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A DEA APPROACH TO THE RELATIVE EFFICIENCY OF PORTUGUESE PUBLIC UNIVERSITIES*

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Abstract

We employ Data Envelopment Analysis, to estimate efficiency scores for Portuguese public universities. The input measures are constructed from the number of teachers and from universities' spending while the output measures are based on the undergraduate success rate and on the number of doctoral dissertations. Using frontier analysis we are able to separate universities that might qualify, as "performing well" from those where some improvement might be possible. This could imply a better allocation by the universities of the usually scarce public financial resources available to tertiary education by the universities.

Key words: tertiary education, efficiency, DEA

JEL Classification: C14, H52, I21

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1. INTRODUCTION

Good performance in higher education is expected to produce positive growth effects, and tertiary education in many European countries still lags behind the level achieved in other developed economies. Another view alleged by some academic work and held in reports from international organisations, that the public sector remains inefficient in most European countries.[1] Furthermore, according to the OECD (2004), in 2001 the average share of public spending in total spending for tertiary education in the OECD and in Portugal was 79.3 percent and 92.3 percent respectively. These factors seem sufficient motivation to address the issue of the efficiency of public tertiary expenditure in Portugal.

The proper measurement of public sector performance, particularly when it concerns services provision, is a delicate empirical issue and the related literature, principally when it comes to aggregate data, is still limited. This measurement issue is here considered in terms of efficiency measures comparing public resources – total expenditure and number of teachers per student – used by Portuguese public universities, and indicators of the universities' output, such as the success rate of undergraduate students or doctoral dissertations.

Using frontier analysis we focus on how close public universities are to operating on the efficient frontier. We study the efficiency of Portuguese public universities in 2003 by applying Data Envelopment Analysis (DEA), to a set of 52 public universities/faculties/institutes and also to a sub-set of faculties/institutes.

The remainder of the paper is organised as follows. In section two we present some stylised facts concerning the tertiary education in Portugal, and review some of the related existing literature on education efficiency. Section three briefly addresses the DEA methodology. Section four explains the data, and discusses the results of our efficiency analysis. Section five contains our concluding remarks.

2. TERTIARY EDUCATION IN PORTUGAL AND LITERATURE OVERVIEW

2.1. Tertiary education in Portugal

Tertiary education in Portugal has traditionally been a publicly provided one, with the exception of the Portuguese Catholic University which has a special status. Only since the late 1980s privately run universities started to provide a more consistent alternative thereby increasing the offer of available places for students

[1] Afonso, Schuknecht and Tanzi (2005) report the existence of relative public spending inefficiencies across OECD countries.

at the tertiary education level. Nevertheless, since data regarding private tertiary education institutions, for instance that concerning total expenditures, are not easy to come across from a unified source, we will only address the public segment of the of the tertiary education sector which is by far the larger.[2]

The Portuguese tertiary public sector includes both universities and the so-called polytechnic institutes (*Politécnicos*). While in the polytechnics have been more oriented towards 3-year degrees, universities have offered 4, 5 or 6-year undergraduate degrees. The latter are also entitled to award Masters and Doctorate degrees.[3] In our analysis, only universities will be used since one of our selected outputs, doctoral dissertations, is not conferred by the polytechnics. The number of places available in tertiary education is determined every year by the institutions and approved by the government. All degrees have a *numerus clausus* fixed by each institution according to its capacity. Additionally, faculties and institutes have to specify a minimum entrance requirement for their various degrees.[4]

The proportion of students enrolled in tertiary education in Portugal, as a percentage of all pupils and students was 17 per cent in 1999/2000, slightly above the EU average of 15 per cent. Indeed, in parallel with the overall trend in the EU, the number of students in tertiary education more than doubled over the last 25 years. However, Portugal is still below average in terms of tertiary education in the EU. For instance, the percentage of population between 30 and 34 years of age that held a tertiary education qualification in 2000 was 11.3 per cent in Portugal, well below the 24.6 per cent average in the EU-15 (cfr. Eurostat, 2002), which constitutes a much important accumulated stock.

During the period 1993/94-2003/04, the overall number of teachers in public tertiary institutions in Portugal increased around 48.1 per cent. The more significant rise occurred in the "polytechnic" sector, 158.9 per cent, while public tertiary university teachers increased by 16.9 per cent between 1993 and 2003 (see OCES, 2004b). Regarding public universities the number of teachers per 100 students decreased from 9.6 in 1993 to 8.3 in 2003.

Another interesting point to make concerning the structure of public universities' teachers is the fact that there seems to be some skewing towards the assistant professors category during the period 1993-2003. In other words, it looks as if there are too few full professors in relative terms. One of the reasons

[2] There are also tertiary degrees provided by military institutions. Given the particularities of such institutions, and data availability, those institutions are not included in the sample.

[3] The academic degrees confered by Portuguese Universities are: graduation or first degree (usually 4-5 years, but there are also 6-years degree: *Licenciatura*); Master degree (*Mestrado*, includes writing a thesis, and a public examination); doctoral degree (*Doutoramento*, includes writing a thesis, and a public examination); and the *Agregação* degree (includes writing two reports, and a public examination).

[4] There are national competitive examinations for the canditates with satifactory school and exam results. The candidates' marks have to be above a minimum set by each institution. For some degrees (music, sports) selection is on the basis of ability.

behind this reality is the rather fixed number of places for each category of academic staff in Portuguese universities.

