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ON THE EFFICIENCY OF PUBLIC HIGHER EDUCATION INSTITUTIONS IN PORTUGAL: AN EXPLORATORY STUDY*

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Abstract

In a context of financial stringency like that characterizing the current economic landscape in Portugal and in several other countries, accountability and efficiency questions gain an additional relevance in the higher education sector. In this paper we apply DEA techniques to evaluate the comparative efficiency of public higher education institutions in Portugal. The analysis is performed for three separate groups: public universities, public polytechnics and the several faculties of University of Porto. By using several inputs and outputs at the institutional-level, we are able to identify the most technically efficient institutions that may work as benchmark in the sector. The results suggest that a great portion of institutions may be working inefficiently, contributing to a significant waste of resources. This exploratory study is a first step towards a deeper understanding of the efficiency determinants of higher education institutions.

Keywords: DEA; Higher Education; Technical Efficiency; Universities; Polytechnics
JEL Codes: C14; H52; I23

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1 Introduction

Expenditure on education, and higher education in particular, accounts for a significant share of public spending. Furthermore, there is evidence of an increasing relative importance of public expenditure in this item over the last two decades, with greater emphasis in countries where the levels of government intervention were rather low, such Portugal (e.g., Afonso and St. Aubyn, 2005).[1] Moreover, under the current financial stringency and the consequent growing pressure for diversification of funding sources by higher education institutions, accountability and cost-effectiveness became a critical topic in higher education during the most recent years. A significant number of empirical studies have hitherto considered the possibility that inefficiency exists in education, particularly in higher education sector (Worthington, 2001). This raises a concern among policymakers and institutional administrators, as good performance in higher education is believed to produce positive growth effects (Blanchard, 2004). Such literature has been using a variety of empirical techniques that allow the identification of “efficient” institutions and their comparison with the “inefficient” counterparts. The measurement of institutional efficiency is thus recognized as a first step for the implementation, monitoring and/or evaluation of public-sector reforms.

The development of nonparametric methods such as Data Envelopment Analysis (DEA) (Charnes et al., 1978) has resulted in burgeoning literature on efficiency assessments of decision-making units (DMUs) across different industries. Part of the usefulness of DEA relies on the fact that, besides producing a ranking of sampled institutions based on efficiency measured by a technical efficiency score, it also identifies the over-use of specific resources that cause any given institution to fall where it does in the analysis, providing as well a custom list of peers for any given institution. These peer institutions are the ones to whom an administrator should look when trying to determine to what extent operational procedures might be copied – or at least learned from – in order to address the over-use of resources.

However, despite studies of the efficiency of colleges and universities in general are by no means new, with some of the earliest evidence dating back to the early 1970s (Eckles, 2010), the

[1] In 2007, OECD countries, on average, spent around 4.6% of their GDP on educational institutions at primary, secondary and tertiary levels. In particular, the expenditure in tertiary education has been corresponding to about 1.2% of GDP. In the same year, Portuguese spending in tertiary/higher education was around 1% of Portuguese GDP (OECD, 2011). In 2008, 10.9% of total Portuguese government spending was assigned to education items and in 2009 this share was already 11.6% (World Bank - World Development Indicators).

issue of university/school efficiency was the subject of a limited number of studies. Actually, in spite of the usefulness of DEA methodology in the context of higher education, less than 4% of the DEA articles published in scientific journals over the period 1950-2007 focused on higher education issues (Wolszczak-Derlacz and Parteka, 2011).

In this paper we construct a MatLab code to apply DEA techniques to evaluate the comparative efficiency of public Higher Education Institutions in Portugal, where repeated calls for more efficiency in this sector has been made over the most recent years (e.g., Amaral and Magalhães, 2002; Afonso et al., 2005; Sarrico et al., 2009). We use several input and output measures in order to solve an optimization problem that provides us the efficiency score for each Higher Education Institution (HEI), as well as information on peers, i.e., the institution(s) against which each technically inefficient institution may benchmark. As input measures, we use data on financial resources, expenditures and academic staff (all of them divided by the total number of enrolled students). As output indicators, we work with the total number of graduate students, the number of courses offered (both measuring outcomes of the teaching activity of HEIs) and the number of PhD degrees awarded (a proxy for the research activity of the institution). All the data were obtained at the institutional-level, for the year 2008, being collected from the Ministry of Finance (*Conta Geral do Estad*o) and from the Ministry of Education and Science. The analysis is performed for three independent groups of HEIs: public universities[2], public polytechnics and the several faculties of University of Porto.

Evaluations of the efficiency of the higher education sector in Portugal are limited. From the best of our knowledge only Afonso and Santos (2008) have used DEA to study the technical efficiency of public Portuguese universities for the year 2003[3]. We extend their study by adding new inputs and outputs to the analysis, by including polytechnics and by offering new evidence on the technical efficiency of public HEIs for a more recent year. This is still an exploratory study and hence our results must be understood as a first step towards a deeper assessment of the efficiency of public HEIs in Portugal. Despite still preliminary, our results may call for

[2]We have excluded Universidade Aberta from our analysis of public universities, given its different status and its unique nature of teaching provision.

[3]Afonso and St. Aubyn (2005) and Bonaccorsi et al. (2007) have also provided valuable contributions, though their studies present evidence at a more aggregated level, where efficiency in education for Portugal is studied and presented in an international context. Sarrico et al. (2009) have also analyzed the productivity of Portuguese universities in terms of graduates, doctoral degrees awarded and publications, but using other empirical methodologies.

further attention by public authorities and motivate additional research. Actually, some research avenues are also derived from this exploratory study.

The remainder of this paper is structured as follows. Section 2 presents some recent literature using DEA to evaluate the efficiency in higher education sector. Section 3 briefly discusses the DEA methodology. Section 4 describes the data and provides some preliminary statistics. Section 5 presents and discusses the results from the implementation of DEA to the three groups of HEIs. Finally, Section 6 concludes and derives potential lines of future research.

2 Higher Education Performance Evaluation using DEA: An Overview

The growing public concern with performance and efficiency in the higher education sector is partly justified, on the one hand, by the massive expansion of higher education systems worldwide – which means that HEIs must search for means of catering for a growing and increasingly diverse population of students in a more efficient way – and, on the other hand, by the gradual process of greater independence from the Government budget – which has been hastened by the current economic challenges and the associated financial constraints, leading to additional pressures for a greater autonomy of HEIs.

In the Portuguese case, we observe that public universities and polytechnics are becoming more independent, relying less on government funding and more on other sources of revenues (OECD, 2003; Teixeira et al., 2006). This has been intensifying the competitive environment in the market of higher education, where HEIs, despite their not-for-profit nature, respond increasingly more to market-like regulatory mechanisms (Teixeira et al., 2004).

Public funding "rules" are strongly dependent on the number of enrolled students, so HEIs have been competing for an increasing number of students over the time. For that aim, they have been trying to become more diversified, in order to satisfy not only a larger student population, but also a more heterogeneous one (e.g., Rossi, 2009; Teixeira et al., 2012). Additionally, research funding relies more and more on institutions' performance and merit, which intensifies the race, mainly among public universities (Jongbloed and Vossensteyn, 2001). Actually, we can assert that we are living the "rankings" and the "reputation age", which justifies the need for more efficient and responsive institutions in the market of higher education.

