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Determinants of Technical Efficiency for Portuguese Public Higher Education Institutions taking Research and Education into Account

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Master in Economics

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June, 2026

BUSINESS SCHOOL

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Dedico esta Tese à minha Família

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Resumo:

Esta tese analisa os determinantes da eficiência técnica em 32 Instituições de Ensino Superior Públicas Portuguesas, incluindo universidades e politécnicos, no ano letivo de 2023/24. Do ponto de vista metodológico, aplica-se um modelo de Análise Envoltória de Dados (DEA) em duas etapas com correção de *bootstrap* duplo e orientação para o *output*, conforme estabelecido por Simar & Wilson (2007). Para colmatar lacunas proeminentes na literatura, a análise isola os dois principais objetivos institucionais: a Investigação e o Ensino, e desconstrói-os analiticamente em dimensões distintas de métricas de Qualidade e Quantidade, resultando num novo quadro analítico assente em quatro eixos. Os resultados empíricos revelam que a Investigação e o Ensino possuem determinantes de eficiência distintos, revelando vários *trade-offs* e complementaridades entre e dentro dos objetivos e dimensões institucionais considerados. Consequentemente, este estudo fornece perspetivas valiosas sobre a forma como fatores institucionais, tais como a estrutura de financiamento, a presença em regiões centrais ou a relevância de áreas académicas específicas, influenciam a eficiência técnica. Adicionalmente, são obtidos os rankings de eficiência técnica para todas as instituições de ensino superior analisadas, identificando aquelas que necessitam de maiores melhorias. Estes resultados são de elevada utilidade prática para os gestores institucionais e decisores políticos em Portugal. A tese encerra com recomendações de políticas públicas direcionadas, enquadradas pelas limitações inerentes à investigação.

Palavras-Chave: Instituições de Ensino Superior, Eficiência Técnica, Portugal, DEA com *Bootstrap* Duplo, Investigação, Ensino

Classificação JEL: I23, C14

Abstract:

In this thesis we seek to study determinants of technical efficiency in 32 Portuguese Public Higher Education Institutions, including both Universities and Polytechnics, in the academic year 2023/24 making use of a two-stage double bootstrap DEA methodology following an output-orientation as established in Simar & Wilson (2007). To address prominent gaps in the literature we isolate the two main institutional goals: Research and Teaching and deconstruct both these further between two dimensions: Quality and Quantity metrics, giving us a new analytical framework with four axes of analysis. The empirical findings reveal that Research and Teaching efficiency have different determinants, uncovering a number of trade-offs and complementarities between and within the institutional goals and dimensions considered. This provides valuable insight on how institutional factors such as funding structure, presence in central regions and predominance of given academic fields affect technical efficiency. We also obtain rankings of technical efficiency for all Higher Education Institutions considered, revealing those who are more in need of improvement. These results are valuables to institutional managers and policymakers in Portugal. The thesis concludes with targeted policy recommendations, framed alongside the inherent limitations of the research.

Keywords: Higher Education Institutions, Technical Efficiency, Portugal, Double Bootstrap DEA, Research, Teaching

JEL Classification: I23, C14

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List of Abbreviations:

- **BA** – Bachelor of Arts
- **CNAEF** – Classificação Nacional de Áreas de Educação e Formação
- **CRS** – Constant Returns to Scale
- **DEA** – Data Envelopment Analysis
- **DGEEC** – Direção-Geral de Estatísticas da Educação e Ciência
- **DGES** – Direção-Geral do Ensino Superior
- **DMU** – Decision-Making Unit
- **DRS** – Decreasing Returns to Scale
- **E.S.E.** – Escola Superior de Enfermagem
- **E.S.H.T.** – Escola Superior de Hotelaria e Turismo
- **E.S.N.** – Escola Superior Náutica
- **FE** – Fixed Effects
- **FTE** – Full-time equivalent
- **HE** – Higher Education
- **HEI** - Higher Education Institution
- **IGeFE** – Instituto de Gestão Financeira da Educação
- **IO** - Input Orientation
- **IRS** – Increasing Returns to Scale
- **MA** – Master of Arts
- **N-CRS** – Normal Constant Returns to Scale
- **N-DEA** – Normal Data Envelopment Analysis
- **N-VRS** – Normal Variable Returns to Scale
- **OO** – Output Orientation
- **Pol.** – Instituto Politécnico de
- **RE** – Random Effects
- **RJIES** – Regime Jurídico das Instituições de Ensino Superior
- **SAS** – Serviço de Ação Social
- **SFA** – Stochastic Frontier Analysis

- **SW** – Simar and Wilson
- **SW-CRS** – Simar-Wilson Constant Returns to Scale
- **SW-VRS** – Simar-Wilson Variable Returns to Scale
- **TE** – Technical Efficiency
- **U.** – Universidade de
- **VRS** – Variable Returns to Scale

1. Introduction:

The recent years have seen a massification of higher education with a great increase in number of attending students and graduates leading to an expansion of the education system in many countries (Mammadov & Aypay, 2020; Quiroga-Martínez et al., 2018), normally associated with the positive effects on economic growth governments identify with Higher Education (HE) (Agasisti et al., 2021; Pedro et al., 2022; Thai & Noguchi, 2021).

At the same time the resources available to Higher Education Institutions (HEI), particularly those made available by the State, have not fully accompanied this expansion, putting pressure on HEI to continue delivering quality outputs under greater financial pressure (Almeida et al., 2025; Alvarez-Sández et al., 2023). This is particularly true in Southern Europe after the austerity measures following the Sovereign Debts Crisis (Martínez-Campillo & Fernández-Santos, 2020).

Lastly, there is also increasing international pressure. HE has not been immune to globalization, which led to a marketization of academia, and a change from a perspective of liberal arts to one of entrepreneurship, with more market-focused research and international competition to capture the best human resources, both talented professors and students, and monetary resources (Slaughter & Rhoades, 2009). The result of this is that efficiency becomes an important factor to adequately compete, particularly when associated with more restrictive public budgets talked above (Cantele et al., 2016).

A combination of these three factors led evaluations of efficiency in HE to become popular in academic literature (See, 2026), however the unique characteristics of HEI compared to other businesses limit what is understood by efficiency. HEI are multi output and input institutions, they have diverse goals and, particularly in the public sphere, do not tend to be profit seeking institutions, which limits efficiency analysis, as price information is rare, leading technical efficiency analysis to be more popular.

Instead of profit, three camps can be roughly identified as goals of HEI: Teaching, associated with the formation of new graduates and development of human capital, Research, associated with the production of new knowledge, and Third-Mission goals, which includes societal responsibilities such as the transference of knowledge to the market through partnerships or patents or social responsibilities (Agasisti et al., 2021; Pedro et al., 2022). How much each HEI values each goal also depends, which reflects the highly heterogeneous nature of HE (Johnes, 2006).

Much of this is reflected in the Portuguese HE sector. Portuguese HE had a total of 186,780 students enrolled in 1990/91 academic year (Cerdeira et al., 2021), which have since more than doubled to 448,235 in 2023/24 according to the Portuguese Directorate-General for Education and Science Statistics (DGEEC). At the same time financial pressure has mounted. Funding as a whole has increased over this period, particularly with the assistance of EU funding. However, while in the 90s the State represented nearly the totality of funding for HEIs, and the student fees were very small, the equivalent to 6 euros yearly (Cerdeira et al., 2024), in 2023, public funding only accounts for 50% of total funding, a process of divestment which took speed in 2008 and the troika years, and an increase in student fees, which, as of 2026, for undergraduates is 697 euros yearly, and bigger for master and PhD students, and higher dependence on outside funding (Cerdeira et al., 2024).

In this context, measuring the efficiency of Portuguese HEI is necessary as well, however most studies in this realm are aged, normally going back to the crisis years (Afonso & Santos, 2008; Cunha & Rocha, 2012; Vasquez et al., 2012), or have more limited samples when they are recent, apart from other methodological issues (Pedro et al., 2022). But more than measurement, identifying which factors affect efficiency in Portuguese HE is as important, although frequently absent, as new changes to public financing of HEI (Portaria nº101/2024) took efficiency as a factor, altering the financing formula and impacting public financing for Portuguese HEIs, making identifying relevant factors necessary for the management of HEI that may want to access more funding.

