	drs
Univ127	Universidad de Montevideo	0,4000	0,4000	1,0000	-
Univ128	Universidad de Piura	1,0000	1,0000	1,0000	-
Univ129	Universidad de San Andres	0,0800	0,0800	1,0000	-
Univ130	Universidad del Pacifico	0,3613	0,4691	0,7701	drs
Univ131	Universidade de Brasilia	0,3585	1,0000	0,3585	irs
Univ132	Universitat Autonoma de Barcelona	0,6773	1,0000	0,6773	irs

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Univ133	University College London	0,2820	0,4830	0,5838	drs
Univ134	University Of Nevada, Reno	0,4635	0,6667	0,6953	irs
Univ135	University of Alabama	0,3895	0,6667	0,5843	irs
Univ136	University of Arizona	0,7339	1,0000	0,7339	irs
Univ137	University of Bologna	0,7484	1,0000	0,7484	drs
Univ139	University of California, Los Angeles	0,2281	0,3161	0,7216	drs
Univ142	University of Illinois at Urbana-Champaing	0,3664	0,4794	0,7644	drs
Univ143	University of International Business and Economics	0,6146	1,0000	0,6146	irs
Univ144	University of Kentuky	1,0000	1,0000	1,0000	-
Univ145	University of Lausanne	1,0000	1,0000	1,0000	-
Univ146	University of Mannheim	0,3990	0,6667	0,5984	irs
Univ147	University of Maryland Baltimore County	0,7127	1,0000	0,7127	irs
Univ148	University of Maryland College Park	0,3476	0,5890	0,5902	drs
Univ149	University of Melbourne	0,3153	0,3333	0,9458	irs
Univ150	University of Michigan - Ann Arbor	0,1488	0,2190	0,6793	drs
Univ151	University of Minnesota - Twin Cities	0,1544	0,2000	0,7721	irs
Univ152	University of Missouri-Columbia	0,7505	1,0000	0,7505	drs
Univ153	University of North Carolina at Chapel Hill	0,3365	0,6008	0,5600	drs
Univ154	University of Notre Dame	0,3909	0,4638	0,8428	drs
Univ155	University of Oregon	0,9513	1,0000	0,9513	irs
Univ156	University of Pennsylvania	0,2078	0,4957	0,4191	drs
Univ157	University of Pittsburgh	0,4167	0,6667	0,6250	irs
Univ158	University of Rochester	0,5000	0,5000	1,0000	-
Univ159	University of Southern California	0,7051	0,8845	0,7972	drs
Univ160	University of St. Gallen	0,4352	0,6667	0,6527	irs
Univ161	University of Sydney	0,4000	0,4000	1,0000	-
Univ162	University of Texas at Austin	0,3693	0,4000	0,9233	irs
Univ163	University of Tokyo	0,1175	0,1743	0,6742	drs
Univ164	University of Toronto	0,1699	0,1818	0,9345	irs
Univ165	University of Utah	0,6161	1,0000	0,6161	irs
Univ166	University of Virginia	0,3698	0,5105	0,7244	drs
Univ167	University of Warwick	0,7339	0,8609	0,8524	drs
Univ168	University of Washington	0,4504	0,8433	0,5340	drs
Univ169	University of Wisconsin-Madison	0,1062	0,2365	0,4491	drs
Univ170	University of Wyoming	0,8298	1,0000	0,8298	irs
Univ171	University of Zurich	1,0000	1,0000	1,0000	-
Univ173	Università degli Studi di Torino	0,4952	0,5000	0,9904	irs
Univ174	Vanderbilt University	0,7125	0,7782	0,9156	drs
Univ175	Vassar College	0,3333	0,3333	1,0000	-
Univ176	Washington University in St. Louis	0,3181	0,3499	0,9089	drs
Univ177	Wellesley College	0,2000	0,2000	1,0000	-
Univ178	Wesleyan University	1,0000	1,0000	1,0000	-
Univ179	Western University	0,5910	0,6667	0,8865	irs