2.2. Literature overview

The available empirical literature on tertiary education efficiency mostly uses the DEA framework. For instance, some related references are: for the US Breu and Raab (1994); for Australia Coelli (1996); for Canada McMillan and Datta (1998); for Britain Johnes (1999); for Norway Førsund and Kalhagen (1999); for Australia Avkiran (2001), for the US Calhoun (2003); for Australia Carrington, Coelli, and Rao (2004); for Germany Warning (2004); and for the Netherlands Cherchye and Abeele (2005). The analysis of efficiency and performance in tertiary education is usually applied to universities in one country. Nevertheless, Joumady and Ris (2005) report results for several European countries (Austria, Finland, France, Germany, Italy, the Netherlands, Spain, and UK), based on collected survey data.

Some of the input measures used in the existing literature include, for instance, staff numbers, non-staff numbers, percentage of faculty with a doctoral degree, total expenditure, expenditure with academic staff, and other expenditures. In terms of output measures, the most commonly used variables, are the graduation retention rate, freshmen retention rate, student numbers, both graduate and undergraduate, total number of certificates conferred, and research publications and citations.

In related cross-country efficiency studies, Clements (2002) uses Free Disposable Hull (FDH) analysis to measure the efficiency of education spending in the European Union. St. Aubyn (2003) reports results of FDH analysis applied to education spending in OECD countries while Afonso and St. Aubyn (2005) use both FDH and DEA for a cross-country analysis of efficiency in education and health.

3. ANALYTICAL FRAMEWORK

Data Envelopment Analysis, originating from Farrell's (1957) seminal work and popularised by Charnes, Cooper and Rhodes (1978), assumes the existence of a convex production frontier. The production frontier in the DEA approach is constructed using linear programming methods. The term "envelopment" stems from the fact that the production frontier envelops a set of observations.[5] The term

[5] Coelli, Rao and Battese (1998) and Sengupta (2000) introduce the reader to this literature and describe several applications.

"firm", sometimes replaced by the more encompassing Decision Making Unit (henceforth DMUs), which was coined by Charnes et al. (1978), may include non-profit or public organisations, such as hospitals, universities or local authorities.[6]

The general relationship that we expect to test, regarding efficiency in tertiary education, can be given by the following function for university *i*:

$$Y_i = f(X_i),\ i=1,\ldots,n \qquad (1)$$

where we have Y_i – indicators reflecting education output; X_i – spending or number of teachers in university *i,* either per student or in some other measure. If $Y_i < f(x_i)$, it is said that university *i* exhibits inefficiency. For the observed input level, the actual output is smaller than the best attainable one and inefficiency can then be measured by computing the distance to the efficiency frontier.

The purpose of an input-oriented example is to study the amount by which input quantities can be proportionally reduced without changing the output quantities produced. Alternatively, and by computing output-oriented measures, one could also try to assess how much output quantities can be proportionally increased without changing the input quantities used. The two measures provide the same results under constant returns to scale but give different values under variable returns to scale. Nevertheless, since the computation uses linear programming, which is not subject to statistical problems such as simultaneous equation bias and specification errors, both output and input-oriented models will identify the same set of efficient/inefficient producers or DMUs.

The analytical description of the linear programming problem to be solved, in the variable-returns to scale hypothesis, is sketched below for an input-oriented specification. Suppose there are *k* inputs and *m* outputs for *n* DMUs. For the i-th DMU, y_i is the column vector of the inputs and x_i is the column vector of the outputs. We can also define *X* as the $(k \times n)$ input matrix and *Y* as the $(m \times n)$ output matrix. The DEA model is then specified with the following mathematical programming problem, for a given i-th DMU:[7]

$$\begin{aligned} &\min_{\theta,\lambda} \theta \\ &\text{s.to} \quad -y_i + Y\lambda \geq 0 \\ &\qquad \theta x_i - X\lambda \geq 0\,. \\ &\qquad n1'\lambda = 1 \\ &\qquad \lambda \geq 0 \end{aligned} \qquad (2)$$

[6] See Dyson et al. (2001) for the ideal conditions on the use of the DEA methodology.

[7] We present here the equivalent envelopment form, derived by Charnes et al. (1978), using the duality property of the multiplier form of the original programming model.

In problem (2), θ is a scalar (that satisfies $\theta \leq 1$), more specifically it is the efficiency score that measures technical efficiency. It measures the distance between a university and the efficiency frontier, defined as a linear combination of best practice observations. With $\theta<1$, the university is inside the frontier (i.e. it is inefficient), while $\theta=1$ implies that the university is on the frontier (i.e. it is efficient).

The vector λ is a $(nx1)$ vector of constants that measures the weights used to compute the location of an inefficient DMU if it were to become efficient. The inefficient DMU would be projected on the production frontier as a linear combination of those weights, related to the peers of the inefficient DMU. $n1$ is a n-dimensional vector of ones. The restriction $n1'\lambda = 1$ imposes convexity of the frontier, accounting for variable returns to scale. Dropping this restriction would amount assuming that returns to scale were constant.

4. EFFICIENCY ANALYSIS OF TERTIARY EDUCATION SPENDING IN PORTUGAL

4.1. Data and measurement issues

In our study we assess the efficiency of a set of Portuguese public universities in 2003. More precisely, we were able to collect data for 52 universities/faculties/institutes. Data for the subset of faculties/institutes were dependent on availability. For 8 DMUs (universities) only aggregated data were available and not by faculty. All these DMUs are listed in the Appendix alongside with a short code name, which identifies each faculty in terms of the results reported ahead in the paper.[8]

Selection of the DMUs is grounded in the fact that most public universities in Portugal aggregate several faculties or institutes, depending on their organisational framework. For instance, the Technical University of Lisbon is organised with institutes while the University of Oporto is organised with faculties. Still other universities do not have a fully-fledged segmentation either in terms of institutes or in terms of faculties. Data limitations prevented us from using either degree or department specific information, which in theory would have allowed a more homogeneous sample. Naturally, a note of cautioun has to be made when dealing with a heterogeneous set of universities, and this is long standing issue regarding

[8] Our data sources are:
- Success rate (%), 2003, OCES (2004a). [http://www.oces.mcies.pt/];
- Doctorate certificates in 2002-03, per 100 teachers, constructed with data from OCES: http://www.oces.mcies.pt/;
- Teachers and FTE teachers per 100 students, 2003. Includes overall number of teachers in the following categories: full Prof., associate Prof., assistant Prof., teaching assistant, trainee teaching assistant, and others ("leitor", "monitor"). OCES (2004b);
- Average spending per student, 2000-03, euros, *Conta Geral do Estado – 2000, 2001, 2002, 2003*. Direcção-Geral do Orçamento. [http://www.dgo.pt/cge/]

efficiency analysis. The literature has offered some solutions to deal with subject-mix, but this outside the scope of this exploratory study (see Sarrico and Dyson (2004).