Another recent change altered the picture of Portugal's HE system. Portuguese HE is a dual system composed of 2 distinct HEI types: Universities, traditionally divided between education and research, and Polytechnics normally focused on applied teaching. However, a recent change in the law (Lei nº16/2023) allowed for the first time Polytechnics to have PhD programs, one of the biggest barriers between both types of HEI, combined with the recent alteration in early May of 2026 to the Legal Regime of HEI (RJIES), which, among other changes, gave polytechnics the option of changing their official name from Polytechnic Institute to Polytechnic University. The blurring of differences is only reinforced as Polytechnics expand their teaching offer and scientific research, leading some to question the persistence of the dual model (Teodoro, 2026). Whilst in the literature the focus is normally on more traditional universities, the evolution of the national picture means we must account for polytechnics in our research, to identify if there are still persistent efficiency differences between the two.

Throughout this thesis, we will also seek to address a number of gaps in traditional technical efficiency literature. Two of these gaps mold our research: the first is the lack of differentiation between research

and teaching as goals, which are normally either mashed together, or one is focused on whilst other is ignored (Maral & Çetin, 2024), the second is the quantitative focus of most analysis, ignoring the quality of outputs (Almeida et al., 2025). The combined result is that determinants may be poorly identified, and trade-offs and complementarities that lie beneath go ignored, which may lead to wrong conclusions, that may be conveyed to stakeholders such as governments or HEI management, on how exactly given factors influence efficiency.

We will seek to answer the following research questions:

RQ1: How do Portuguese Public HEI compare in terms of technical efficiency?

RQ2: Which environmental factors impact technical efficiency in the Portuguese Public HE System?

RQ3: What trade-offs and complementarities are present when we take Research and Teaching, Quality and Quantity into account in separate analysis?

The thesis will be organized as follows: in Section 2 we will have the literature review, in order to identify the adequate methodology, common determinants considered and what gaps in the literature the thesis will fill. In Section 3 we develop the chosen methodology, a two-stage double-bootstrap DEA. Section 4 presents the sample of HEI we will study and the relevant variables for DEA and subsequent regression. In Section 5 we present and discuss the results, and in Section 6 we conclude by presenting the implications of our discoveries to stakeholders as well as limitations and possible extensions for this thesis.

2.Literature Review:

2.1. Concept of Technical Efficiency:

Whilst efficiency is an important concept in economics since the inception of the discipline (Pareto, 1906), the Microeconomic idea of Efficiency would be more clearly established by Koopmans (1951) but truly grounded by Farrell (1957). As Worthington (2001) explains, Farrel, inspired by Koopmans work, divided the at the time concept of Economic Efficiency of firms (also called Productive Efficiency) into two halves, Technical Efficiency, which implies using resources in the most efficient way according to the technology available, and Allocative Efficiency, which implies using said resources, or inputs, in the most optimal proportion given their prices, that is, choosing between different technically efficient combinations. Only when a firm is both technically and allocatively efficient could it be said to be economically efficient.

Farrell's seminal paper on the subject (Farrell, 1957) was first a critique of the existing methodologies used to ascertain efficiency. At the time most made use of labor productivity ratios, index numbers or cost measures, but the new methodology he introduced, which we discuss in this section, ended up revolutionizing the field of efficiency measurement, giving origin to a subfield sometimes called Frontier Analysis, which focused on measuring technical efficiency.

Farrel also established a general distrust of the use of theoretical models to benchmark efficiency. According to his critique, these models were of hard application in complex settings of firms or whole industries and were generally over-optimistic regarding what levels of efficiency could be achieved. Instead, he focused on what was actually achieved, what could be observed, stating "it is far better to compare performances with the best possibly achieved than with some unattainable ideal" (Farrell, 1957:255). Measurement and analysis of technical efficiency therefore have tended to focus on the observed standard as well, on the best that was actually achieved in a given context.

Another factor that helped cement the division between technical and allocative efficiency is that technical efficiency does not deal with prices, therefore it could be more easily applied to entities (not just firms) operating in sectors that were not solely driven by profit, such as our case of public Higher Education. The scale of application does not matter much either, whilst in his work Farrel clearly focused on firms and industries, methodologies based on his work saw applications in comparing even entire countries (e.g. Agasisti, 2011).

2.2. Methodologies to measure Technical Efficiency:

The unique thing about Farrell (1957)'s work at the time, which differentiated it from some of his inspirations such as Koopmans (1951) was that he moved beyond the theoretical and developed a methodology to effectively measure Technical Efficiency for the firms, henceforth called Decision-Making Units (DMU), of a given industry.

His approach consisted of estimating an "efficient isoquant", the frontier, from those DMU observed which dominated the others in term of the use of a given input compared to the outputs considered, and then all other DMU would be compared based on their distance from this estimated frontier, with all firms at the frontier being considered technically efficient and all above being inefficient. Due to the way it is constructed, there are always some DMU that are efficient, a characteristic the other methodologies derived from his work would also carry. Most importantly he expanded the method to be able to handle cases of multiple outputs and inputs, a clear improvement against at the time existing methods (mostly indexes).

His work would also establish some distinctions which would be prevalent in all other subsequent methodologies, such as the distinction between input orientation (where efficiency was interpreted as producing the same output with less inputs), which was what he used in his empirical application, and output orientation (where efficiency was interpreted as producing more output with the same inputs). He also identified the main weakness of this approach that the subsequent methodologies of frontier analysis would also share: the sensibility to input and output choice and its measurements, as well as to the introduction and removal of DMU. He concluded:

> "Technical efficiency, then, is defined in relation to a given set of firms, in respect of a given set of factors measured in a specific way, and any change in these specifications will affect the measure. This is inevitable in any such measure. But with these qualifications it functions in a natural and satisfactory way as a measure of efficiency." (Farrell, 1957:260)

Despite the importance I have attached so far to Farrell's work, it would be largely ignored for nearly two decades after its publication (Coelli et al., 2005). In the mid 70's a new surge of interest would lead to the development of two new methodological approaches directly inspired by his work that would become dominant in the field of frontier/efficiency analysis, these were the Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA) (Cooper & Lovell, 2011).

SFA originated in Aigner et al. (1977), and as Cooper & Lovell (2011) notes it originated from a "theoretical contradiction" of having a definition of a production function that established it as a maximum

but empirical econometric estimates of said functions that placed some producers clearly above it. SFA was created to address this contradiction. The main idea of their SFA was to introduce noise into Frontier analysis, something that Farrell (1957) and others' work did not do, which now could be distinguished from actual inefficiency.

Since its inception, SFA was and is a more traditionally econometric method, based on regression, however this is also its main weakness. As it is a parametric approach it requires a functional form to be selected beforehand for the cost function of the firms being evaluated. Likewise distributional assumptions have to be made, and the methodology can only handle either one output with multiple inputs or one input with multiple outputs (Lampe & Hilgers, 2015). Whilst later advances would expand the scope of SFA to encapsulate multiple outputs and inputs simultaneously, and to allow for different functional forms for different groups of DMU, these methods are more complex to compute.

The second alternative to arise was DEA, which originated in Charnes et al. (1978) in its constant returns to scale (CRS) version and was later adapted by Banker et al. (1984) into a variable return to scale (VRS) version to account for possible large size differences in DMU. Contrary to SFA which originated in a theoretical bind, DEA was born by solving practical problems of industrial application in American oil refineries (Cooper & Lovell, 2011).

The basis of the DEA presented in Charnes et al. (1978) was a series of weighted ratios of outputs and inputs, with endogenously chosen weights, adapted to each input/output mix under the restriction that said weights don't make any other DMU more than 100% efficient, i.e. the data itself determines the weights, avoiding arbitrariness or subjectivity. This method is non-parametric and based on linear programing, therefore it does not need an established functional form and can handle multiple inputs and outputs simultaneously, but it is fully deterministic, it cannot account for noise and is vulnerable to outliers.

Whilst the original DEA assumed CRS, i.e. that doubling inputs would lead to doubling outputs, since early it was apparent that this could not suffice if DMU differed wildly in size. The introduction of VRS by Banker et al. (1984) permitted not only to take into account large size differences in DMU for more accurate scores but also when combined with the CRS estimates, they enabled the calculation of scale efficiency, that is, to separate pure technical efficiency (the VRS scores) associated with managerial choices and performance from scale efficiency (obtained from the ratio of CRS to VRS scores) associated with sub-optimal sizes of DMU.