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Univ180	Williams College	0,1345	0,5770	0,2331	drs
Univ181	Wuhan University	0,4092	0,6667	0,6139	irs
Univ182	Yale University	0,1294	0,3800	0,3404	drs
Univ183	Yonsei University	0,3333	0,3333	1,0000	-
Univ184	Zhejiang University	0,2713	1,0000	0,2713	irs

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Table A4: Linear production function with different inefficiency term distributions

VARIABLES	(1) Placement	(2) Placement	(3) Placement
Faculty	0.107***	0.107***	0.107***
	(0.0143)	(0.0140)	(0.0140)
Article Downloads	0.00703	0.00703	0.00703
	(0.00669)	(0.00658)	(0.00658)
Citations	0.00411***	0.00411***	0.00411***
	(0.000634)	(0.000622)	(0.000622)
Private university	4.126***	4.126***	4.126***
	(1.262)	(1.240)	(1.240)
Years from establishment	0.00393	0.00393	0.00393
	(0.00451)	(0.00444)	(0.00444)
Constant	-3.515*	-3.464	-3.464
	(1.902)	(4.452)	(5.520)
Observations	174	174	174
R-squared	0.466		
Distribution	OLS	Half-normal	Truncated normal

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

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Table A5: Cobb-Douglas production function with different inefficiency term distributions

VARIABLES	(1) ln(Placement)	(2) ln(Placement)	(3) ln(Placement)
Faculty	0.00618***	0.00618***	0.00618***
	(0.00128)	(0.00125)	(0.00125)
Journal Downloads	0.000723	0.000723	0.000723
	(0.000598)	(0.000588)	(0.000588)
Citations	0.000363***	0.000363***	0.000363***
	(5.66e-05)	(5.56e-05)	(5.56e-05)
Private university	0.396***	0.396***	0.396***
	(0.113)	(0.111)	(0.111)
Years from establishment	0.000372	0.000372	0.000372
	(0.000403)	(0.000396)	(0.000396)
Constant	0.717***	0.723	0.721*
	(0.170)	(0.903)	(0.386)
Observations	174	174	174
R-squared	0.385		
Distribution	OLS	Half-normal	Truncated normal

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

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Table A6: Translogarithmic production function with different inefficiency term distributions

VARIABLES	(1) ln(Placement)	(2) ln(Placement)	(3) ln(Placement)
ln(Faculty)	-0.759	-0.759	-0.759
	(0.611)	(0.590)	(0.590)
ln(ArticleDownloads)	1.006	1.004	1.005
	(1.083)	(1.045)	(1.045)
ln(Citations)	-0.181	-0.182	-0.181
	(0.559)	(0.540)	(0.540)
ln(Faculty)²	0.0699	0.0699	0.0699
	(0.0560)	(0.0541)	(0.0541)
ln(Faculty)* ln(ArticleDownloads)	0.0391	0.0390	0.0391
	(0.0899)	(0.0867)	(0.0867)
ln(Faculty)* ln(Citations)	0.0594	0.0595	0.0594
	(0.0866)	(0.0836)	(0.0836)
ln(ArticleDownloads)²	-0.00381	-0.00370	-0.00380
	(0.0834)	(0.0805)	(0.0805)
ln_downjournal_citations	-0.155*	-0.155*	-0.155*
	(0.0923)	(0.0890)	(0.0890)
ln(Citations)* ln(ArticleDownloads)	0.0835*	0.0835**	0.0835**
	(0.0424)	(0.0409)	(0.0409)
ln(Years from establishment)	0.0317	0.0317	0.0317
	(0.0789)	(0.0762)	(0.0762)
Private university	0.395***	0.395***	0.395***
	(0.120)	(0.116)	(0.116)
Constant	-1.250	-1.236	-1.244
	(3.655)	(3.586)	(3.544)
Observations	174	174	174
R-squared	0.364		
Model	OLS	Half normal	Truncated normal

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

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Table A7: rankings produced by each methodology