All these reasons have been supporting the need for evaluating the efficiency in higher education sector, particularly that of individual HEIs. Simultaneously, from the methodological point of view, DEA has become a popular tool for measuring the efficiency of non-profit institutions such as hospitals, schools and universities in particular (see, for instance, Sarrico and Dyson, 2000; Worthington, 2001; Johnes, 2006; Thanassoulis et al., 2011), as it constitutes a non-parametric linear programming multiple input and output technique that presents several advantages over other methodologies[4].

The concept of "technical efficiency" at the institutional level has thus gained an increasing relevance, especially among economists (Worthington, 2001), when referring to the most technologically efficient manner of using productive resources. In other words, technical efficiency was understood to imply the maximum possible output from a given set of inputs. In the (higher) education context, technical efficiency became hence associated to the physical relationship between the resources used (say, capital, labor and equipment) and some education outcome(s).

Accordingly, efficiency analyses started to be used in higher education sector as a way to evaluate how efficiently the resources are being used, as they provide us some efficiency score that represent a measure of the (maybe composite) output produced, given a bundle of inputs. In particular, using an input-oriented approach (see Section 3), we can evaluate the extent to which HEIs generate sufficient outcome, given their main resources. This explains why both a cross-country and a cross-institution comparison can be of particular interest, not only for academics, but also for a policy purpose, as it allows to identify some potential benchmarks, either at the international landscape (for the cross-country analyses), or within a country and a particular higher education system (for the cross-institution cases). As a result, evaluations of technical efficiency in higher education sectors constitute a small but important step, demonstrating how such a technique can help individual institutions to identify the need of improving their relative performance and allow stakeholders interested in accountability to evaluate the relative efficiency of HEIs.

Table 1 provides a summary of some of the most recent empirical studies using the DEA methodology to assess higher education efficiency in several countries.[5] From the main literature on this topic, we confirm that efficiency analyses on higher education typically use as

[4]See Section 3 for more details on the methodological issues of DEA.

[5]For prior literature on the efficiency measurement in the higher education sector through DEA or other methods see the survey of Worthington (2001).

inputs the number of students, the academic staff, the financial resources of the institutions, as well as their main expenditures. Some studies still focus on some particular types of efficiency, namely research efficiency and/or teaching efficiency (e.g., Joumady and Ris, 2005; Kantabutra and Tang, 2010). As outputs, it is usual to use the total number of graduates (successful leavers), the employability rate, some research outcomes (as the number of publications, citations or registered patents) or even some kind of ranking that measures the relative position or the reputation of the institutions.

Overall, the literature has been confirming that technical inefficiency is a common phenomenon in higher education around the world. Actually, several cases of waste of resources have been documented over the most recent years, especially among public-owned institutions, claiming for further attention by regulators and public authorities. We add to this literature by providing new evidence on the Portuguese case.

Table 1: Selective empirical studies using DEA to evaluate the efficiency of Higher Education Institutions

Reference	Country	Sample of HEIs	Data/Years	Inputs	Outputs	Main Conclusions
Athanassopoulos and Shale (1997)	UK	45 universities	1992-93	Number of undergraduates, postgraduates and academic staff; mean A-level entry score over the last three years; research income; expenditure on library and computing services	Number of successful leavers; number of higher degrees awarded; weighted research rating	Universities are clustered into 3 main groups: low cost and high outcome efficiency; high cost and low outcome efficiency; high cost and high outcome efficiency.
Joumady and Ris (2005)	8 European countries	209 HEIs	1998	Different according to the models. E.g.: teaching characteristics; equipment; course contents; intensity of graduate job search; quality of the relation between universities and the labor market	Different according to the models. E.g.: levels of generic and vocational competencies acquired; vertical/horizontal competencies match	UK, the Netherlands and Austria had good performance in all the specifications under test; France and Germany were located on an average level of inefficiency; Spain, Finland and Italy were at the bottom of the group.
Johnes (2008)	England	112 HEIs	1996/97-2004/05	Number of full-time undergraduate and postgraduate students; academic staff; administrative expenditures; expenditures on centralized academic services	Degrees awarded (graduate and postgraduate) and research income received	Rapid changes in the higher education sector appear to have had a positive effect on the technology of production but this has been achieved at the cost of lower technical efficiency.
Johnes and Yu (2008)	China	109 regular universities	2003-04	Staff time, quality of staff, postgraduate input, research expenditure and capital inputs (books and area of buildings)	An index of the prestige of the HEI (reputation measure), index of total number of publications, research publications per academic staff (productivity)	Geographical location is important (HEIs in the coastal zone are more efficient), but funding sources do not. Comprehensive universities consistently have higher average efficiency than specialist institutions.
St. Aubyn, Pina, Garcia and Pais (2009)	EU, Japan and USA	Public or government-dependent HEIs	1998-2005	Academic staff and number of students	Number of graduates; THES - QS recruiter survey ranking; THES - QS peer survey ranking; published articles; citations	Ireland, Japan, Sweden, UK and the Netherlands were very close to the efficient frontier; Bulgaria, Spain, Hungary, Czech Republic, Slovakia, Estonia, Portugal and Greece were found to be highly inefficient.
Agasisti and Pérez-Esparrells (2010)	Italy and Spain	57 Italian and 46 Spanish public institutions	2004-05	Number of students, number of PhD students, number of professors, financial resources	Number of graduates; amount of external resources attracted to research activities	In Italy, the improvement of performance over time was due to major "technological changes", while in Spain it was due to "pure" efficiency (arising from new funding models)
Eckles (2010)	USA (27 states)	93 private liberal arts colleges	2006-07	Cost per undergraduate, full-time faculty (%), students in the top 10% of their high school class (%) and 25th percentile of entering students' SAT scores	Six-year graduation rate	18 colleges are found to be technically efficient. Among these, it is possible to identify peers for each of the technically inefficient institutions.
Kantabutra and Tang (2010)	Thailand	22 public universities (18 government-dependent universities and 4 autonomous universities) - 267 faculties	2003-06	For TEM (Teaching Efficiency Model): annual operating budget; number of academic staff; number of non-academic staff For REM (Research Efficiency Model): amount of internal and external research fund	For TEM: Number of graduates at the undergraduate/master degree levels; employment rate For REM: Number of publications in internationally/nationally refereed journals; Number of PhD degrees	Public universities in Thailand were more efficient in teaching than in research.
Wolszczak-Derlacz and Partera (2011)	Austria, Finland, Germany, Italy, Poland, UK and Switzerland	259 public universities	2001-05	Total academic staff, total number of students and total revenues	Number of graduations and number of scientific publications	Only 5% of HEIs are 100% efficient. Universities from Switzerland obtained the best efficiency scores.

Source: Own elaboration. Studies are presented in chronological order.

3 Data Envelopment Analysis: methodological issues[6]

Efficiency, in particular, technical efficiency, is the comparison between inputs used in a certain activity and the produced outputs and their optimal values (Worthington, 2001). Decision Making Units – the target of evaluation under DEA techniques – by performing the same type of functions and having identical goals and objectives, can be understood as, for instance, firms, government bodies, non-profit institutions or even countries. When a DMU attains the optimal level of output with a given amount of inputs, taking technology as given, we say that this DMU is technically efficient, that is, it is operating at the production possibility frontier. In opposition, when it produces less than the output that could be attained with the current bundle of inputs, the DMU is said to be inefficient.