Throughout the years, these approaches gained popularity and varied applicability, but not in the same weight, as Cooper & Lovell (2011) note, DEA's foundational papers citations outnumber SFA's 2 to 1, whilst in their bibliometric analysis of these methods, of Lampe & Hilgers (2015)'s 4800 publications sample, only 800 pertain to SFA, whilst more than 4000 are DEA-based.

Despite its popularity, the information the DEA itself can provide is quite limited, it merely compares the DMU's according to their technical efficiency, and scale efficiency if we compute it, but it could not explain the results as it is a non-parametric approach meant to only measure it, so it became common to apply a second-stage regression on DEA scores, the idea being that the DEA calculates the scores, and the regression helps identify the environmental factors that explain them (McDonald, 2009). In their review of DEA applications, Camanho et al. (2024) found that 55% of their sample applied a second-stage regression after DEA.

Due to the nature of DEA scores, the regression applied would be a Tobit (since DEA scores are bounded) or a regular OLS, and these are still the most popular options (Camanho et al., 2024), however, critics such as Simar and Wilson (2007) argue that these methods may be flawed. According to them, since DEA scores are built relative to each other and generated with (finite sample) bias instead of observed, it is incorrect to use regressions which rely on an assumption of independent observations, and inference based on such regressions would not be valid.

Their solution was a procedure that altogether came to be known as Simar and Wilson's (SW's) methodology. They explicitly modeled efficiency to give it a coherent Data Generation Process that traditional two stage DEA lacked and replaced the second stage regression by a truncated regression which was more compatible with DEA's structure because it recognized that DEA scores are limited (unlike OLS) but did not censor scores equal to 1 (unlike Tobit). The methodology made use of Bootstrap procedures to generate pseudo samples and help with the finite sample bias of DEA, when only applied to the residuals of the truncated regression this was a Single Bootstrap Procedure (Algorithm 1), which allowed for valid second-stage inference, but it could also be applied to the DEA, being known as Double Bootstrap procedure (Algorithm 2), which both corrected the Bias in the DEA and allowed for inference.

This methodology and its critique of traditional two-stage regressions were not universally accepted, in particular, McDonald (2009) argued that the proposed invalidity of traditional two stage regressions was exaggerated, and that these methods, while flawed, presented perfectly valid approximations. He pointed out that DEA was often chosen because it did not need parametric assumptions, but the use of Simar and Wilsons methodology needs strong assumptions about the distribution of inefficiency, an increase in

computational intensity and the need to justify tuning choices for comparatively very little gain in term of accuracy.

This counter to Simar and Wilson (2007) original critique helps explain why Tobit and OLS second-stage regressions are still more popular, however Moradi-Motlagh and Emrouznejad (2022) point out, SW's methodology has also become widespread over the last 20 years.

2.3. Measuring Higher Education Efficiency:

The idea of technical efficiency is particularly attractive for education, including higher education (HE), where large scale state intervention, including public provision of education, makes prices harder to discern, if they exist at all, and puts in doubt if the profit motive is followed. In general, what we find is that two-stage DEAs are far more popular than SFA when applied to HE (Ferro & D'elia, 2020) but still not as popular as conventional DEA (See, 2026), implying that most focus in the literature is still on measuring of efficiency rather than explaining it.

While both SFA and DEA were applied in the field of higher education, there are some problems with applying Frontier Analysis in general to HE, the main issue being that Higher Education Institutions (HEI), that is Universities, Polytechnics and other Superior Schools, have more than one goal, and the goals may be generally ill-defined. Maral and Çetin (2024) identify three: Teaching, Research and Third mission (social impact goals).

As Ferro and D'elia (2020) and Johnes (2006) point out, this will be compounded by a difficulty in selecting or even finding proper inputs and outputs, particularly because each goal of the HEI, such as Teaching or Research, is likely to have some shared inputs, but also a number of unique inputs and certainly unique outputs, many of which are hard to measure and may not be widely available publicly or not be comparable across HEI, a problem we will certainly develop later.

This, Johnes (2006) claims, can also explain why DEA is far more popular than SFA in evaluating HEI, whilst even the most basic versions of DEA can handle multiple inputs and outputs simultaneously, only more complex SFA can do this. Another problem the same author points out is the need to define a functional form for the cost function, this is already an issue normally and contributes to the relatively lower popularity on the SFA in general, however here it is even more problematic due to the high heterogeneity of HEIs, which are generally more independent than the institutions at lower education levels, and have unique structures, preferred teaching methods, classes, courses and goals, making any functional form chosen unlikely to fit most HEIs in the sample.

Lastly, the explanation for the popularity of Two-stage DEA in particular can also be found in Johnes (2006) who argues that HEI's performance is many times dependent on environmental variables outside their control. Using a regression in the second stage is a popular way to account for these influences.

2.4. Empirical Studies of Higher Education Efficiency:

Now that we reviewed the concept of technical efficiency and the methodologies that can be used to measure it, and the conceptual problems with applying them to higher education, we can start to address some of the concerns exposed in the previous chapters. Here we will review empirical applications which aim to not only measure technical efficiency in HE, but also explain the results through 2nd stage regressions, that is, to identify determinants.

We seek to identify how the problem of the multiple goals of HEI is addressed by these practical applications, the orientation (input-orientation (IO) or output orientation (OO)), what inputs and outputs are used and how many, the typical sample sizes (divided in the number of HEI and time length considered), what second-stage regression is chosen, and what environmental variables are used. A list of selected studies and their characteristics, organized by their publication year, is presented Table 1.

The studies presented are not meant to be representative of the vast empirical literature on the topic, but they allow us to draw some conclusions. First of all, the presence of recent studies employing Simar and Wilson (2007)'s Double bootstrap DEA (e.g. Agasisti et al., 2021; Thai & Noguchi, 2021) legitimize the methodology in current times, whilst the table also reinforces the diversity of possible alternatives: Tobit (e.g. Agasisti & Ricca, 2016), Beta Regression (e.g. Soummakie & Wegener, 2024) and Painel Data Regression (e.g. Papadimitriou & Johnes, 2019; Quiroga-Martínez et al., 2018) are also examples of viable options. The number of HEI included varies deeply between papers, from as low as 15 (Mammadov & Aypay, 2020) to as high as 500 (Wolszczak-Derlacz, 2017), and so does the time length considered, from one academic year (Tran & Villano, 2017) to up to 17 (Papadimitriou & Johnes, 2019). This variation demonstrates the versatility of the methodology.

Reference	Goals	Sample	Methodology	Inputs	Outputs	Ind. Variables
(Soummakie & Wegener, 2024)	Research	50 –Turkey 2014-2019	DEA with 2nd stage Beta Regression (OO)	Yearly research funding, Number of professors (full, associate and assistant) and Research Assistants (5)	H-index (productivity of research), Number of articles published, Number of graduate degrees programs (3)	Age, Size and Ownership Status
(Agasisti et al., 2021)	Research Teaching Third Mission	449–Russia 2012-2015	Double Bootstrap DEA (OO)	Income from all sources, Number of Academic Staff and % of which hold advanced degrees (3)	Number of Publications, Income from grants of applied research, Number of graduates (3)	% of master's students, % of full-time students, Dummy if the location is in the capital of the region, Share of students of that region enlisted in that university, Dummy for the presence of medical faculty
(Thai & Noguchi, 2021)	Research Teaching	74-Japan 2010-2016	Double Bootstrap DEA (IO)	Costs with teachers, Staff and Other operating expenses (3)	Number of enrollments at undergraduate, master and phd level, Number of publications, Income from hospitals (5)	Proportion of full-time teachers, of operating grants, Resident income per capita, Size (via dummies), Attached hospital and Science faculty dummies
(Martínez-Campillo & Fernández-Santos, 2020)	Research Teaching	47-Spain 2002/03-2012/13	Double Bootstrap DEA (OO)	Students, Academic Staff, Total Revenue (3)	Graduates and Publications (2)	Number of Academic Degrees offered, Age, Specialization in technical fields, a Degree program in Medicine, Regional Location (16 dummies), Crisis years
(Moreno-Gómez et al., 2020)	Research Teaching (Divided)	78-Colombia 2015-2017	Double Bootstrap DEA (IO)	Students, Full time and Part time faculty (3)	Graduates, Publications (2)	Ownership. Proportion of phd staff, Age, Number of campuses and Geographic location
(Mammadov & Aypay, 2020)	Research	15-Turkey 2017	DEA + Tobit (OO and IO)	Academic staff per program and Number of research projects (2)	Citation per publication, Ratio of research project income to total appropriations and Ratio of phd graduates per number of phd programs (3)	Ratios of: Staff to departments, Projects to departments, Avg citations, Revenue from research projects to total allowance, Number of PhD to doctoral programs
(Brzezicki, 2020)	Teaching	93-Poland 2011-2014	Double Bootstrap DEA (OO)	Fixed assets value, Academic Staff (2)	Graduates, Graduate earnings (2)	Age, Practical studies ratio, First level studies, Part time studies, Total number of studies, Province, Number of cities in the province, Distance between HEI and provincial capital, Companies with foreign capital, Expenditure on R&D, GDP per Capita, NEETs number
(Papadimitriou & Johnes, 2019)	Research Teaching	138-England 1996/97-2012/13	DEA and RE Panel Data Regression	FTE Undergraduates, Postgraduates and Academic staff, Expenditure on administration, Capital inputs (5)	Undergraduate first-degree qualifications, Postgraduate degree qualifications, Income from research grants (3)	Dummy variables for mergers, Ratio of students in medicine, HEI type dummies, Proportion of income from the government, Total number of FTE students
(Quiroga-Martínez et al., 2018)	Research Teaching	30-Argentina 2004-2013	DEA and FE Panel Data Regression (OO)	Academic staff, Students, Total budget (3)	Graduates, Publications (2)	Categories of academic staff, Different budgets. Administrative staff, Yearly dummies