Having said this, our DMUs are both primarily faculties and institutes, but universities are also considered as an aggregate institution. This segregation of DMUs can also be found in the Annual State General Account (*Conta Geral do Estado*), published by the Portuguese Ministry of Finance, taking into account the relative autonomy of the several bodies of the Central Government.

Concerning the selection of outputs and inputs, as a general rule of thumb (Bowlin, 1998) there should be at least three DMUs for each input and output variable used in the model since with less than three DMUs per input and output, there is the risk that too many DMUs will turn out to be efficient. This allows having sufficient degrees of freedom when implementing the DEA methodology. Therefore, and since we have at least 33 DMUs, considering only faculties and institutes, it would be possible to use a total number of say 4 or 5 inputs and outputs. Additionally we need relatively homogeneous DMUs, with the same inputs and outputs in positive amounts. A missing value for either inputs or outputs consequently implied dropping the respective DMU from the data set.

Output data

Performance measurement in higher education generally proves to be a difficult task. Indeed, it is not easy to assess the performance of a university using market mechanisms such as profits as an output. Moreover, homogeneous performance indicators are not easily available for the Portuguese public tertiary education sector.

For our first output measure we used the success rate in the year 2002/03 of the undergraduate students enrolled for the first time, on a faculty or institute basis.[9] This measure ranges from 37.1 percent (UNL-FCT) to 95.9 percent (UP-FMD), as can be seen in the Appendix. The method used to be obtain the success rate has a downside for some degrees; the computed success rate can actually exceed 100 percent. This is due to the fact that the calculation does not take into account the students that switch change degree during their studies, and end up graduating in a different subject, which naturally distorts the success rate of that particular degree (see OCES [2004a]). This question was relevant for three medical

[9] This is the OECD survival rate concept, as mentioned in OCES (2004a): "Survival rate at the tertiary level is defined as the proportion of new entrants to the specified level of education who successfully complete a first qualification. It is calculated as the ratio of the number of students who are awarded an initial degree to the number of new entrants to the level *n* years before, *n* being the number of years of full-time study required to complete the degree."

faculties and also for a sports faculty, where the success rate was above 100 percent. We excluded these faculties from our sample, therefore restricting our initial sample, which may impinge on the results. The relevance of such performance measure is also corroborated by the regular calls made by the OECD that policymakers should try to increase success rates, via quality improvements and a diversification of education programmes.

As a second output measure, and in order to try to capture somehow another side of the universities' performance outcome, we used the number of Doctorate certificates conferred by each DMU. We only take into account the doctoral dissertations actually obtained in Portugal, and we do not consider the equivalences attributed to certificates obtained abroad, in order to better assess the internal use of financial and physical resources involved in such postgraduate degrees. Notice that information was homogeneously available from a single source for the number of Doctorate certificates and not for the number of doctoral students. Another useful output, research publications and citations, is unfortunately not available on a homogeneous basis for all the DMUs.

Operationally we use the cumulative number of Doctorate certificates conferred in the years 2002-2003 per 100 teachers in each DMU. This is intended both to smooth some possible peak in one year, eventually some data errors, and also to avoid excluding many universities/faculties that conferred no Doctorate certificates in a given year. It seems adequate to use as an output indicator the ratio of Doctorate certificates per teacher since this is the possible proxy to measure the scientific "production" of the university/faculty's staff, given the non-availability of operational information regarding the research publications of the academic staff. In this case the number of Doctorate certificates per undergraduate student, is not relevant since the main question is to assess the extent of participation of academic staff in the formation of Doctorate students. The number of Doctorate certificates conferred ranged from nil certificates per 100 teachers (UL-FBA) to 27.7 certificates per 100 teachers (UTL-ISA).

It must be borne in mind that some universities seem to have shown, at least in the past, different preferences with regard to doctoral programmes and degrees. However, this heterogeneous set of preferences is naturally difficult to take into account in our analysis. Additionally, and as some colleagues within the Portuguese higher education system mentioned to us, sometimes the information compiled by the OCES – *Observatório da Ciência e do Ensino Superior*, lags behind the actual data.

Input data

The success rates we use, computed by the OCES, are for degrees whose standard duration varies between 4 and 5 years, while for the medical faculty

degrees usually take 6 years. This is aligned with the fact that we take 4 years averages of total spending as well. Hence, one of our selected inputs will be the average total spending per student for the years 2000, 2001, 2002 and 2003. Total spending is taken from the Annual State General Account. This average measure of financial input ranged from 2021 euros (UL-FD) to 12015 euros (UTL-ISA). The use of total spending seems justified by the fact that in most universities there is a need for academics to perform administrative tasks. On the other hand, the lack of more detailed and homogeneous publicly available data works as a deterrent.[10]

We selected a second input, measured in physical terms, which is the teachers-to-students ratio in public universities in the year 2003/04. More precisely, we used the variable "Teachers per 100 Students" since higher performance is supposedly directly linked with higher input levels. This physical input ranged from 3.5 teachers per 100 students (UNL-FD) to 27.8 teachers per 100 students (UNL-FCM).