University	DEA-CRS	DEA-VRS	Linear	Cobb-Douglas	Translog
American University	49	72	129	127	122
Amherst College	44	72	119	129	125
Arizona State University	1	1	154	167	170
Athens University of Economics and Business	27	1	157	160	154
Australian National University	91	122	109	75	83
Bilkent University	47	72	140	134	138
Bocconi University	173	1	2	10	9
Bogazici University	140	101	43	47	41
Boston College	59	71	164	120	136
Boston University	31	1	172	164	173
Brandeis University	105	136	104	74	78
Brigham Young University	157	168	16	15	17
Brown University	132	94	132	64	73
California Institute of Technology	1	1	159	173	174
Cambridge University	149	97	18	17	16
Carleton College	110	137	48	44	45
Carnegie Mellon University	62	101	146	121	120
Catolica Lisbon School of Business and Economics	1	1	143	165	163
Central European University	103	134	99	70	74
Centro de Estudios Monetarios y Financieros	145	122	28	33	30
Centro de Investigación y Docencia Económica	85	72	59	84	84
Claremont McKenna College	80	122	93	77	75
Colby College	45	72	98	119	123
Collegio Carlo Alberto	56	64	155	126	135
Columbia University in the City of New York	152	119	19	35	31
Cornell University	121	96	148	78	88
Dartmouth College	90	1	161	105	98
Davidson College	66	101	57	73	96
Delhi School of Economics	164	160	17	11	13
Dickinson College	21	1	75	132	109
Duke University	159	155	24	25	29
ENSAE Paris	143	72	32	58	53
Ecole Normale Superieure	88	101	39	54	54
Ecole Polytechnique	109	137	77	57	56
Fudan University	82	122	108	79	60
Georgetown University	148	159	36	27	34
Getulio Vargas Foundation	168	167	9	5	5

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Grinnell College	20	1	79	137	124
HEC Montreal	1	1	134	153	157
Harvard University	131	1	54	161	65
Haverford College	46	72	94	114	116
Heidelberg University	13	1	150	168	166
Indian Institute of Technology	113	1	44	102	107
Indian Statistical Instititute	158	160	15	12	12
Indiana University Bloomington	102	133	73	52	57
Instituto Tecnologico Autonomo de Mexico	163	169	8	4	3
KTH Royal Institute of Technology	43	1	88	135	137
Korea University	11	1	153	171	171
Koç Üniversitesi	138	156	38	32	28
Lahore University of Management Sciences	23	1	82	133	108
Lewis And Clark College	17	1	92	145	164
London School of Economics and Political Science	169	1	3	31	7
Ludwig Maximilian University of Munich	1	1	170	174	172
Luiss Guido Carli University	141	1	33	93	97
Maastricht University School of Business and Economics	1	1	168	172	169
Macalester College	81	122	58	61	55
Massachusetts Institute of Technology	118	1	163	139	117
McGill University	99	101	90	81	87
Miami University	12	1	141	163	160
Michigan State University	100	90	136	67	77
Middlebury College	63	101	126	111	111
Mount Holyoke College	65	101	69	86	101
National Taiwan University	153	149	31	24	25
National University of Singapore	125	122	63	51	59
Nazarbayev University	123	1	34	96	85
New Economic School	167	171	10	6	6
New York University	73	1	171	131	143
New York University Abu Dhabi	79	122	103	85	81
Northeastern University	15	1	118	157	151
Northwestern University	136	98	76	46	51
Nova School of Business and Economics	42	1	135	148	149
Occidental College	48	72	84	108	150
Oxford University	161	1	21	28	19
Paris School of Economics	89	1	174	107	52
Peking University	174	174	4	1	1
Penn State University	51	63	147	112	133
Pomona College	124	149	40	37	38