Reference	Goals	Sample	Methodology	Inputs	Outputs	Ind. Variables
(Wolszczak-Derlacz, 2017)	Research Teaching	152+348 EU+US 2000-2012	Double Bootstrap DEA (OO)	Academic staff, Nonacademic staff, Revenue and Students (4)	Publications and Graduates (2)	Dummies for departments (medical and engineering departments), GDP of the region, Number of departments, Year of foundation and the Structure of funding (% from state, % from tuition)
(Tran & Villano, 2017)	Research Teaching	100-Vietname 2011/12	Double Bootstrap DEA (IO)	Academic Staff, Nonacademic staff, Floor area for academic spaces, Operating expenditures, Average scores of national entrance (5)	FTE undergrad students, FTE postgrad students, Completion rate and Revenue from research-related activities (4)	Age, Location (main city), Ratio of staff with postgraduate degrees, Tuition fees revenue, Government funding revenue
(Cantele et al., 2016)	Research Teaching	73-Italy 2010	Bootstrap DEA + Tobit (OO)	Students, Staff costs and Academic staff (3)	Graduates, % of regular graduate students and Research quality (3)	Geographical location, Size, Ownership structure and Human resource composition (% of researchers on teaching staff, and of teaching staff on administrative staff)
(Agasisti & Ricca, 2015)	Research Teaching	77-Italy 2007-2011	DEA + Tobit Regression (OO)	Students and Faculty staff (2)	Graduates and Revenue from research grants (2)	Location dummies, Presence of medical courses, % of revenue from student fees, % of foreign students, % of BA students over MA students, Ownership
(Lee, 2011)	Research	37-Australia 2006-2009	Double Bootstrap DEA (IO)	FTE Academic staff, Expenditure on buildings, plant and equipment (2)	National competitive grants, Industry grants, Other public sector grants, Research publications, Number of master's and doctorates students (5)	Actual student load, Location, Proportion of associate professors and Institutional grant schemes
(Wolszczak-Derlacz & Parteka, 2011)	Research Teaching	259-EU 2001-2005	Double Bootstrap DEA (OO)	Number of Students, Academic Staff and Revenue (3)	Number of Graduates and Publications (2)	GDP of the region where it is located, Number of faculties, Dummy for a medical degree, Year of foundation, Division of funding revenue, Share of Women on Academic Staff

Table 1 - Empirical Articles Reviewed

Most studies recognize a dual goal for HEI, associated with research and education, some add the third mission as well: (Agasisti et al., 2021; Maral & Çetin, 2024). The multiple goals were tackled in two ways: either including both goals in the same analysis and ensuring at least one output respective to each identified goal (e.g. Wolszczak-Derlacz, 2017; Wolszczak-Derlacz & Parteka, 2011) or by focusing on either teaching (e.g. Brzezicki, 2020) or Research (e.g. Lee, 2011; Mammadov & Aypay, 2020; Soummakie & Wegener, 2024).

In terms of inputs and outputs, they both tend to vary between 2 and 5 in the studies considered here. Some inputs seem near obligatory, such as academic staff (sometimes broken down by qualifications as in Soummakie and Wegener (2024), for example, although this seems more common when focusing on research), some measure of revenue and the number of students enrolled, sometimes in different complexities (e.g. when available, studies use full time equivalent measures of staff to account for differences full-time and part-time professors).

In outputs there also seem to be two obligatory presences: number of graduates (or graduation rates) for teaching output and number of publications for research output. Besides those, a number of more unique inputs and outputs can be identified even in the relatively small sample above, these depend on the availability of data of the country, and also the focus of the DEA.

Most DEA were output-oriented, input orientation was only picked when the characteristics of the HE system in question were more coherent with this orientation as was the case in Tran and Villano (2017). The focus was tendentially on VRS results, as in most HE systems there is a large degree of variation in HEI sizes, but most studies also compute CRS in order to obtain Scale efficiency metrics.

Lastly, many explanatory variables can be identified in the second-stage regressions applied. Some denote institutional characteristics mostly through binary variables, such as ownership status (e.g. Soummakie & Wegener, 2024), year of foundation (Wolszczak-Derlacz & Parteka, 2011), type of HEI and if the university offers a particular degree, normally in the field of medicine which, as Wolszczak-Derlacz (2017) notes helps take into account the abnormal costs involved with having such fields available, and sometimes STEM as well (Thai & Noguchi, 2021).

A metric of the size of the institution, such as the number of students (sometimes presented in a quadratic configuration), particularly if it was not included as an input (e.g. Papadimitriou & Johnes, 2019) or dummies built through it, or others such as the number of courses offered (e.g. Martínez-Campillo & Fernández-Santos, 2020) or the number of departments/faculties (e.g. Wolszczak-Derlacz & Parteka, 2011)

are also common size proxies. The prestige of the HEI is also accounted for, normally through the use of age as a proxy variable (Tran & Villano, 2017).

Studies that deal with multiple countries, such as Wolszczak-Derlacz (2017) or with larger countries, such as Agasisti et al. (2021) also tend to include metrics to account for economic differences between HEI locations, which can take the form of some measure of regional GDP being included or location dummies denoting the presence in given regions, like in Martínez-Campillo and Fernández-Santos, (2020) or if the HEI is located in a central position such as a big metropolis or the regional capital, as Agasisti et al. (2021) does.

Variables to consider as well are those that identify particular aspects of either the student population, the labor force composition and funding structure. These are normally represented through various ratios. For the student population, examples include the proportion of overseas students (Agasisti & Ricca, 2015; Papadimitriou & Johnes, 2019), ratio of students on certain degrees, such as medical degrees, normally in replacement of a dummy (Papadimitriou & Johnes, 2019) or certain HE cycles, such as master's students over bachelors students (Agasisti et al., 2021; Tran & Villano, 2017). For labor the focus tends to be on academic staff, with ratios of full-time professors (Quiroga-Martínez et al., 2018), associate professors (Lee, 2011) or researchers (Cantele et al., 2016). Lastly, regarding funding the common ratio is public funding over internally generated revenue (or some derivative thereof) (Agasisti & Ricca, 2015; Papadimitriou & Johnes, 2019; Tran & Villano, 2017; Wolszczak-Derlacz, 2017; Wolszczak-Derlacz & Parteka, 2011).

In terms of signs, due to the nature of DEA, which is highly sensible to output/input choice and sample composition, as well as the fact that many different HE systems are considered in the literature, it's common to have contradictory results if a variable appears across more than two studies. Take, for example, a dummy for medical degree: in some papers it is relevant and has a positive effect on efficiency (Wolszczak-Derlacz & Parteka, 2011), in others it has a negative effect (Thai & Noguchi, 2021) and in others it is not relevant at all (Agasisti & Ricca, 2015; Martínez-Campillo & Fernández-Santos, 2020). However, one conclusion can still be reached of particular relevance to this thesis: HEI located in central, developed regions tend to have higher efficiency levels (Cantele et al., 2016; Martínez-Campillo & Fernández-Santos, 2020; Tran & Villano, 2017).