Several methods may be used to perform an efficiency analysis of a set of DMUs. These may be mainly divided into parametric (e.g., Stochastic Frontier Analysis) and non-parametric methods. Both of these estimate a production frontier, but while in the former case the frontier is parametric, in the latter it is a non-parametric piece-wise linear frontier that envelops the data. In particular, DEA is a non-parametric approach that involves the use of linear programming methods to construct a non-parametric frontier and to evaluate the relative Input-Output efficiency of a DMU. Efficiency measures are thus calculated relatively to this frontier.

There are several advantages of DEA over other techniques, which justify their preference by several authors in the literature. DEA can be a powerful tool when used wisely. Being often recognized as a multi-dimensional method, DEA can cover multiple input and output measures and, moreover, it does not require any specific assumption on the functional relationships between those inputs or outputs (i.e., on the functional form of the production technology). As a result, DEA estimates of technical efficiencies are free of possible errors resulting from incorrect assumptions. Other attractive feature of DEA is that it allows the weights assigned to each input and output to vary by observation. This means that no unit can be penalized by taking an unorthodox production approach, as it might be by the imposition of a uniform set of weights across all units (Johnes, 2008). Finally, DMUs are directly compared against the "best practice" or the peer combination of DMUs, which may be of great value for practitioners and public authorities.[7]

[6]DEA's origins date back to Farrell (1957). For a thorough presentation of the method see Coelli et al. (1998) or Cooper et al. (2004, 2007).

[7]For further arguments for the dominance of DEA over other methodologies in education efficiency measure-

However, the same characteristics that make DEA a powerful tool can also create some drawbacks. The results can be influenced by random errors, measurement errors or extreme events, claiming for additional care and awareness by the researcher when interpreting the results. Obviously, the results are also dependent on the selection of input and output measures and although it is a good method at estimating "relative" efficiency of a DMU, it converges slowly to the "absolute" efficiency. In other words, DEA can tell us how well we are doing compared to our peers but not compared to a "theoretical maximum". In addition, this method does not provide information about the statistical significance of the results, so statistical tests are difficult to perform. Accordingly, we argue that DEA should be (and in this case it will be) used as a complementary methodology to a more thorough evaluation of DMUs' efficiency.

In practice, analyzing the efficiency of DMUs is then a set of linear programming problems. We can assume Constant Returns to Scale (CRS), which means that the DMUs are able to linearly scale the inputs and outputs without increasing or decreasing efficiency, implying that there is no significant relationship between DMUs' scale and efficiency. In other words, big universities are not more efficient than smaller ones in transforming their inputs to outputs. Under VRS, an increase in inputs is expected to result in a disproportionate increase in the outputs, for instance, due to decreasing marginal returns.[8]

The measurement of the efficiency score can be obtained using two different perspectives: input-orientation and output-orientation. Under input-orientation, outputs are considered to be fixed and inputs must be adjusted to maximize the efficiency. Accordingly, the purpose of an input-oriented study is to evaluate by how much input quantity can be proportionally reduced without changing the output quantities. Alternatively, by using the output-oriented approach, one could also try to assess how much output quantities can be proportionately increased without changing the input quantities used. Both methods provide the same results under CRS, but give different values under VRS. Nevertheless, both output and input-oriented models will identify the same set of efficient/inefficient DMUs. In this study, we will perform DEA using an input-orientation perspective, aiming at identifying potential cases of waste of resources among the several public HEIs in Portugal.

ments studies see, for instance, Worthington (2001).

[8]Our MatLab code was designed in order to allow both types of analysis – CRS and VRS (see the Appendix). However, we will focus on the VRS efficiency scores, which are based on a more reasonable assumption.

Formally, under an input-orientation perspective we have to deal with the following problem:

Input-Orientation[9] – Constant Returns to Scale

$$
\begin{aligned}
&\min_{\theta,\lambda} \theta \\
&\text{s.t.} \\
&Y\lambda \geq Y_i \\
&X\lambda \leq \theta X_i \\
&\lambda \geq 0
\end{aligned}
\tag{1}
$$

Input-Orientation – Variable Returns to Scale

$$
\begin{aligned}
&\min_{\theta,\lambda} \theta \\
&\text{s.t.} \\
&Y\lambda \geq Y_i \\
&X\lambda \leq \theta X_i \\
&N1'\lambda = 1 \\
&\lambda \geq 0
\end{aligned}
\tag{2}
$$

where λ is the vector of relative weights $(N \times 1)$ given to each DMU and N is the number of DMUs. Assuming that the DMUs have I inputs and O outputs: X represents the matrix of inputs $(I \times N)$ and Y is the matrix of outputs $(O \times N)$. The column vectors for the inputs and outputs for each DMU are represented as X_i and Y_i, respectively.

An additional restriction should be inserted in the optimization problem if we want to evaluate the DMUs under VRS, $N1'\lambda = 1$, where $N1'$ is a vector of ones. This restriction imposes convexity of the frontier, accounting for VRS. Dropping this restriction would amount to admit that returns to scale are constant. Finally, the efficiency score (θ) is a scalar that measures the technical efficiency and assumes values between 0 and 1. The efficiency score measures the distance between the DMU under analysis and the efficiency frontier, defined as a linear combination of the "best practice" observations. With $\theta < 1$, the DMU is inside the frontier (i.e. it is relatively inefficient), while under $\theta = 1$ the DMU will be on the efficiency frontier, being considered technically efficient.

[9] Note that despite we are searching for the optimal level of efficiency of DMUs, this is a minimization problem because we are performing an input-orientation analysis, where we try to minimize the bundle of inputs for a given level of outputs.

4 Data and Preliminary Statistics

Prior to the implementation of DEA, we need to define some inputs and outputs. Following the main literature, we have considered as inputs the total funding[10] of the institution, the total expenditures[11] and the total number of academic staff. All these three inputs were weighted by the total number of enrolled students of each institution, in order to control for the HEIs' relative size. These inputs work as the main resources required for the normal performance of Higher Education Institutions. As outputs, we have considered the total number of graduate students, the total PhD degrees awarded and the total number of courses offered. The total number of PhD degrees can be understood as a proxy for the research capacity of the institutions (Kantabutra and Tang, 2010). The other two outputs reflect the teaching activity of HEIs. All these data refer to the year 2008. Data on total funding was obtained from the Ministry of Finance[12] and the remaining data was collected from GPEARI – Ministry of Education and Science[13].

The analysis will be performed for three groups of institutions: 14 public universities, 20 public polytechnics and the 14 faculties that compose the University of Porto.[14] A detailed list of the institutions considered in each DEA analysis and the corresponding set of inputs and outputs are presented in Table 2. Table 3 provides some descriptive statistics on the inputs and outputs used in each of the groups of HEIs.

[10]The total funding of the institution includes the income received from tuition fees, provision of goods and services, government funding (core budget funding), third-party funding (e.g. European Union) and capital revenues.

[11]The total expenditures considered for each institution include mainly the expenditures with academic and non-academic staff and several capital expenditures, which are the most important components of HEIs' expenditure.

[12]*Conta Geral do Estado 2008 – Direcção Geral do Orçamento*, available at http://www.dgo.pt/politicaorcamental/Paginas/Conta-Geral-do-Estado.aspx?Ano=2008.

[13]GPEARI stands for *Gabinete de Planeamento, Estratégia, Avaliação e Relações Internacionais*. It is the official office aiming to provide the statistical and policy support to MCTES (*Ministério da Ciência, Tecnologia e Ensino Superior*), now MEC (*Ministério da Educação e Ciência* – Ministry of Education and Science).