This input was also used in a slightly different way. Instead of using simply the teachers-to-students ratio, we also had available the so-called full-time equivalent ratio (FTE), which measures the number of teachers in terms of a full time equivalency. In other words, and since some teachers are not teaching on a full time basis, this indicator corrects the number of teachers accordingly. Naturally, the magnitude of such correction differs among schools. The teachers-to-students FTE ratio ranged from 3.5 teachers per 100 students (UNL-FD) to 13.5 teachers per 100 students (UNL-FCM). The raw data and their sources are reported in the Appendix.

Additional alternative input measures would be the breakdown of total spending into academic and non-academic staff related. However, these data are not publicly available, from a unique source in a homogeneous way.

4.2. DEA results of efficiency analysis

When performing DEA analysis an option has to be made between constant returns and variable returns to scale. Under constant returns to scale one assumes that there is no significant relationship between the scale of operations and efficiency. In other words, big universities are not more efficient than smaller ones in transforming their inputs to outputs. On the other hand, under variable returns to scale an increase in inputs is expected to result in a disproportionate increase in the outputs delivered by the DMUs, due to decreasing marginal returns. For all our

[10] More detailed data at the faculty/institute level only started to be published in 2005 for the 2004 Annual State General Account.

specifications we will centre our analysis on the variable returns to scale efficiency scores.

We report input and output oriented results because we believe it is useful to have both sets of results. It is true that, as mentioned by the referee, in this case an output oriented analysis is more straightforward to convey since the DMUs are more constrained when changing their budgets and their staff. However, we cannot discard the possibility of actual changes in the inputs, be it via the initiative of the universities, which is nevertheless possible, or via the initiative of the government, which is more likely in the case of this sample of public tertiary education institutions.

Taking advantage of the available information on the universities' spending, we performed the DEA analysis using two inputs, the teacher-student FTE ratio and expenditure per student, together with the aforementioned success rate as the output measure. A caveat relates to the fact that some degree of correlation cannot be avoided among the inputs used. Due to the lack of available data on spending for some universities on a faculty basis, the initial sample consists of 33 faculties or institutes. We report in Table 1 the results of this two-input one-output analysis.

From the results we see that the empirical production function includes four DMUs: UL-FD, UNL-FD, UP-FD, and UP-FMD. Still from Table 1 we observe that the average input efficiency socre is 0.678 implying, in principle, that on average the faculties/institutes in the sample might be able to achieve a similar level of performance using 32.2 per cent feuer resources that they were using. The average output efficient score equals 0.766, which indicates that with the same inputs, the average DMU seems to be obtaining a performance about 23.4 percent less than it should if it were on the production possibility frontier. The scope for both input and output efficiency improvement seems to be relevant for some faculties/ institutes since the efficiency scores are well below the average scores.

Additionally, one should notice that the first three (law) faculties among the efficient DMUs are then the peers of most of the other DMUs. This result must be read with caution given the abovementioned heterogeneity issues in the sample. It also provides motivation for the analysis performed below at the university level, where more aggregate DMUs are used.

We further broadened the analysis in order to consider also our second output measure, the number of Doctorate certificates conferred per 100 teachers. The results are reported in Table 2.

By comparing this new set of results, which has two output indicators, with the previous results that have just one output, we can see that, as expected, two more DMUs are now located on the empirical production possibility frontier: UTL-ISA and UTL-FMD. The DMUs that were already on the frontier also keep their positions. There is also an overall increase in the average output efficiency scores. Again, we must make a caveat regarding the fact that in this heterogeneous sample there are different subject mixes and diverse cost structures.

TABLE 1

(M1) DEA results: 2 inputs (FTE teacher ratio, 2003; spending per student) and 1 output (success rate, 2003): faculties and institutes

Faculty/Institute	Input oriented		Output oriented	
	VRS TE	Rank	VRS TE	Rank
UC-FCT	0.440	27	0.638	25
UL-FL	0.610	13	0.534	30
UL-FD	1.000	1	1.000	1
UL-FC	0.363	31	0.574	29
UL-FF	0.438	28	0.838	13
UL-FPCE	0.456	25	0.708	21
UL-FMD	0.287	33	0.613	27
UL-FBA	0.611	12	0.650	24
UNL-FCT	0.470	24	0.415	33
UNL-FCSH	0.516	18	0.635	26
UNL-FD	1.000	1	1.000	1
UNL-FE	0.603	14	0.758	18
UNL-FCM	0.481	22	0.916	8
UNL-ISEGI	0.616	11	0.483	31
UP-FL	0.635	9	0.747	19
UP-FD	1.000	1	1.000	1
UP-FC	0.453	26	0.675	23
UP-FE	0.486	21	0.876	11
UP-FF	0.750	7	0.971	6
UP-FEC	0.887	6	0.985	5
UP-FPCE	0.487	20	0.796	16
UP-FA	0.625	10	0.454	32
UP-ICBAS	0.288	32	0.744	20
UP-FMD	1.000	1	1.000	1
UP-FBA	0.472	23	0.805	14
UP-FCNA	0.660	8	0.693	22
UTL-IST	0.384	29	0.781	17
UTL-ISEG	0.537	17	0.878	10
UTL-ISA	0.376	30	0.850	12
UTL-FMD	0.499	19	0.910	9
UTL-ISCSP	0.999	5	0.602	28
UTL-FA	0.551	16	0.936	7
UTL-FMH	0.561	15	0.800	15
Average	0.678		0.766	

VRS TE – variable returns to scale technical efficiency.