2.5. Literature gaps:

Many gaps in the literature are identified in the empirical papers presented above, by the authors themselves. In their future research agenda, Almeida et al. (2025) identify these recommendations and future research paths suggested by a large number of applied DEA studies aimed at measuring technical efficiency in HEI.

As we already noted in Section 2.3 and Almeida et al. (2025) confirms, few studies consider environmental variables, focusing solely on measuring technical efficiency across HEI but not explaining it (Papadimitriou & Johnes, 2019; Soummakie & Wegener, 2024). To this, Almeida et al. (2025) also adds the need for more diverse variables in the 2nd stage regression. To address this, we introduce variables that are rarely present in the literature, in addition to more common findings.

Second, most variables considered are purely quantitative (Almeida et al., 2025; Thai & Noguchi, 2021; Wolszczak-Derlacz, 2017). Both inputs and outputs tend to ignore quality to focus on quantity, which may be an error in an era in which HEI compete internationally to attract high quality students and researchers. Of the above papers, only Brzezicki (2020) addressed this by calculating a DEA focused on teaching quantity and other focused on teaching quality (using graduate salary level as a proxy). He found is that not only is quality relevant, but environmental variables impact quantity and quality efficiency differently. We take inspiration from this in the thesis by presenting both joint and separate quantity/quality scores and regressions. We only add quality in outputs, the lack of quality in inputs is a gap we do not seek to address.

Lastly, as we already saw, when addressing the dual goals of Research and Teaching (and sometimes Third mission), Frontier Analysis tends to either focus on one of the goals or include both in the same DEA. This may be flawed, as Maral and Çetin (2024) point out, the first solution ignores a big part of the HEI activities, whilst the second risks ignoring that different HEI have different orientations and missions, and may be wrongfully labeled inefficient for not contributing to a goal that is outside their focus, this last part is important because our sample includes polytechnics. In the above studies, only Moreno-Gómez et al. (2020) addresses this by calculating separate DEAs for Research and Teaching, finding that different variables impact both differently. We will do the same, with the intent of identifying trade-offs/complementarities between the two goals. This means this thesis will consider 4 dimensions: Research, Teaching, Quantity and Quality.

2.6. Evidence from Portugal:

Before moving on, we must also consider what evidence there is for Portugal. Whilst application of DEA is also widespread in Portugal, particularly in analysis of the public sector, in terms of HE application it is more limited. Four works could be found. The first three are: one paper (Afonso & Santos, 2008), one working paper (Cunha & Rocha, 2012) and one PhD thesis (Vasquez et al., 2012), all from the years of the sovereign debt crisis where public spending efficiency became a hot button issue. They all focus on the public HEIs with differing samples and all use traditional DEA or superefficient DEA (Vasquez et al., 2012) with no second-stage regression and their most recent data is of the academic year of 2007/08. This thesis distinguishes itself from them in both goals (we seek to identify determinants of efficiency, not just measure it) and method (two-stage DEA).

The fourth work is more recent and presents higher similarity with our own. Pedro et al. (2022) is a Two-stage DEA study investigating efficiency in Portuguese HE. It uses a regular DEA and a Tobit for regression. It focuses on the public HE system with a sample of 23 HEI that includes all Universities but only 9 out of the 19 polytechnics due to lack of Data. It uses data for the year 2017, so it is more recent but still nearly 10 years old. It, like this thesis, also separates the three goals of HE into three DEA: Teaching, Research and Social Responsibility (we only consider the first two) and focuses on this last one in order to evaluate its impact on regional development. It uses 8 common inputs and 3 unique outputs for each goal.

For the regression, the following environmental variables are considered: a dummy if the HEI is in an Insular Region, the ratio of the nº of firms with R&D activities by total number of firms in the region (NUTS 3), rate of firms total investment in the region, rate of PhDs of science and technology in the region. These variables are focused on the characteristics of the region in which the HEI is located, in accord with the goal of using the distinct efficiency scores to evaluate their impact on regional development. This is the main disparity from this thesis. We will acknowledge location through a dummy, but our focus is the HEIs themselves and our environmental variables are all factors internal to each HEI, controllable or not by them so we have a different analysis with similar methodology.

Lastly, we mention Pedro et al. (2026) which does not measure efficiency but seeks to identify good input and outputs to address efficiency in Portuguese HE, some of which we use in our analysis, although the paper was published halfway through the thesis, so its influence is limited.

3. Methodology:

3.1. General methodology:

This thesis will follow a two-stage DEA approach applied to 32 HEI that belong to the Portuguese Public Higher Education System, and we focus on the Academic Year of 2023/24. The first stage will be composed of a DEA meant to measure technical efficiency, the second stage will consist of a truncated regression with the DEA efficiency scores as the dependent variable, with the goal of identifying the environmental variables that influence these results.

We will focus on Research and Teaching. Third Mission goals were excluded due to lack of data. To address one of the literature gaps identified previously, we will conduct two separate two-stage DEAs, each focusing on one of the goals. This will allow us to account for different inputs and outputs associated with both goals, but also to identify possible trade-offs and complementarities present in achieving efficiency in each goal. We will also seek to account for quality and quantity differences by estimating DEA scores with only the correspondent output, addressing the second of the identified literature gaps.

Since our main focus is on the second stage, we will make use of Simar and Wilson (2007)'s (SW) proposed Dual Bootstrap DEA (also called Algorithm 2). This will ensure proper inference in the regression, but also less biased DEA scores in the First-Stage. Whilst we acknowledge criticism such as those in McDonald (2009), the translation of this procedure into modern programs such as Stata, where this analysis will be conducted, by the likes of Badunenko and Tauchmann (2019), eases its computational intensity. The main problem with SW is that our sample is small, but we can control this by making use of a small number of input/outputs and by limiting the number of independent variables in the regression.

The remainder of this chapter is split into two parts, each focusing on a stage of our analysis, where more detail will be put into the application of the methodology in each.

3.2. First-stage: Data Envelopment Analysis

As we already noted, we will have two distinct DEAs, one Research-focused (DEAr), the other Teaching-focused (DEAt). In both, each DMU corresponds to a Public HEI operating in Portugal in the academic year 2023/24.

Since our sample is composed of Public Institutions, many of their inputs, particularly funding, are in part decided politically, whilst increasing labor or capital cannot be done without lengthy public tender processes, so it is fair to assume that, in a short period such as a single academic year, the HEI cannot

significantly alter inputs (although they do have more freedom than other public entities), therefore we adopt an output-orientation for both DEAs (efficiency is taken as achieving a higher number of outputs making use of unaltered quantities of inputs).

HEIs in general are very heterogeneous in many aspects, including size. In terms of enrolled students, in the academic year of 2023/24, they can go from as high as 50,000 (U. Lisboa) to as low as 900 (Escola Superior Náutica Infante D. Henrique). This huge variation in size leads us to adopt a VRS approach first defined in Banker et al. (1984).

This configuration will apply to both our Research-focused and Teaching-focused DEA, for each DMU in our sample we solve the following linear programming problem:

$$\max_{\theta,\lambda} \theta \quad i = 1, \dots, 32 \quad s.t. \tag{1}$$

$$\sum_{j=1}^{32} \lambda_j y_{mj} \geq \theta y_{mi}, \qquad m = 1,2 \tag{2}$$

$$\sum_{j=1}^{32} \lambda_j x_{kj} \leq x_{ki}, \qquad k = 1,2,3 \tag{3}$$

$$\sum_{j=1}^{32} \lambda_j = 1 \tag{4}$$

$$\lambda_j \geq 0, \quad j = 1, \dots, 32 \tag{5}$$

The above equations (1) to (5) establish the initial calculus of the DEA. Equation (1) is our objective function; it defines the linear programing problem behind the DEA. It computes the output expansion factor (θ), that is, how much output a given DMU (i) can increase proportionally without changing the quantity of inputs (output-orientation), in the context of the observed data and the frontier defined by the best achieving DMUs (j).

The remaining equations are restraints. The individual outputs and inputs are represented by m and k respectively. (2) defines the output constraint, this ensures that the expansion factor estimated maintains the observed outputs (y) in the frontier defined by the best performing DMUs and not above it. (3) represents the input constraint which imposes that the expansion of outputs only occurs without changing the quantity of inputs (x) the DMU is observed to have. (4) establishes that the frontier estimated must be concave (the production possibility set be convex), and it is imposed due to the VRS specification and (5) establishes that the weights (λ_j) of each DMU in the frontier that are computed are non-negative.