[14]Due to some restrictions on data availability, we had to consider fewer outputs in some cases. For universities, the outputs are the 3 variables stated above (the total number of graduate students, the total number of PhD degrees and the number of courses of the institution). For polytechnics, given that these institutions do not offer PhD courses, the output "total number of PhD degrees awarded" was excluded. For the faculties of University of Porto, we have no disaggregated data on courses, so we only has considered as outputs the total graduate students and total PhD degrees.

Table 2: Sample of HEIs and respective input and output measures for the DEA

Group A: Public Universities	**Group B: Public Polytechnics**	**Group C: Faculties of University of Porto**
Universidade dos Açores (UAC)	IP Beja (IPBeja)	F Letras (FLUP)
Universidade do Algarve (UALG)	EN Infante D. Henrique (ENIDH)	F Direito (FDUP)
Universidade de Aveiro (UA)	ESE Coimbra (ESEC)	F Medicina (FMUP)
Universidade da Beira Interior (UBI)	ESE Lisboa (ESELX)	F Ciências (FCUP)
Universidade de Coimbra (UC)	ESE Porto (ESEP)	F Engenharia (FEUP)
Universidade de Évora (UE)	ES Hotelaria e Turismo do Estoril (ESHTE)	F Farmácia (FFUP)
Universidade de Lisboa (UL)	IP Guarda (IPG)	F Economia (FEP)
Universidade da Madeira (UMA)	IP Bragança (IPB)	F Psicologia e C. Educação (FPCEUP)
Universidade do Minho (UMinho)	IP Castelo Branco (IPCB)	F Arquitectura (FAUP)
Universidade Nova de Lisboa (UNL)	IP Coimbra (IPC)	F Desporto (FADEUP)
Universidade do Porto (UP)	IP Leiria (IPLeiria)	Instituto de Ciências Biomédicas Abel Salazar (ICBAS)
Universidade Técnica de Lisboa (UTL)	IP Lisboa (IPL)	F Medicina Dentária (FMDUP)
Universidade de Trás-os-Montes e Alto-Douro (UTAD)	IP Portalegre (IPPortalegre)	F Belas Artes (FBAUP)
Instituto Superior de Ciências do Trabalho e da Empresa (ISCTE)	IP Santarém (IPSantarém)	F Ciências da Nutrição e Alimentação (FCNAUP)
	IP Setúbal (IPS)	
	IP Tomar (IPT)	
	IP Viana do Castelo (IPVC)	
	IP Viseu (IPV)	
	IP Cávado e Ave (IPCA)	
	IP Porto (IPP)	
Inputs: Total Funding per student; Total Expenditure per student; Academic Staff per Student		
Outputs: Total graduate students; total PhD degrees awarded; total number of courses	**Outputs:** Total graduate students; total number of courses	**Outputs:** Total graduate students; total PhD degrees awarded

Source: Own elaboration.

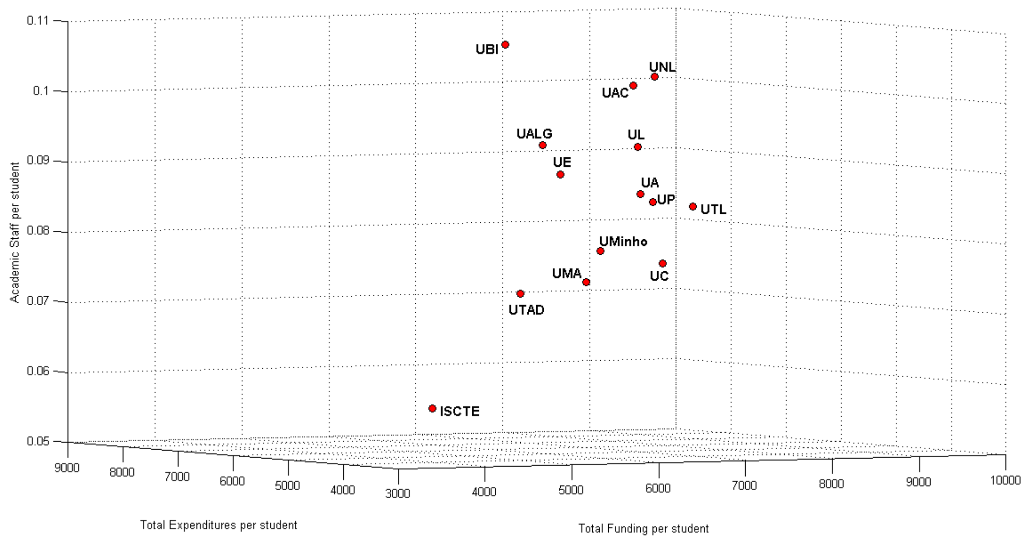
Table 3: Descriptive statistics on inputs and outputs, by groups of HEIs

		Group A: Public Universities		**Group B: Public Polytechnics**		**Group C: Faculties of University of Porto**	
		Mean	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
	Total funding per student	7613	1572	6263	1824	7038	2410
Inputs	Total expenditure per student	6718	1229	5445	1443	5814	1884
	Academic staff per student	0.08	0.01	0.10	0.04	0.09	0.04
	Total Graduate Students	2786	1817	1217	1045	523	467
Outputs	Total PhD degrees awarded	89	76	n.a.	n.a.	17	20
	Total number of courses	160	80	38	23	N.A.	N.A.

Source: Own elaboration; data for the year 2008; n.a. – not applicable; N.A. – not available

In order to provide some preliminary ideas about the differences at the institutional-level, both in terms of inputs and outputs, we briefly present the relative position of HEIs from the different groups. Figure 1 represents the relative position of public universities at the three inputs considered in the DEA. ISCTE was, in 2008, the public university in the sample with lower resources per enrolled student. In opposition, UNL was one of the top institutions, regarding the level of available inputs. UBI appears as the university with highest academic staff per enrolled student, though with weaker position in the remaining inputs.

Figure 1. Relative position of Universities – Inputs

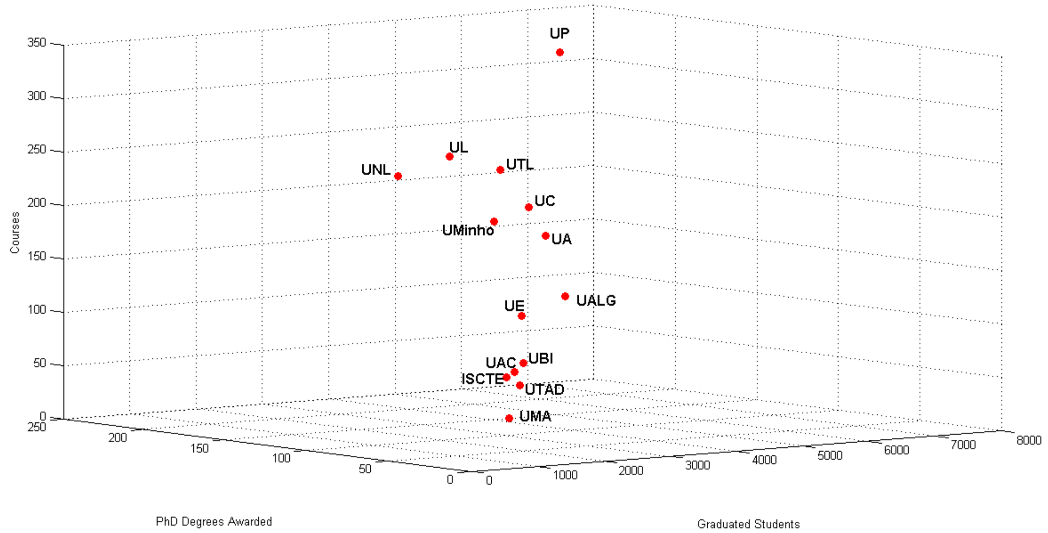


Source: Own elaboration.