Considering the number of awarded doctoral degrees as an additional output measure, this can be expected to improve the ranking of the DMUs that are quite above average regarding this indicator. This is the case, for instance in Model 2 (Table 2), of UTL-ISA, UL-FC, and UP-ICBAS, where output efficiency ranking

TABLE 2

(M2) DEA results: 2 inputs (FTE teacher ratio, 2003; spending per student) and 2 outputs (success rate, 2003; Doctorate certificates per 100 teachers): faculties and institutes

Faculty/Institute	Input oriented		Output oriented	
	VRS TE	Rank	VRS TE	Rank
UC-FCT	0.441	30	0.752	25
UL-FL	0.638	13	0.604	30
UL-FD	1.000	1	1.000	1
UL-FC	0.742	10	0.940	10
UL-FF	0.438	31	0.875	17
UL-FPCE	0.471	27	0.770	21
UL-FMD	0.287	33	0.613	29
UL-FBA	0.611	18	0.650	27
UNL-FCT	0.470	28	0.632	28
UNL-FCSH	0.621	15	0.762	22
UNL-FD	1.000	1	1.000	1
UNL-FE	0.603	19	0.758	24
UNL-FCM	0.481	25	0.916	14
UNL-ISEGI	0.616	16	0.507	32
UP-FL	0.677	11	0.814	19
UP-FD	1.000	1	1.000	1
UP-FC	0.453	29	0.762	23
UP-FE	0.614	17	0.954	9
UP-FF	0.985	8	0.998	7
UP-FEC	0.887	9	0.985	8
UP-FPCE	0.592	21	0.936	11
UP-FA	0.625	14	0.473	33
UP-ICBAS	0.598	20	0.929	13
UP-FMD	1.000	1	1.000	1
UP-FBA	0.472	26	0.805	20
UP-FCNA	0.660	12	0.700	26
UTL-IST	0.384	32	0.911	15
UTL-ISEG	0.537	24	0.903	16
UTL-ISA	1.000	1	1.000	1
UTL-FMD	1.000	1	1.000	1
UTL-ISCSP	0.999	7	0.602	31
UTL-FA	0.551	23	0.936	12
UTL-FMH	0.578	22	0.845	18
Average	0.668		0.828	

VRS TE – variable returns to scale technical efficiency.

positions improve by 11, 19, and 7 places respectively, vis-à-vis Model 1 (Table 1).

A similar analysis was made for the set of 14 universities in our sample, at the aggregate level. We made several combinations of the two inputs and of the

two outputs variables used previously for the analysis of the faculty and institutes sub-sample. The results are reported in Tables 3, 4, and 5.

TABLE 3

(M3) DEA results: 2 inputs (FTE teacher ratio, 2003; spending per student) and 1 output (success rate, 2003): universities

University	Input oriented		Output oriented	
	VRS TE	Rank	VRS TE	Rank
ISCTE	1.000	1	1.000	1
UA	0.782	14	0.690	13
UAL	0.854	9	0.757	10
UAV	0.863	7	0.978	5
UBI	0.854	10	0.623	14
UC	1.000	1	1.000	1
UE	0.893	6	0.729	11
UL	0.821	12	0.827	8
UM	0.907	5	0.791	9
UMI	1.000	1	1.000	1
UNL	0.795	13	0.699	12
UP	0.923	4	0.992	4
UTAD	0.827	11	0.901	7
UTL	0.858	8	0.971	6
Average	0.884		0.854	

VRS TE – variable returns to scale technical efficiency.

TABLE 4

(M4) DEA results: 2 inputs (FTE teacher ratio, 2003; spending per student) and 2 outputs (success rate, 2003; Doctorate certificates per 100 teachers): universities

University	Input oriented		Output oriented	
	VRS TE	Rank	VRS TE	Rank
ISCTE	1.000	1	1.000	1
UA	0.782	14	0.690	13
UAL	0.854	9	0.757	10
UAV	0.863	8	0.978	6
UBI	0.854	10	0.644	14
UC	1.000	1	1.000	1
UE	0.893	7	0.735	11
UL	0.844	11	0.831	8
UM	0.907	6	0.791	9
UMI	1.000	1	1.000	1
UNL	0.799	13	0.730	12
UP	0.927	5	0.993	5
UTAD	0.827	12	0.901	7
UTL	1.000	1	1.000	1
Average	0.896		0.861	

VRS TE – variable returns to scale technical efficiency.

TABLE 5

(M5) DEA results: 1 input (FTE teacher ratio, 2003) and 2 outputs (success rate, 2003; Doctorate certificates per 100 teachers): universities

University	Input oriented		Output oriented	
	VRS TE	Rank	VRS TE	Rank
ISCTE	1.000	1	1.000	1
UA	0.782	14	0.690	13
UAL	0.854	9	0.757	10
UAV	0.863	8	0.978	6
UBI	0.854	10	0.626	14
UC	1.000	1	1.000	1
UE	0.893	7	0.732	11
UL	0.844	11	0.831	8
UM	0.907	6	0.791	9
UMI	1.000	1	1.000	1
UNL	0.799	13	0.712	12
UP	0.927	5	0.993	5
UTAD	0.827	12	0.901	7
UTL	1.000	1	1.000	1
Average	0.896		0.858	

VRS TE – variable returns to scale technical efficiency.

Using two inputs – FTE teachers-to-students ratio and spending per student – and one output – the success rate – the empirical production possibility frontier includes three universities: UC, UMI, and ISCTE (see Table 3). When an additional output is considered, Doctorate certificates per teacher, another DMU (UTL, the DMU with the highest number of Doctorate certificates per 100 teachers in the sample) appears located on the frontier (see Table 4). This is also true for the specification with two outputs and the FTE teachers-to-student ratio and spending per student as a single input (see Table 5). Overall, the average efficiency scores for the sub-sample of universities are quite similar in the three alternative specifications, around 0.88-0.90 and 0.85-0.86 respectively for the input and output oriented versions.