Below we present an example of the frontier generated by a VRS, output-oriented DEA, with one input and two outputs, as presented in Sözen et al. (2012)'s work, where each letter is equivalent to a DMU. All those in the frontier are efficient (E, F, G and H), and we can see the logic behind the methodology, those units that achieve the better output-input ratios are considered efficient and mold the frontier. All outside the frontier are inefficient (D, B, A and C), the expansion factor is how much C's Y1 and Y2 (outputs) would have to be multiplied by so that C moves to C'.

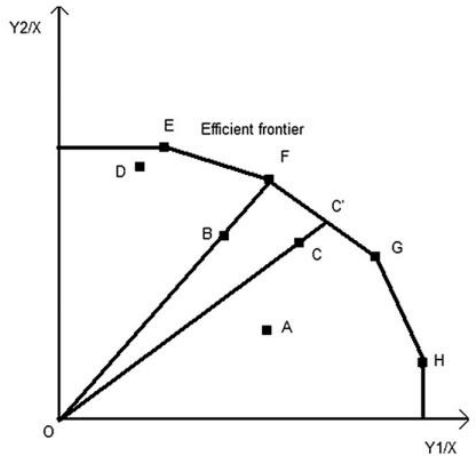


Figure 1 - VRS Output-oriented 1-input 2-output DEA graphical example

Both DEAs will have a 3-input, 2-output configuration, the exact inputs and outputs will be explained in the Data chapter below. This configuration cannot be represented graphically; thus, our example uses one input and two outputs. This input and output configuration comfortably satisfies the common rule of thumb applied in DEA literature to ensure a well specified DEA (with a long history but established in this form in Cooper et al. (2007)). It establishes a relation between the total number of DMU (n = 32) and the total number of outputs (g = 2) and inputs (s = 3):

$$n \geq \max[g \times s, 3(g + s)] \tag{6}$$

So far, we only have shown the regular DEA. To apply the double bootstrap methodology a bootstrap procedure must be applied to correct the finite-sample bias in this DEA, making the analysis more robust to outliers. This will imply re-estimating a number of artificial frontiers with datasets that mimic the original. The result of this bootstrap procedure is the bias-corrected DEA measurements (θ^*), or expansion factor, we will use in stage 2. It can be interpreted as the factor by which the observed outputs of a given DMU must be multiplied by so that the DMU in question is considered efficient with the input endowment it is observed to possess. If this factor takes the value of 1, the HEI is efficient, otherwise it is not. Due to

the bootstrap, a DMU may not take a value of 1 if it is not consistently considered efficient across all simulations, so contrary to normal DEA we may have no efficient DMU.

We will follow a homogeneous bootstrap procedure, which implies an assumption that all HEI have the same underlying technology such that inefficiency has the same distribution for all DMU. This is a strong assumption, as we mentioned, there is a big degree of heterogeneity between DMUs, so this is a limitation of our study. The number of repetitions for the bootstrap will be set at 100. This is the standard recommended by Simar and Wilson (2007) and adopted by Badunenko and Tauchmann (2019) in their Stata code.

The expansion factor we calculated is not the most readable metric of Technical Efficiency. For better interpretation and analysis, we must compute this metric:

$$TE_i = \frac{1}{\theta_i^*}; \qquad 0 < TE_i < 1 \tag{7}$$

If we have a technical efficiency level of 1, that DMU is efficient, if it is below 1, it is inefficient and can be interpreted as follows: if TE = 0.8 for a given DMU, with the inputs it has, that DMU is only producing 80% of the outputs it could if it was efficient.

As we said, our focus is the VRS, bias-corrected scores, however the normal DEA VRS scores, as well as the normal and bias-corrected CRS scores (the mathematical formula for these is the same as the VRS, but without restriction (4)) will also be computed in order to conduct robustness testing. Likewise, other configurations besides the main 3-input, 2-output model we presented here will also be computed for the same reason. The first is an exclusion of our student input to a 2-input 2-output model as was done by Wolszczak-Derlacz (2017) and two 3-input 1-output DEAs, each focusing on quantity and quality like Brzezicki (2020) did.

From here, some basic comparisons of HEI can be made allowing us to answer our first research question, that is, how Portuguese public HEIs compare in terms of technical efficiency. We will also compare in terms of scale efficiency and the quantity and quality focused scores. We can take some conclusions, but limited, justifying a 2nd stage regression.

3.3. Second Stage: Truncated Regression

In the second stage, we will seek to follow through on the main purpose of this thesis and answer our two remaining research questions: what are some of the determinants of teaching and research efficiency in Portuguese HEI and what trade-offs and complementarities in reaching efficiency in these goals can be identified.

Since we are following a Double Bootstrap procedure as defined in Simar and Wilson (2007), our second stage regression will be a Truncated regression. It is used because it considers the bounded nature of DEA scores (they are always larger than 1) and also due to these scores being not observed but estimated and therefore highly correlated. These two points are problematic when applying the other two more popular options: OLS and Tobit regressions, and since here is where we fulfill our main goal, ensuring proper inference is important.

As said, the main dependent variable is the bootstrap-corrected VRS Efficiency Scores (θ_i^*) obtained in the first stage. The independent variables will be addressed in the data chapter below. The functional form is as follows:

$$\theta_i^* = z_i'\beta + \varepsilon_i \; ; \; \theta_i^* \geq 1 \tag{8}$$

$$\varepsilon_i \sim N(0, \sigma^2); \; \varepsilon_i \geq 1 - z_i'\beta \tag{9}$$

Here z_i are our independent variables, β represents our coefficient matrix which we will seek to estimate, and ε_i is our error term which SWs methodology assumes follows a normal distribution but truncated to the left.

Since we have two distinct DEAs, we will have six main regressions, three with the DEAr results as the dependent variable (global, quantity and quality), and three others with the DEAt scores (global, quantity and quality). Since one of our goals is to identify possible trade-offs or complementarities in achieving efficiency in these goals, the way we achieve this is by using the same set of independent variables in all regressions.

The estimation will be done through Maximum Likelihood. We will apply 1000 repetitions in the bootstrap procedure that are standard in Simar and Wilson (2007), which is also the procedure normalized in Badunenko and Tauchmann (2019).

The main assumption required by the double-bootstrap procedure is separability, that is, the independent variables considered in the truncated regression must be environmental, and therefore must not affect the frontier, the underlying production technology. Due to the absence of formal tests, we must justify this theoretically, which we will do in the next chapter for each independent variable.

After estimating the model, once again we will conduct robustness tests. For this we will once again use our normal VRS, normal CRS and Bias-corrected CRS results as alternative independent variables and look for large variations in results. We will also estimate limited models without some independent variables when that proves necessary. We will also regress the DEA scores calculated with no student input we already calculated in the 1st stage. We will also compute regressions with 500 and 2000 bootstrap

procedures in order to gauge the impact of the change on the relevant variables (Wolszczak-Derlacz & Parteka, 2011). Lastly, other popular models such as OLS or Tobit will also be used to test our results.

Proving robust, we will test the individual significance of our independent variables, compare our results of both regressions, note possible trade-offs and complementarities, and discuss these results and their implication for the HEIs themselves as well as for policy.

A note on interpretation of coefficients. Our second stage truncated regression seeks to explain inefficiency, that is, the distance from the frontier, therefore coefficients must be interpreted as such: a positive coefficient implies that an independent variable contributes to increasing inefficiency, that is to decreasing efficiency, and vice versa. This will be considered during inference, but it is noted here to avoid future confusion.

4.Data:

4.1. Sample:

As mentioned before, our sample will be composed of the 32 HEI that compose the Portuguese public HE system and will focus on the year 2023/24. The focus on the academic year of 2023/24 is due to this being the most recent academic year for which data was widely available.

The private side of the HE system is composed of roughly 61 HEI, but these were excluded from the analysis due to lack of some important data, the small research output (many HEI had less than 10 published papers in the whole of 2023 and 2024) and small teaching output as well (in 2023/24 only 20% of HE students were enrolled in a private HEI). We instead chose to proceed with a more rich and focused analysis of the public sector HEI.