Figure 2 mimics the above analysis now for the relative position of universities regarding their outputs. In 2008, UP was at a remarkable position, accounting for more than 18% of total graduate students from public universities, 19% of total PhD graduates and 14% of the total number of courses offered by HEIs in the same group. In the other extreme, we found several institutions as UMadeira, UAçores, UTAD, ISCTE and UBI.

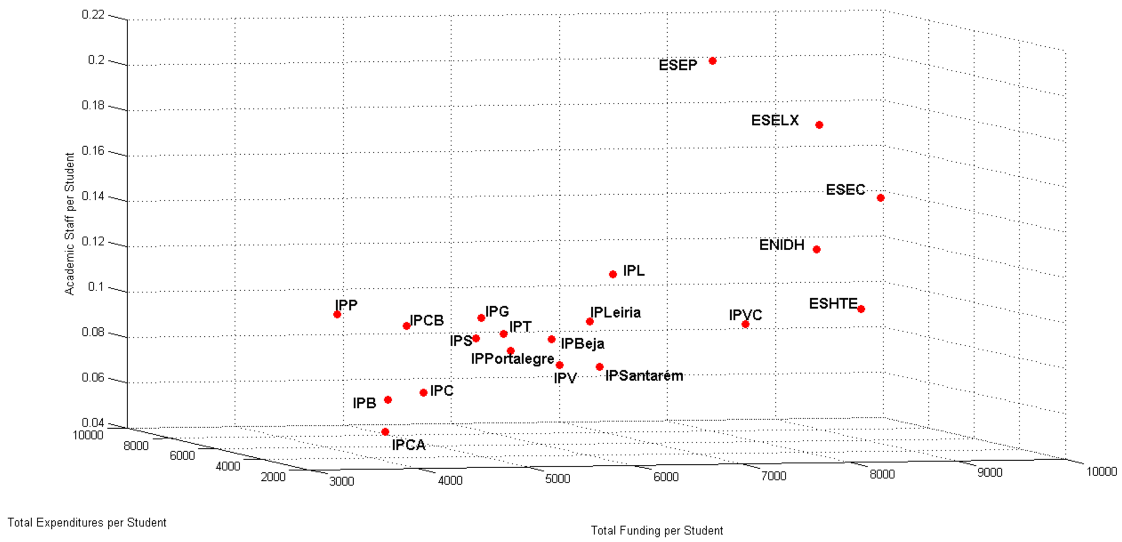
Figure 3 replicates Figure 1, but now for public polytechnics. Regarding inputs, we observe a notable position for the three nursing schools (from Porto, Coimbra and Lisboa). Their highest relative position at funding and expenditures can be explained by the type of courses offered by these institutions, as the programs from health and medical sciences are typically much more expensive than, for instance, courses from social sciences. At the other extreme, we find some institutions like IP Cávado and Ave, IP Bragança and IP Coimbra.

Figure 2. Relative position of Universities – Outputs



Source: Own elaboration.

Figure 3. Relative position of Polytechnics – Inputs

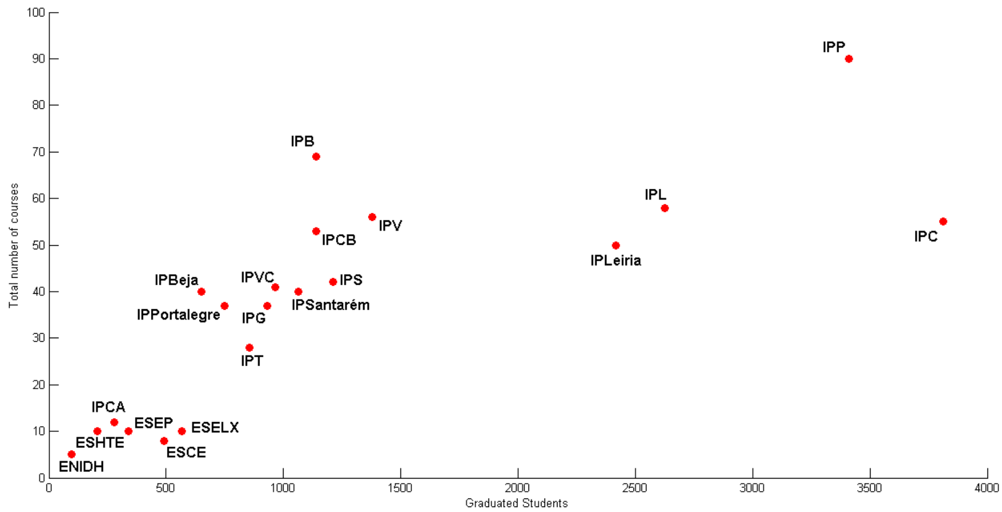


Source: Own elaboration.

Regarding the relative position of polytechnics at the outputs-level (Figure 4), IP Porto is the institution with the strongest position, followed by the polytechnics from Coimbra, Lisboa and Leiria. At the bottom of the list, with very weak relative positions, we find several institutions as *Escola Náutica, Escola Superior de Hotelaria e Turismo do Estoril*, the three nursing schools and the IP from Cávado and Ave.

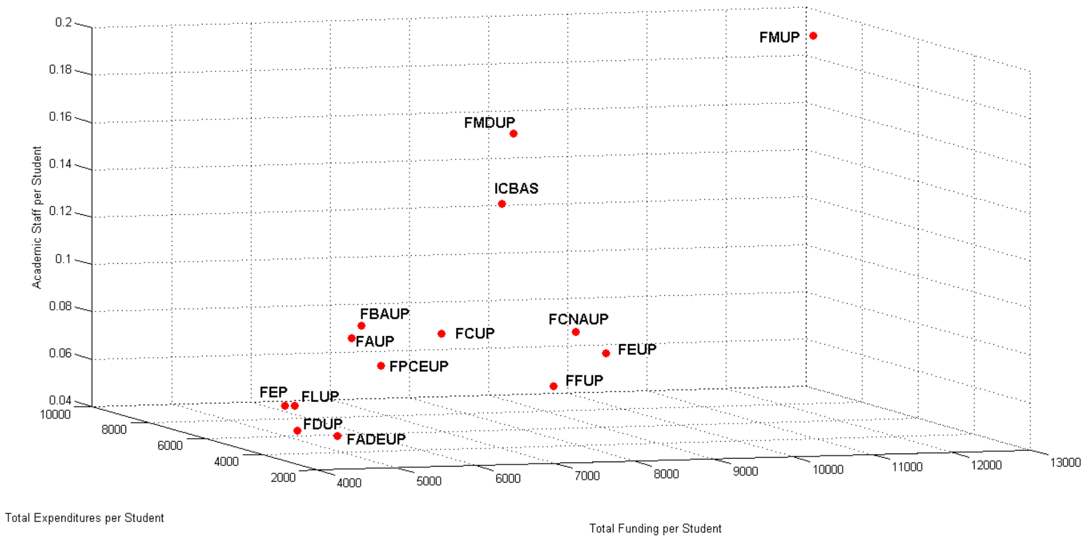
Finally, Figures 5 and 6 report some information about the several faculties of University of Porto. The faculty registering the highest relative position at funding, expenditures and total academic staff (values per enrolled student) is *Faculdade the Medicina*, given the type of courses offered by this faculty, which are much more expensive and difficult to sustain, requiring higher levels of funding and spending. At the input level, we find FEP, FLUP, FDUP and FADEUP in the lowest relative positions. Regarding the two output measures considered for this third set of HEIs (total number of graduates and total PhD degrees), FEUP occupies the best relative position, while FEP occupies a much more modest place. Several faculties present very weak relative positions, namely FAUP, FBAUP, FMDUP, FDUP and FCNAUP.