From this set of results for the universities sub-sample, and for the DMUs located on the frontier, we can also observe that UC and UMI report above average results for the success rate, below average numbers for the FTE teachers-to-students ratio and for the spending per student variable, together with above average Doctorate certificates per 100 teachers. This pattern also applies to ISCTE, even though this DMU is at the average regarding Doctorate certificates per 100 teachers. On the other hand, UTL above average results for the success rate and for the number of Doctorate certificates per 100 teachers, while also having above average FTE teacher-to-student and spending per student ratios.

We summarise in Table 6 the main findings of our non-parametric analysis, performed for the various sub-samples of universities/faculties/institutes, by reporting

data for the descriptive statistics of efficiency scores as well as the respective model specifications.

TABLE 6

Descriptive statistics of efficiency scores and model specification

			M1	M2	M3	M4	M5
Efficiency scores	Average	Input	0.678	0.668	0.884	0.896	0.896
		Output	0.766	0.828	0.854	0.861	0.858
	Maximum		1	1	1	1	1
	Minimum	Input	0.287	0.287	0.782	0.782	0.782
		Output	0.415	0.473	0.623	0.644	0.626
	Std. dev.	Input	0.213	0.218	0.074	0.078	0.078
		Output	0.170	0.158	0.138	0.135	0.139
Nº of DMUs			33	33	14	14	14
Nº of efficient DMUs			4	6	3	4	4
DMUs on the frontier			UL-FD, UNL-FD, UP-FD, UP-FMD	UL-FD, UNL-FD, UP-FD, UP-FMD, UTL-ISA, UTL-FMD	UC, UMI, ISCTE	UC, UMI, UTL, ISCTE	UC, UMI, UTL, ISCTE
Inputs			- FTE teachers-to-students ratio - Spending per student	- FTE teachers-to-students ratio - Spending per student	- FTE teachers-to-students ratio - Spending per student	- FTE teachers-to-students ratio - Spending per student	- FTE teachers-to-students ratio
Outputs			- Success rate	- Success rate - Doctorate certificates per teacher	- Success rate	- Success rate - Doctorate certificates per teacher	- Success rate - Doctorate certificates per teacher

Naturally, one has to be careful when assessing these results since we are measuring efficiency by using a limited number of inputs and outputs. Additional useful output measures would be the research output of each faculty, or the grades of students when enrolling in tertiary education. Unfortunately these data were not available from unified sources or from the universities themselves for that matter.

5. CONCLUSION

In this paper we employed a non-parametric methodology, Data Envelopment Analysis, to assess the relative efficiency of Portuguese public universities (rather than departments) with data reported to 2003. Our input measures were based on information for the full-time equivalent teacher-to-student ratios and on the

university's spending per student. We used as output measures the success rate of undergraduate students and the number of doctoral dissertations per 100 teachers. The results from our empirical analysis in evaluating efficiency in Portuguese public tertiary education allowed us to compute efficiency scores for each faculty/institute, including estimates of efficiency losses. It also allowed us to construct rankings of the faculties/institutes, thereby including the identification of some less efficient cases.

The efficient DMUs are located across universities and across degrees. For the sub-sample of faculties/institutes overall input efficiency is around 0.67, implying that on average the faculties/institutes might be able to achieve the same level of performance using 33 per cent fewer resources that they were using. Regarding output efficiency, the average overall efficiency scores range from 0.77 to 0.83, which would mean that with the same inputs, the average faculty/institute seems to be obtaining a performance that is between 23 and 17 percent less than it should if it were located on the production possibility frontier. When using only the aggregate universities' sub-sample the efficiency scores are somewhat higher and place inefficiencies between 12 and 15 percent.

Our results must be seen as a first step towards assessing the efficiency of public tertiary education expenditure in Portugal, and the conclusions drawn upon the reported evidence must be read with care. Overall, indeed as a matter of common sense, one should be aware that simply putting more money into a promising activity, i.e. tertiary education, does not necessarily improve output proportionally. This hypothesis is not denied by our results. In fact, we were able to separate universities that might qualify, as "performing well" from those were some improvement might be possible in terms of efficiency. As a relevant policy implication this could imply better allocation, of the scarce public financial resources available to public tertiary education by the universities.

On the other hand, there is no similar measure of success for graduate students (including particularly Masters' students) like the one we used for undergraduate students, and this is an area where available information seems to be lacking. Naturally, some universities have a relatively higher number of graduate students than others, which may be due to different orientation and/or positioning in the tertiary education market. One would like to control for that factor as well.

Additionally, we can mention a number of possible avenues for further research. Again and as previously pointed out, a richer dataset, comprising the research output of the faculty staff - for example, refereed articles in international journals would be an improvement for this analysis. Data on university departments would also be welcomed since efficiency results are inevitably, and to some degree, "veiled" when aggregating data per university or per faculty. Moreover, expanding the analysis also to the polytechnic segment of the public tertiary education system could be envisaged as further possible work. It would also be useful to assess if the universities

reported here as being far away from the production possibility frontier consistently remain in that position over time. Here, a time frame analysis would be necessary, but the relevant data are mostly not available.

Finally, and as future work, inefficiencies could be explained using non-discretionary inputs, which are not included in the DEA calculations, through the estimation of Tobit models. This would not be a straightforward task given the difficulties in selecting such variables, which are theoretically outside the university's power.[11] For instance, useful candidate variables the share of academic staff with doctoral degrees, student quality, the location of the university, regulatory constraints, or economic conditions, but this is outside the scope of the current study.

[11] See, for instance, Afonso and St. Aubyn (2006) for a related discussion on non-discretionary inputs.