Not all public HEI will be considered. Universidade Aberta was excluded, since it is a special case focused on e-learning and lifelong education, which lacked many key variables for the analysis, and presented outlier values in many others due to its unique teaching methodology. Escola Superior de Enfermagem de Coimbra was excluded for lack of available key data. The various military and police HEI were also excluded due to also having a unique purpose and lacking some data. All other public HEI were included: all 13 universities, 15 polytechnics and 4 independent superior schools, as can be seen in the table below, identified by their name ("ESTAB") and unique DGES (Direção-Geral do Ensino Superior) code ("CODE"):

ESTAB	CODE	StuEnrl	NumPub
U. Açores	0100	2931	615
U. Algarve	0200	10298	1474
U. Aveiro	0300	16202	5081
U. Beira Interior	0400	8133	1719
U. Coimbra	0500	24254	6709
U. Évora	0600	8255	1495
U. Nova Lisboa	0900	24213	4517
U. Minho	1000	16531	4857
U. Porto	1100	36696	11945
U. Trás-os-Montes	1200	8419	1830
U. Madeira	1300	3723	1830
U. Lisboa	1500	50356	11963
Pol. Beja	3020	3246	209
Pol. Cávado e Ave	3030	7257	187

ESTAB	CODE	StuEnrl	NumPub
Pol. Bragança	3040	10486	954
Pol. Castelo Branco	3050	4741	231
Pol. Coimbra	3060	11327	701
Pol. Guarda	3090	3373	245
Pol. Leiria	3100	12179	833
Pol. Lisboa	3110	12710	518
Pol. Portalegre	3120	2830	227
Pol. Porto	3130	21462	1184
Pol. Santarem	3140	4768	209
Pol. Setubal	3150	7580	387
Pol. Viana do Castelo	3160	5319	562
Pol. Viseu	3180	5763	427
Pol. Tomar	3240	2688	149
ISCTE – IUL	6800	11432	1538
E.S. Enfermagem de Lisboa	7002	1370	192
E.S. Enfermagem do Porto	7003	1659	281
E.S.N. Infante D.Henrique	7105	896	18
E.S. Hotelaria e Turismo Estoril	7110	1675	29

Table 2 - HEI that are included in our analysis, as well as size metrics for their Research (number of publications) and Teaching (number of students enrolled) activity, taken from Scopus and DGEEC respectively

The main sources of data will be: DGES, DGEEC (Direção Geral de Estatísticas da Educação e Ciência), IGeFE (Instituto de Gestão Financeira da Educação), Scopus and individual financial reports from each HEI[1]

Lastly, before advancing to the data for inputs, output and independent variables, we must note that some HEI are classified as Universities, but also have a large polytechnic side composed of internal organic units that function as professionals schools instead of faculties, these are: U. Açores, U. Algarve, U.Aveiro, U.Évora, U.Minho, U.Trás-os-Montes and U.Madeira (DGES). Some sources, such as DGEEC, split the data

[1] Brandão et al., 2025; Conde et al., 2025; Escola Superior de Enfermagem do Porto, 2025; Escola Superior Náutica Infante D. Henrique, 2025; ESEL - Divisão de Serviços de Gestão Administrativa & ESEL - Divisão de Recursos Financeiros e Patrimoniais, 2025; Grupo Instituto Politécnico de Beja, 2025; Grupo Público Universidade do Minho, 2025; Instituto Politécnico de Bragança, 2025; Instituto Politécnico de Castelo Branco, 2025; Instituto Politécnico de Leiria, 2025; Instituto Politécnico de Portalegre, 2025; Instituto Politécnico de Setúbal, 2025; Instituto Politécnico de Tomar, 2025; Instituto Politécnico de Viana do Castelo, 2025; Instituto Politécnico de Viseu, 2025; Instituto Politécnico do Cávado e do Ave, 2025; Instituto Politécnico de Santarém, 2025; Politécnico de Lisboa - Planeamento e Controlo de Gestão, 2025; Presidência do Politécnico da Guarda, 2025; Presidência do PPORTO, 2024; Reitoria da Universidade de Aveiro, 2025; Reitoria da Universidade de Lisboa, 2025; Reitoria da Universidade do Porto & Serviços Partilhados da Universidade do Porto, 2025; Reitoria da Universidade Nova de Lisboa, 2025; Reitoria ISCTE, 2025; Universidade Beira Interior, 2025; Universidade da Madeira, 2024; Universidade de Coimbra - Divisão de Planeamento Gestão e Desenvolvimento, 2025; Universidade de Évora - Divisão de Planeamento e Garantia da Qualidade et al., 2025; Universidade de Trás-os-Montes e Alto Douro, 2024; Universidade do Algarve, 2025; Universidade dos Açores, 2025

of these HEI in two, for the polytechnic and university sides, others such as IGeFE and Scopus, as well as most individual financial reports, do not, so we aggregate the data of the two sides whenever they appear separately.

4.2. Inputs and Outputs:

We start with the Teaching DEA inputs:

Name	Stata	Explanation	Source
Total Revenue	TotFin	Total revenue available to the institutions in 2024, taken from their consolidated accounts and activity plans, and measured in euros.	Financial Reports
Students Enrolled	StuEnr	Number of Students enrolled in each HEI in the academic year of 2023/24, independent of cycle or course in which they are enrolled	DGEEC
Number of Academic Staff (FTE)	AcStaff	Full-Time Equivalent number of Academic Staff employed by each HEI in the academic year of 2023/24, regardless of category (Assistants, Associates and Full Professors) and status (tenured and contract)	DGEEC

Table 3 - DEAt inputs, explanation and source

The inputs selected for both DEAs are fairly standard in the literature (see Ferro & D'elia, 2020) and also recommended by Pedro et al. (2026). Here we do not address the issue of quality, whilst this is an existent gap, we focus this issue on the outputs.

Total Revenue is the main resource available to the HEI, the money the institution has available to spend, and can be divided in three slices: Public funding (transfers from the state and EU funds), Internally generated revenue (mostly from student fees, or "propinas") and funds balance from previous year (the "profit" that remains from 2023). While most data is for 2024, some of the HEI present consolidated accounts that give us the actual revenue generated, whilst others only have activity plans available, but if they are from 2025, they also present this information as well on their projections. Lastly, U.Madeira only presents data for 2023 at the date data was extracted, but since it's only a year difference and revenues of HEI do not vary much year by year, we carry this value forward to avoid taking an important HEI out of the sample.

The second input, Students Enrolled, in the DEAt follows a logic similar to natural resources in normal firms, they are going to be "transformed" into the "final product", that is, graduates. Their use as an input also allows us to take size differences into account, complementing the VRS configuration. Since this input is quite unique, we also compute a version of the DEAt without it to see if the ranking is affected much, as recommended by Wolszczak-Derlacz (2017).

Lastly, we use the measure of Academic Staff as our labor input. Here we include all academic staff, including teaching assistants and invited professors, as they all contribute to the teaching process. Our measures are in full-time equivalent, which allow us to consider that many professors do teaching as a

part-time (for example, if a professor only teaches 50% of the normal class time, he counts as 0.5 in these statistics). This is the optimal labor measure in the literature.

The DEAr inputs are similar, but slightly different:

Name	Stata	Explanation	Source
Total Revenue	TotFin	Total revenue available to the institutions in 2024, taken from their consolidated accounts and activity plans, and measured in euros.	Financial Reports
Students Enrolled in Master's or PhD	Mdenrl	Number of Students enrolled in each HEI in the academic year of 2023/24, in 2nd cycle (Master) and 3rd Cycle (PhD) as well as Integrated Master's	DGEEC
Number of Academic Staff (excluding TAs) – FTE	AFFTEstf	FTE measure of Academic Staff focusing on Full, Associate and Assistant Professors and purely research Staff but excluding Teaching Assistants, Visiting Professors and Monitors	DGEEC

Table 4 - DEAr Inputs, explanation and source

Total revenue is exactly the same as in DEAt, with the same logic. Here the labor input is smaller, as we focus on the Academic Staff that has research has one of their functions, therefore excluding Teaching Assistants and other smaller categories. Lastly, we also focus only on those students enrolled in 2nd cycle (Masters) and 3rd cycle (PhDs) courses, as normally those are the ones that contribute to research through their thesis work (even if only some are published, particularly master students). We also exclude this last variable in a more restricted DEA to gage impact.