Figure 4. Relative position of Polytechnics – Outputs



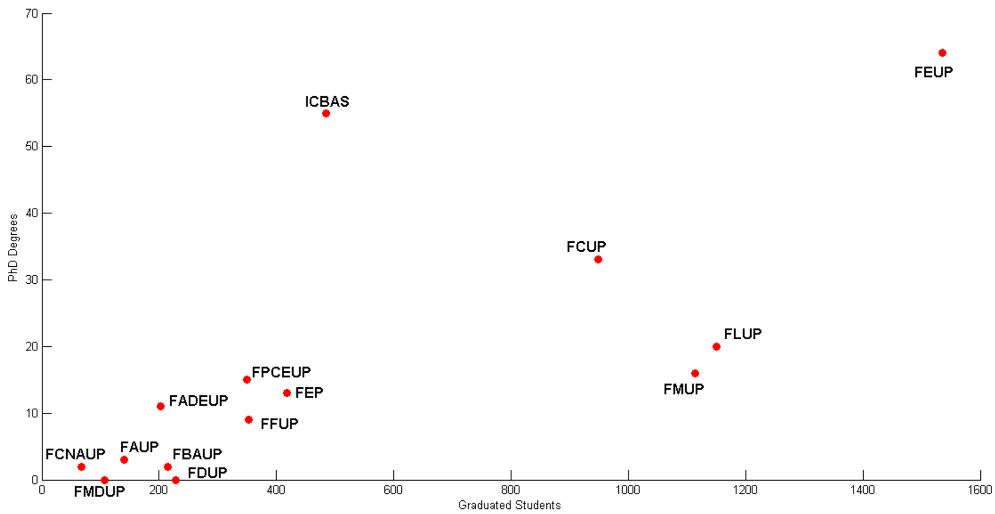
Source: Own elaboration.

Figure 5. Relative position of the Faculties of University of Porto – Inputs



Source: Own elaboration.

Figure 6. Relative position of the Faculties of University of Porto – Outputs



Source: Own elaboration.

5 DEA Results

5.1 Public Universities

DEA results for Public Universities, in Table 4, show that input efficiency scores are larger or equal (in the case of UAC) to 0.590. The theoretical efficient frontier is defined only by two DMUs: UP and ISCTE. The less efficient DMUs are UAC and UBI. In fact, by recalling Figure 1, we have seen that UBI was intensive in some particular inputs (namely regarding academic staff per student), though its output level was not correspondingly high in the same year. In particular, UBI only accounted for 4% of the total graduated students and 2% of total doctoral degrees from public universities in 2008. These relative positions were translated into an efficiency score of 0.692, which means that UBI would be able to achieve the same level of performance by using about less 30% of its resources/inputs. Similarly, the efficiency score of 0.59 for UAC means that, in order to move to the efficiency frontier, by keeping the same level of outputs, it should have reduced its inputs by 41% in 2008.

Regarding the most efficient HEIs (UP and ISCTE), we must recall their relative positions at input and output levels. Despite their weaker performance on the outputs side, ISCTE was, in the year under observation, the institution with the lowest levels of inputs (Figure 1). For UP, instead, we noted an outstanding relative position at outputs (Figure 2), but a moderate position at inputs (Figure 1). However, the results point out that these two institutions were the only ones using the minimum level of inputs needed to produce their outputs.

DEA also allows obtaining information on peers. A peer is an institution against which the technically inefficient institution(s) may benchmark – in this case, UP and ISCTE. Accordingly, the set of peers for each institution that is not on the production frontier is weighted (using the lambda values from the linear program) according to how much influence the peer had on the score of the focus institution. From the results, we verify that UP is identified as the most relevant benchmark regarding technical efficiency for the several universities from Lisbon (UL, UNL, UTL). ISCTE, in turn, was identified as the most important peer for UAC, UBI and UE. In the remaining cases, both UP and ISCTE assumed significant weights as reference HEIs regarding technical efficiency.

Finally, it is possible to observe that, overall, input efficiency was around 0.8321, which implies that, on average, Portuguese public universities might be able to achieve the same level of outputs using less 16.79% of the inputs/resources that they used in 2008. In other words, we confirm the suspect that there seems to be some theoretical “waste” of resources in several HEIs.

Table 4: DEA Results for Group A: Public Universities

DMU	DMU name	Efficiency Score	Rank	Benchmark/Peers (weight)
1	Universidade dos Açores (UAC)	0.590	13	11 (0.038); 14(0.962)
2	Universidade do Algarve (UALG)	0.775	9	11 (0.312); 14(0.688)
3	Universidade de Aveiro (UA)	0.825	6	11 (0.466); 14(0.534)
4	Universidade da Beira Interior (UBI)	0.692	12	11 (0.056); 14(0.944)
5	Universidade de Coimbra (UC)	0.966	2	11 (0.556); 14(0.444)
6	Universidade de Évora (UE)	0.730	11	11 (0.239); 14(0.761)
7	Universidade de Lisboa (UL)	0.881	5	11 (0.726); 14(0.274)
8	Universidade da Madeira (UMA)	0.784	8	14(1.000)
9	Universidade do Minho (UMinho)	0.929	3	11 (0.520); 14(0.480)
10	Universidade Nova de Lisboa (UNL)	0.759	10	11 (0.675); 14(0.325)
11	**Universidade do Porto (UP)**	**1.000**	**1**	**11 (1.000)**
12	Universidade Técnica de Lisboa (UTL)	0.913	4	11 (0.650); 14(0.350)
13	Universidade de Trás-os-Montes e Alto-Douro (UTAD)	0.806	7	14(1.000)
14	**Instituto Superior de Ciências do Trabalho e da Empresa (ISCTE)**	**1.000**	**1**	**14(1.000)**
	Mean	**0.8321**		**-**

Source: Own elaboration based on the DEA results obtained from MatLab. Bolds identify technically efficient universities.

5.2 Public Polytechnics

Table 5 reports the results for public polytechnics. The results of the efficiency analysis for this group of HEIs show that input efficiency scores are larger or equal to (for ESELX) 0.420. Results point out that the theoretical efficient frontier is defined by five DMUs: IPBeja, ESHTE, IPCB, IPLeiria and IPCA. The less efficient DMUs are ESELX and ESEP. The efficiency score of 0.420 for ESELX which means that, in order to move towards the efficiency frontier, by keeping the same level of outputs, it should have reduced its inputs by 58%. The measure of this efficiency score was calculated taking as benchmark some of the efficient DMUs, namely DMUs 6 (ESHTE) and 19 (IPCA), with a relative weight of 38% and 62%, respectively.