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APPENDIX

TABLE A1

List of universities, faculties and institutes

CODE	FACULTY / INSTITUTE /UNIVERSITY
UA	*UNIVERSIDADE DOS AÇORES*
UAL-FCHS	UNIVERSIDADE DO ALGARVE-FACULDADE DE CIÊNCIAS HUMANAS E SOCIAIS
UAL-FCMA	UNIVERSIDADE DO ALGARVE-FACULDADE DE CIÊNCIAS DO MAR E DO AMBIENTE
UAL-FCT	UNIVERSIDADE DO ALGARVE-FACULDADE DE CIÊNCIAS E TECNOLOGIA
UAL-FE	UNIVERSIDADE DO ALGARVE-FACULDADE DE ECONOMIA
UAL-FERN	UNIVERSIDADE DO ALGARVE-FACULDADE DE ENGENHARIA A RECURSOS NATURAIS
UAV	*UNIVERSIDADE DE AVEIRO*
UBI	*UNIVERSIDADE DA BEIRA INTERIOR*
UC-FCT	UNIVERSIDADE DE COIMBRA - FACULDADE DE CIÊNCIAS E TECNOLOGIA
UC-FD	UNIVERSIDADE DE COIMBRA - FACULDADE DE DIREITO
UC-FE	UNIVERSIDADE DE COIMBRA - FACULDADE DE ECONOMIA
UC-FF	UNIVERSIDADE DE COIMBRA - FACULDADE DE FARMÁCIA
UC-FL	UNIVERSIDADE DE COIMBRA - FACULDADE DE LETRAS
UC-FPCE	UNIVERSIDADE DE COIMBRA - FACULDADE DE PSICOLOGIA E DE CIÊNCIAS DA EDUCAÇÃO
UC-FCDEF	UNIVERSIDADE DE COIMBRA - FACULDADE DE CIÊNCIAS DO DESPORTO E DA EDUCAÇÃO FÍSICA
UE	*UNIVERSIDADE DE ÉVORA*
UL-FL	UNIVERSIDADE DE LISBOA - FACULDADE DE LETRAS
UL-FD	UNIVERSIDADE DE LISBOA - FACULDADE DE DIREITO
UL-FC	UNIVERSIDADE DE LISBOA - FACULDADE DE CIÊNCIAS
UL-FF	UNIVERSIDADE DE LISBOA - FACULDADE DE FARMÁCIA
UL-FPCE	UNIVERSIDADE DE LISBOA - FACULDADE DE PSICOLOGIA E CIÊNCIAS DA EDUCAÇÃO
UL-FMD	UNIVERSIDADE DE LISBOA - FACULDADE DE MEDICINA DENTÁRIA
UL-FBA	UNIVERSIDADE DE LISBOA - FACULDADE DE BELAS ARTES
UM	*UNIVERSIDADE DA MADEIRA*
UMI	*UNIVERSIDADE DO MINHO*
UNL-FCT	UNIVERSIDADE NOVA DE LISBOA - FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNL-FCSH	UNIVERSIDADE NOVA DE LISBOA - FACULDADE DE CIÊNCIAS SOCIAIS E HUMANAS
UNL-FD	UNIVERSIDADE NOVA DE LISBOA - FACULDADE DE DIREITO
UNL-FE	UNIVERSIDADE NOVA DE LISBOA - FACULDADE DE ECONOMIA
UNL-FCM	UNIVERSIDADE NOVA DE LISBOA - FACULDADE DE CIENCIAS MÉDICAS
UNL-ISEGI	UNIVERSIDADE NOVA LISBOA - INST. SUPERIOR ESTATÍSTICA E GESTÃO DA INFORMACÃO
UP-FL	UNIVERSIDADE DO PORTO - FACULDADE DE LETRAS
UP-FD	UNIVERSIDADE DO PORTO - FACULDADE DE DIREITO
UP-FC	UNIVERSIDADE DO PORTO - FACULDADE DE CIÊNCIAS
UP-FE	UNIVERSIDADE DO PORTO - FACULDADE DE ENGENHARIA
UP-FF	UNIVERSIDADE DO PORTO - FACULDADE DE FARMÁCIA
UP-FEC	UNIVERSIDADE DO PORTO - FACULDADE DE ECONOMIA
UP-FPCE	UNIVERSIDADE DO PORTO - FACULDADE DE PSICOLOGIA E CIÊNCIAS DA EDUCAÇÃO
UP-FA	UNIVERSIDADE DO PORTO - FACULDADE DE ARQUITECTURA
UP-ICBAS	UNIVERSIDADE DO PORTO - INSTITUTO DE CIÊNCIAS BIOMÉDICAS DE ABEL SALAZAR
UP-FMD	UNIVERSIDADE DO PORTO - FACULDADE DE MEDICINA DENTÁRIA
UP-FBA	UNIVERSIDADE DO PORTO - FACULDADE DE BELAS ARTES
UP-FCNA	UNIV. DO PORTO - FACULDADE DE CIÊNCIAS DA NUTRIÇÃO E ALIMENTAÇÃO
UTL-IST	UNIV. TÉCNICA DE LISBOA - INSTITUTO SUPERIOR TÉCNICO
UTL-ISEG	UNIV. TÉCNICA DE LISBOA - INSTITUTO SUPERIOR DE ECONOMIA E GESTÃO
UTL-ISA	UNIV. TÉCNICA DE LISBOA - INSTITUTO SUPERIOR DE AGRONOMIA
UTL-FMD	UNIV. TÉCNICA DE LISBOA - FACULDADE DE MEDICINA VETERINÁRIA
UTL-ISCSP	UNIV. TÉCNICA LISBOA - INST.SUPERIOR CIÊNCIAS SOCIAIS POLÍTICA
UTL-FA	UNIV. TÉCNICA DE LISBOA - FACULDADE DE ARQUITECTURA
UTL-FMH	UNIV. TÉCNICA DE LISBOA - FACULDADE DE MOTRICIDADE HUMANA
UTAD	*UNIVERSIDADE DE TRÁS-OS-MONTES E ALTO DOURO*
ISCTE	*INSTITUTO SUPERIOR DE CIÊNCIAS DO TRABALHO E DA EMPRESA*

Note: In italics, universities where no disaggregate data by faculty/institute were available.