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Pompeu Fabra University	133	153	96	38	40
Pontifica Universidad Catolica de Chile	156	164	22	18	18
Pontifical Catholic University of Rio de Janeiro	165	170	11	9	10
Princeton University	134	66	64	91	49
Queen's University	98	101	101	88	92
Renmin University of China	146	146	27	23	23
Rice University	107	137	85	62	69
Rutgers University	112	137	35	39	33
Sabanci University	50	72	65	99	93
Sant'Anna School of Advanced Studies	39	1	107	144	147
Science Po	117	1	158	82	82
Smith College	14	1	100	152	148
Sogang University	18	1	128	159	156
Stanford University	139	100	61	55	70
Stony Brook University	70	1	70	122	119
Sungkyunkwan University	1	1	149	169	159
Swarthmore College	151	165	14	14	14
Tel Aviv University	127	149	30	26	62
Texas A&M University	53	1	115	142	140
The Chinese University of Hong Kong	130	101	47	56	58
The College of William and Mary	126	137	41	40	37
The George Washington University	58	1	166	124	134
The Hebrew University of Jerusalem	129	146	52	42	48
The Hong Kong University of Science and Technology	69	72	78	94	91
The John Hopkins University	114	113	144	83	110
The Ohio State University	60	91	116	98	103
The University of British Columbia	104	121	113	59	79
The University of Chicago	172	148	1	16	21
The University of Edinburgh	26	1	137	154	153
The University of Kansas	40	1	80	130	128
The University of Oslo	29	1	138	155	161
The University of Queensland	25	1	162	166	165
Tilburg University	67	1	45	110	102
Toulouse School of Economics	55	1	173	143	139
Trinity College Dublin	30	1	160	150	152
Tsinghua University	142	1	26	22	24
Tufts University	77	120	133	100	104
UNSW Australia	61	72	127	113	130
Univerisidad Nacional de La Plata	119	101	89	69	63
Universidad EAFIT	19	1	152	162	144
Universidad Torcuato di Tella	170	172	6	2	2

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Universidad de Chile	166	165	23	13	15
Universidad de Los Andes	97	70	142	68	64
Universidad de Montevideo	83	122	51	53	42
Universidad de Piura	22	1	91	140	129
Universidad de San Andres	171	172	7	3	4
Universidad del Pacifico	95	117	117	71	71
Universidade de Brasilia	96	1	71	116	99
Universitat Autonoma de Barcelona	41	1	83	128	132
University College London	120	115	123	48	67
University Of Nevada, Reno	71	72	67	90	90
University of Alabama	87	72	81	95	94
University of Arizona	34	1	60	123	121
University of Bologna	33	1	68	72	39
University of California, Los Angeles	128	145	66	34	44
University of Illinois at Urbana-Champaing	94	116	62	50	46
University of International Business and Economics	54	1	124	138	118
University of Kentuky	1	1	86	136	142
University of Lausanne	10	1	110	147	145
University of Mannheim	84	72	114	103	105
University of Maryland Baltimore County	36	1	72	125	126
University of Maryland College Park	101	93	111	63	72
University of Melbourne	116	137	145	65	68
University of Michigan - Ann Arbor	150	154	29	20	26
University of Minnesota - Twin Cities	147	156	25	19	20
University of Missouri-Columbia	32	1	106	117	114
University of North Carolina at Chapel Hill	106	92	42	41	27
University of Notre Dame	86	118	151	97	113
University of Oregon	24	1	112	149	146
University of Pennsylvania	135	114	87	45	66
University of Pittsburgh	75	72	97	101	106
University of Rochester	64	101	130	109	115
University of Southern California	38	65	169	156	167
University of St. Gallen	74	72	121	106	112
University of Sydney	78	122	125	92	95
University of Texas at Austin	93	122	105	76	86
University of Tokyo	160	163	12	8	8
University of Toronto	144	160	55	30	36
University of Utah	52	1	53	115	127
University of Virginia	92	99	102	66	76
University of Warwick	35	67	165	146	158
University of Washington	72	68	120	80	80
University of Wisconsin-Madison	162	152	5	7	11

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University of Wyoming	28	1	95	141	141
University of Zurich	1	1	167	170	168
Università degli Studi di Torino	68	101	46	60	50
Vanderbilt University	37	69	156	151	162
Vassar College	108	137	56	49	47
Washington University in St. Louis	115	135	139	87	100
Wellesley College	137	156	49	36	35
Wesleyan University	16	1	122	158	155
Western University	57	72	131	118	131
Williams College	154	95	20	21	22
Wuhan University	76	72	74	89	89
Yale University	155	132	13	29	43
Yonsei University	111	137	37	43	32
Zhejiang University	122	1	50	104	61

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