These results for these two nursing schools reflect, again, the corresponding relative positions at inputs and outputs bundles. From Figure 3, we have seen that ESELX and ESEP were the institutions in the group with higher levels of inputs (ESELX and ESEP together accounted for about 6% of the total academic staff of the 20 polytechnics, presenting also significant levels of other inputs). On the other hand, their relative position at the output level (Figure 4) is near the origin of the diagram. So, as their outcomes did not correspond to their comparatively high level of resources, they were found to be technically inefficient, when compared with other polytechnic institutions.

Lastly, it is possible to observe that overall input efficiency is around 0.7793 which implies that, on average, the 20 public polytechnics in our sample would be able to achieve the same level of performance and the same output levels by using 22% less resources.

Table 5: DEA Results for Group B: Public Polytechnics

DMU	DMU name	Efficiency Score	Rank	Benchmark/Peers (weight)
1	**IP Beja (IPBeja)**	**1.000**	**1**	**1 (1.000)**
2	EN Infante D. Henrique (ENIDH)	0.515	14	6 (0.200); 19(0.800)
3	ESE Coimbra (ESEC)	0.555	13	6 (0.546); 19(0.454)
4	ESE Lisboa (ESELX)	0.420	16	6 (0.379); 19(0.621)
5	ESE Porto (ESEP)	0.502	15	6 (0.783); 19(0.217)
6	**ES Hotelaria e Turismo do Estoril (ESHTE)**	**1.000**	**1**	**6 (1.000)**
7	IP Guarda (IPG)	0.741	8	6 (0.403); 19(0.597)
8	IP Bragança (IPB)	0.957	2	6 (0.203); 19(0.797)
9	**IP Castelo Branco (IPCB)**	**1.000**	**1**	**9(1.000)**
10	IP Coimbra (IPC)	0.899	4	6 (0.065); 19(0.935)
11	**IP Leiria (IPLeiria)**	**1.000**	**1**	**11(1.000)**
12	IP Lisboa (IPL)	0.701	9	11 (0.427); 19(0.573)
13	IP Portalegre (IPPortalegre)	0.910	3	1 (0.237); 11(0.314); 19(0.449)
14	IP Santarém (IPSantarém)	0.682	11	19(1.000)
15	IP Setúbal (IPS)	0.790	6	6 (0.304); 19(0.696)
16	IP Tomar (IPT)	0.781	7	6 (0.158); 19(0.842)
17	IP Viana do Castelo (IPVC)	0.614	12	6 (0.094); 19(0.906)
18	IP Viseu (IPV)	0.825	5	6 (0.230); 19(0.770)
19	**IP Cávado e Ave (IPCA)**	**1.000**	**1**	**19(1.000)**
20	IP Porto (IPP)	0.694	10	6 (0.326); 19(0.674)
	Mean	**0.7793**		-

Source: Own elaboration based on the DEA results obtained from MatLab. Bolds identify technically efficient polytechnics.

5.3 University of Porto

Table 6 presents the results of the efficiency analysis for University of Porto. The lower input efficiency score was 0.476 for FMUP, which was found to be the less efficient faculty of the university in 2008, followed by FMDUP. Results suggest that, in the same year, the theoretical efficient frontier was defined by six faculties: FLUP, FDUP, FEUP, FEP, FADEUP and ICBAS.

One more time, remembering the relative locations of the several faculties regarding their input and output levels (Figures 5 and 6), we recall that FMUP and FMDUP occupied the highest positions at the input-level, as the courses offered by these faculties (associated to health and medical sciences) are typically the most costly ones. On the other hand, the outputs of these two faculties in 2008 were comparatively low, mainly for FMDUP. As a result, the result pointing out a technical inefficiency for these faculties is not surprising at all and confirms our expectations.

Regarding the most efficient faculties, we verified in Figure 6 that, for instance, FEUP had an outstanding position at outputs (21% of total graduated students of UP in 2008 and 26% of total PhD degrees), using only a moderated bundle of inputs. Actually, DEA results suggest that in that year FEUP was able to minimize its inputs to achieve the corresponding levels of outputs. In opposition, FEP was one of the faculties with lowest resources per student in 2008, but those resources allowed it to attain a reasonable bundle of outputs (6% of total graduate students of UP and 5% of total PhD degrees), which made it a technically efficient institution in that year in that context.

At last, it is possible to observe that overall input efficiency of UP was around 0.825 which implies that, similarly to the previous cases, there seems to have been some waste of resources in the majority of institutions. For UP in particular, the results suggest that, on average, its 14 faculties could have achieved, in 2008, the same overall level of performance using less 17.5% resources than those effectively used.

In summary, DEA results show that public universities seem to be technically more efficient than polytechnics. In other words, the waste of resources seems to have been less severe in the university subsector. On the other hand, among universities, only 14% of HEIs were found to be technically efficient, while among polytechnics results suggest a higher share of technically efficient institutions (20%). Among the faculties of UP, almost half of the faculties worked efficiently in technical terms in the year under observation, which has surely contributed to the relative efficiency found for UP in group A.

Table 6: DEA Results for Group C: Faculties of University of Porto

DMU	DMU name	Efficiency Score	Rank	Benchmark/Peers (weight)
1	**F Letras (FLUP)**	**1.000**	**1**	**1 (1.000)**
2	**F Direito (FDUP)**	**1.000**	**1**	**2 (1.000)**
3	F Medicina (FMUP)	0.476	9	1(0.961); 2(0.039)
4	F Ciências (FCUP)	0.816	3	1 (0.628); 5(0.308); 10 (0.063)
5	**F Engenharia (FEUP)**	**1.000**	**1**	**5(1.000)**
6	F Farmácia (FFUP)	0.825	2	1(0.157); 2(0.075); 10(0.768)
7	**F Economia (FEP)**	**1.000**	**1**	**7(1.000)**
8	F Psicologia e C. Educação (FPCEUP)	0.758	5	1(0.331); 2(0.003); 5(0.020); 10(0.646)
9	F Arquitectura (FAUP)	0.767	4	7 (1.000)
10	**F Desporto (FADEUP)**	**1.000**	**1**	**10 (1.000)**
11	**Instituto de Ciências Biomédicas Abel Salazar (ICBAS)**	**1.000**	**1**	**11(1.000)**
12	F Medicina Dentária (FMDUP)	0.497	8	7(1.000)
13	F Belas Artes (FBAUP)	0.745	6	7(1.000)
14	F Ciências da Nutrição e Alimentação (FCNAUP)	0.671	7	2(0.916); 5(0.020); 10(0.063)
	Mean	**0.825**		**-**

Source: Own elaboration based on the DEA results obtained from MatLab. Bolds identify technically efficient faculties of UP.

6 Conclusion and Discussion

In this paper, we applied DEA methodology to evaluate the relative efficiency of several groups of HEIs in Portugal. The analysis was performed at three levels, by evaluating three independent groups of HEIs: public universities, public polytechnics and the faculties of University of Porto.

Among public universities, the results show that UP and ISCTE were, in 2008, the most technically efficient institutions. In the set of public polytechnics, we find 20% of institutions in the efficient frontier. For the case of UP in particular, almost half of the faculties were technically efficient in the same year, with particular emphasis for FEP and FEUP. However, on the other hand, the results suggest as well that a great portion of HEIs were working inefficiently, contributing to a significant waste of resources. Actually, in the university (polytechnic) subsector, DEA results show that the same level of outputs could have been achieved by using about less 17% (22%) of the resources effectively used in that year.