TABLE A2

Data set

University/ Faculty/ Institute	Success rate (%), 2003 1/	Doctorate certificates in 2002-03, per 100 teachers 2/	Teachers per 100 students, 2003 3/	FTE teachers per 100 students, 2003 4/	Average spending per student, 2000-03, euros 5/
UA	50.35	6.2	8.8	8.5	8002.01
UAL-FCHS	59.70	na	7.1	7.1	na
UAL-FCMA	60.42	na	7.8	7.3	na
UAL-FCT	59.76	na	9.0	8.8	na
UAL-FE	51.01	na	7.5	6.6	na
UAL-FERN	39.72	na	8.5	7.6	na
UAV	71.37	11.0	8.6	8.2	7055.98
UBI	45.31	8.1	8.8	7.8	5053.00
UC-FCT	57.44	15.6	9.0	8.1	6030.17
UC-FD	73.09	3.2	3.9	3.6	na
UC-FE	37.78	3.1	5.2	5.0	na
UC-FF	89.73	16.4	6.5	6.8	na
UC-FL	61.12	9.4	6.8	6.6	na
UC-FPCE	58.73	15.5	6.0	5.6	na
UC-FCDEF	62.60	10.0	7.5	6.1	na
UE	53.20	9.2	7.8	7.4	5324.44
UL-FL	46.77	9.7	6.5	6.3	3664.48
UL-FD	86.48	4.0	5.7	5.4	2021.06
UL-FC	52.82	23.2	9.8	9.6	7863.32
UL-FF	75.69	8.4	9.9	8.3	5612.38
UL-FPCE	63.96	9.3	8.8	8.3	4912.89
UL-FMD	58.67	1.9	19.2	12.5	9189.16
UL-FBA	57.67	0.0	7.4	7.2	3529.18
UM	57.72	3.1	8.1	7.3	5358.09
UMI	72.95	12.2	7.8	7.2	5119.39
UNL-FCT	37.10	14.6	8.0	7.6	5718.46
UNL-FCSH	56.90	15.0	8.7	8.2	4221.16
UNL-FD	71.43	21.1	3.5	3.5	2952.62
UNL-FE	65.98	2.3	7.7	5.8	4692.58
UNL-FCM	87.90	2.5	27.8	13.5	8540.99
UNL-ISEGI	41.89	5.2	8.9	5.6	5780.15
UP-FL	65.17	10.6	6.2	6.0	3523.51
UP-FD	78.30	8.0	3.8	3.7	2247.73
UP-FC	60.53	13.3	8.1	7.9	5918.26
UP-FE	78.47	14.1	8.5	7.8	6062.43
UP-FF	87.31	8.3	8.3	8.1	6165.95
UP-FEC	85.84	3.5	6.3	6.0	3004.30
UP-FPCE	71.15	17.8	7.9	7.6	4682.70
UP-FA	39.89	4.1	6.4	6.4	3535.70
UP-ICBAS	71.34	22.7	21.3	12.7	8610.59
UP-FMD	95.92	4.2	13.0	12.7	8531.54
UP-FBA	72.67	0.0	9.1	9.0	4606.82
UP-FCNA	60.00	3.8	8.1	5.5	3761.98
UTL-IST	71.19	20.7	9.8	9.0	8413.37
UTL-ISEG	77.63	7.5	7.9	6.9	4746.46
UTL-ISA	78.83	27.7	10.8	10.2	12015.06
UTL-FMD	83.93	18.3	10.0	9.8	10217.92
UTL-ISCSP	50.44	2.2	6.5	4.9	2098.18
UTL-FA	84.53	1.7	9.8	9.1	4639.35
UTL-FMH	71.31	7.7	8.8	7.8	3851.32
UTAD	65.75	8.7	8.4	8.1	5977.51
ISCTE	65.14	9.6	7.4	6.6	4135.02
Average	65.01	9.9	8.7	7.6	5546.03
Maximum	95.92	27.7	27.8	13.5	12015.06
Minimum	37.10	0.0	3.5	3.5	2021.06

na – not available

1/ OCES (2004a). [http://www.oces.mcies.pt/]

2/ Series constructed with data from OCES: http://www.oces.mcies.pt/.

3/ 4/ Includes overall number of teachers in the following categories: full Prof. (*catedrático*), associate Prof. (*associado*), assistant Prof. (*auxiliar*), teaching assistant (*assistente*), trainee teaching assistant (*assistente estagiário*), and others (*leitor, monitor*). OCES (2004b).

5/ *Conta Geral do Estado – 2000, 2001, 2002, 2003*. Direcção-Geral do Orçamento. [http://www.dgo.pt/cge/]

Resumo:

Usamos Análise de Envolvente de Dados (DEA), para estimar coeficientes de eficiência para as universidades públicas Portuguesas. As medidas de input são construídas a partir do número de professores e da despesa das universidades enquanto que as medidas de output são baseadas na taxa de sucesso na conclusão das licenciaturas e no número de dissertações de doutoramento. Com base numa análise de fronteira é possível separar entre universidades que podem ser classificadas como tendo um "bom desempenho" e universidades onde melhores desempenhos são possíveis. Tais resultados podem implicar uma melhor afectação pelas universidades dos habitualmente escassos recursos públicos disponíveis para o ensino universitário.

Palavras-chave: Educação universitária, eficiência e DEA