These results and others obtained for other countries and/or institutions alike should claim for the attention of public authorities, HEIs' administrative and management bodies, as well as several stakeholders interested in HEIs' accountability. Moreover, in a context of financial stringency like that characterizing the current landscape in Portugal and in several other countries, where HEIs must become increasingly more independent from government funding and search for other sources of revenues, the topic of efficiency gains an additional relevance in higher education sector.

This study has thus contributed to provide some new evidence on the effectiveness of the utilization of resources among public HEIs in Portugal and should be viewed as a first step for a more detailed analysis on the topic. From this first, and thus exploratory, study we can mention a number of possible avenues for future research. First, the analysis could be extended and enriched by introducing additional inputs and/or outputs. For outputs in particular, an accurate measurement of research outputs could be of great value, by collecting, for individual HEIs, the number of publication records in international high quality journals in all scientific fields. Collecting these data from sources like Thomson Reuters' ISI Web of Science database, despite challenging and time-consuming, would be a further step towards a more accurate evaluation of HEIs' performance, particularly regarding their research activities.

Second, performing this analysis for other years is also a potential avenue for further research. Observing the technical efficiency in the higher education sector for several years and evaluating how such efficiency has been evolving over time would be a natural extension of the current work.

Finally, and complementarily to this research agenda, we must give a further step in the analysis and search for potential determinants of HEIs' technical efficiency. It would be highly interesting to discover which factors explain the performance of higher education institutions and, consequently, what could be done to improve the efficiency of a single institution. Actually, we believe that there are several factors that could contribute in some way to explain the efficiency scores presented by HEIs over the time. The location of institutions (or some characteristics of the region where HEIs locate), the macroeconomic environment, the maturity of HEIs, their degree of interdisciplinary, the composition of their academic staff, the structure of their funding sources, among other factors, may have some explanatory power for HEIs' technical efficiency. In fact, several differences between HEIs and even unobserved heterogeneity at the institutional-level must be considered when comparing measures of relative efficiency. We leave these questions for future research.

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Appendix

MatLab Code[15]

```
disp('*****************************************************************');
disp(' Efficiency Analysis of Portuguese Public Universities: DEA ');
disp(' Group A ');
disp('*****************************************************************');
%% DEA code in MatLab
%————————————————————————————————-
% Simple CRS/VRS input-oriented DEA:
% Variable Returns to Scale are coded as a default
% Results for Constant Returns to Scale are get by changing the scale
% assumption below for 'CRS'
% We have 15 variables: 1 variable is theta (efficiency score of the DMU)
% 14 variables are lambda's: one for each DMU
% DMU = Decision Making Units (here Public Portuguese Universities)
% So x(1) will be theta, x(2) to x(15) will be the lambda's
% Scale assumption
scale = 'VRS';
fprintf('scale assumption is %s\ n \ n', scale');
% Objective function: the first value represents the coefficient associated
% to the efficiency score of the institution.
% The zeros represent the coefficients of the lambda's, that are the
% weights of comparable institutions. As the lambda's
% do not show up in the objective function, the coefficients must be zero.
f=[ 1; 0; 0; 0; 0; 0; 0; 0; 0; 0; 0; 0; 0; 0; 0];
% Define the matrix of inputs (one column per DMU): 3 inputs
% 1st line corresponds to Input 1: Total Revenues per enrolled student
% 2nd line corresponds to Input 2: Total Expenditures per enrolled student
% 3rd line corresponds to Input 3: Academic Staff per enrolled Student
Input=[ 8788 ... 3799;
7871 ... 3638;
0.100 ... 0.058];
% Define the matrix of outputs (one column per DMU): 3 outputs
% 1st line corresponds to Output 1: Total Graduated Students
% 2nd line corresponds to Output 2: Total PhD Degrees
% 3rd line corresponds to Output 3: Total number of courses
Output=[ 545 ... 1721;
0 ... 43;
85 ... 76];
% we make all elements of this vector to be negative due to the type of the
% constraint for outputs - the constraint is an inequality with ">=", but
% the command LINPROG requires the use of constraints (if they are
% inequalities) with "<=". So we must multiply both parts of the constraint
% by -1 and invert the signal of the inequality from ">=" to "<=".
Output_neg=Output*(-1);
% we must also specify a lower bound on the decision variables:
% all the variables (theta and lambda's) must be non-negative
% lb denotes de vector of lower bound constraints
% ub denotes de vector of upper bound constraints
lb=zeros(15,1);
ub=ones(15,1);
%% Solve the problem for all the DMUs simultaneously
% If the scale assumption is VRS (rather than CRS), we will need one
% more constraint in the problem: the sum of the lambda's must equal 1!
if scale=='VRS'
Aeq=[0 1 1 1 1 1 1 1 1 1 1 1 1 1 1]; % we have a zero in the first position because theta does not show up in this constraint for lambda's
beq=[1]; % the sum of the lambda's must be equal to 1
end
% matrix of results
```

[15]Note: This is an extract of the code constructed for Public Universities (Group A). Additional details on this or other code(s) can be obtained upon request from the authors.

```
results_DEA=[];
% for cycle in order to solve the problem for all the 14 DMUs under study
for i=1:14
fprintf('DMU number %d\n', i);
fprintf('——————-\n\n');
zero_aux=zeros(3, 1); % this is an auxiliar vector - it creates a column of zeros that appears in the first column of matrix Outputs
% the matrix of constraints will be formed for every DMU
% we begin with matrix of outputs
Outputs=[zero_aux Output_neg];
% the first column of Inputs matrix will be the elements of "Input"
% multiplied by -1 for the current DMU (the DMU under evaluation)
Inputs=[Input(:,i)*(-1) Input];
% combine the constraints for Outputs and Inputs into a matrix A
A=[Outputs; Inputs];
% column of Right-Hand Sides (RHS) ('vector b')
% the constraint for Outputs will have the value of output for the DMU
% under evaluation, multiplied by (-1) as explained above. RHS for
% inputs are zeros in this case
b=[Output(:, i)*(-1); zeros(3,1)]; % 3 lines of zeros - 3 inputs)
% call the LINPROG function to solve the linear optimization problem
if scale=='CRS'
dea_solution=linprog(f, A, b, [], [], lb, ub); % CRS - we have empty matrices because in this case we don't have constraints in the form of equalities
elseif scale=='VRS'
dea_solution=linprog(f, A, b, Aeq, beq, lb,ub);% VRS - we replace the empty matrices by the restrictions stored in Aeq and Beq
end
disp(dea_solution);
% obtain the value for the efficiency score for the DMU that is being currently evaluated
fprintf('Value of theta=%5.3f\n\n', dea_solution(1, 1));
% to accumulate results
results_DEA=[results_DEA dea_solution(1, 1)];
% to obtain the weights for the DMUS that work as reference/benchmark
for j=2:15 %because lambda's have numbers from 2 to 15
if (dea_solution(j)>0.000001)
fprintf('DMU %d weight=%5.3f\n', j-1, dea_solution(j));
% we must use 'j-1' because the first lambda is at position 2
end
end
fprintf('——————-\n\n');
end
%obtain all the efficiencies together for all the DMUs
for i=1:length(results_DEA)
fprintf('DMU %d had efficiency %5.3f\n', i, results_DEA(i));
end
disp('--------------------------------------------------------');
disp('DMU efficiency score');
disp('———————————————————');
fprintf('Universidade dos Açores | %5.3f \n', results_DEA(1));
% ...
fprintf('ISCTE| %5.3f \n', results_DEA(14));
disp('--------------------------------------------------------');
```

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