The DEAr and DEAt outputs can be found in the following Tables:

Name	Stata	Explanation	Source
Number of Publications	NumPub	Articles and Reviews published in Scientific journals by authors associated with the HEI in question in the years of 2023 and 2024	Scopus[2]
Average Citations	AvCit	Average Citations accumulated so far on Articles and Reviews published in the years of 2023 and 2024 in Scientific journals by authors associated with the HEI in question.	Scopus[2]

Table 5 - DEAr Outputs, explanation and source

Name	Stata	Explanation	Source
Number of Graduates	Grad	Number of Graduates in courses which attribute a ISCED recognized diploma, regardless of cycle, by HEI in the Academic Year of 2023/24	DGEEC
Employment Rates	PLOY	Employment rate in 2024 from those who graduated from the HEI between 2021 and 2023, regardless of cycle. Built from unemployment rates	DGEEC

Table 6 - DEAt Outputs, explanation and source

The first output of each DEA, the number of Graduates for DEAt and the number of publications in DEAr, are purely quantitative measures of output, that are as common as they come in the literature (by

[2] The data was taken from Scopus using the search by affiliation feature, using each HEIs unique id to avoid double counting issues.

checking Table 1 in the literature review one can easily check that for many studies they are the only outputs considered). We consider the number of graduates in the year 2023/24 regardless of the finished cycle. Regarding the number of publications, we only consider articles and reviews, and since we don't have data exclusive for the academic year of 2023/24, we consider all publications in the regular years of 2023 and 2024, with the weakness that this variable is sensitive to the area of publication.

The second set of outputs for each DEA seeks to account for quality. The lack of quality-focused inputs and outputs is one of the large literature gaps we and Almeida et al. (2025) identified. With these variables we will seek to partially address these gaps.

The Average Citations are built from Scopus Data, and they seek to proxy the quality of the publications of the years 2023 and 2024, by measuring the citations these publications have accumulated thus far (as of 14/03/2026 when the Scopus data was gathered). This variable's main weakness is the dependence of the area of publication. Due to either faster research production or higher volume of research, some areas accumulate citations faster than others, without this being necessarily indicative of quality. We will seek to address the influence of specific areas in the second stage through area specific variables.

The employment rates were built from DGEEC data on unemployment, they will seek to proxy the quality of graduates, although they also account for the connection between employers and the HEI as well. This data is also dependent on the specific dominant areas and location of each HEI.

Following, we will present some descriptive statistics and plots that will show some of the problems illustrated thus far:

Variable	Obs	Mean	Std. dev.	Min	Max
TotFin	32	9.70e+07	1.11e+08	1.06e+07	4.71e+08
StfETI	32	659.6537	651.1805	58.35	3103.867
AFFTEstf	32	549.5259	570.1799	53.74	2690.91
StuEnrl	32	10711.63	10860.27	896	50356
Mdenrl	32	3748.594	5596.409	65	22657
Grad	32	2474.188	2739.467	153	12158
NumPub	32	1972.375	3099.287	18	11963
AvCit	32	12.0348	12.66934	3.5	78.85306
PLOY	32	.9751597	.0123924	.953843	.999221

Table 7 - Stata Output - descriptive statistics for inputs and outputs considered

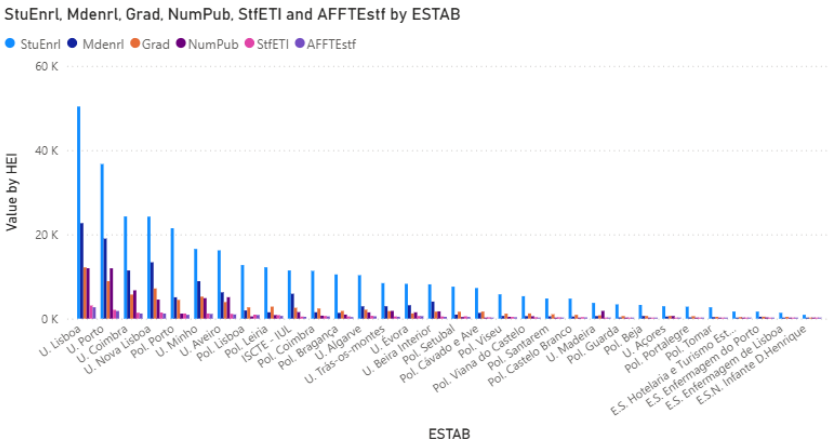


Figure 2 - Comparison of HEI by StuEnrl Mdenrl Grad NumPub StfETI AFFTEstf

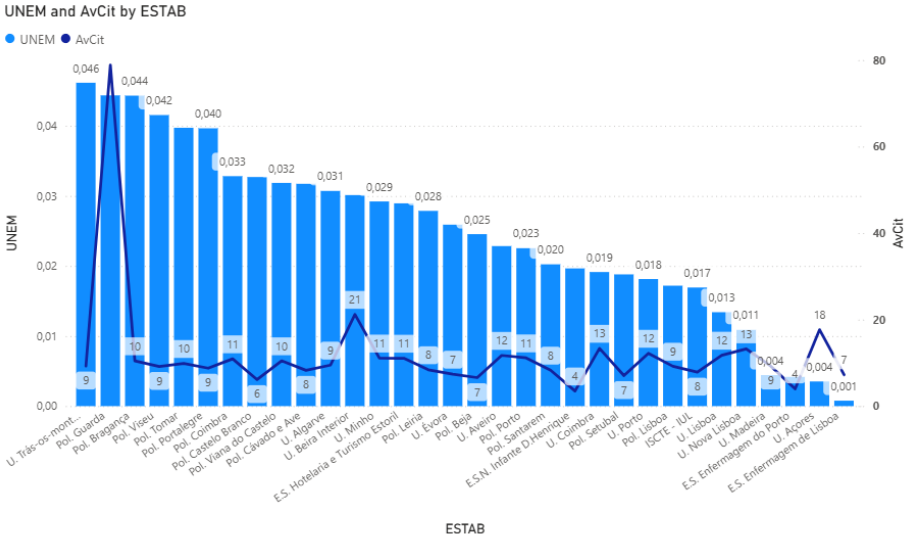


Figure 3 - Comparison of HEI by AvCit and UNEM

Table 7 and Figure 2 show the large size differences in HEI we noted thus far, as well as their different degrees of focus on Research (through the standard deviation of the number of publications).

Figure 3 reveals far more. For example, through the unemployment rates (UNEM in the chart, used instead of employment rates for ease of interpretation) we see the influence of different areas through the low values presented by the E.S.E., the professional nursing schools. We can also see the difference in goals when we compare these results with those of average citations, where they are clearly poorer, revealing a focus on Teaching rather than research.

The Politécnico da Guarda presents an outlier value in its average citations as can be easily seen. This is due to the participation in international research projects which generate highly cited papers, combined with a smaller sample of publications. We will address this by conducting a DEA without this observation

and attesting if this affects our results seriously or not. If they do, we will remove it from the DEAr scores and regression.

4.3. Independent Variables:

We will address the variables that will be taken as independent variables in the truncated regression. Some are common in the literature; others are new additions. We will seek to explain the logic behind their inclusion and their limitations. We will also attest for their separability. The table below presents all variables:

Name	Stata	Explanation	Source
Location	MET	Binary variable that takes the value of 1 if the HEI is located in either the metropolitan area of Lisbon or Porto, built from institutional information	HEI Pages
Type of Institution[3]	Uni	Binary variable that takes the value of 1 if the HEI in question is a university, built from institutional information	Built from DGES
Teacher – Student Ratio	TSRatio	The ratio of Academic Staff (regardless of qualification/regime) to Students Enrolled (regardless of cycle/course) both in headcount, in the academic year 2023/24	Built from DGEEC
% of Students with Social Scholarships	StuSAS	Percentage of students receiving DGES social scholarships (SAS) in a given HEI in the academic year of 2023/24	Built from IGeFE and DGEEC
Courses – Faculties Ratio	CFR	The number of courses offered in the academic year of 2023/24 divided by the number of internal organic units (faculties/schools)	Built from DGEEC
Private-Public Revenue Ratio	rtPropPub	Ratio of the Revenue generated internally by the revenue originated from public sources, the national budget and EU funds, in the year 2024	Built from Financial Reports
% of Students in Health	rtMedStu	Percentage of Students enrolled in courses of the following CNFAE[4]: (9) Health in the academic year 2023/24	Built from DGEEC
% of Students in STEM	rtStemStu	Percentage of Students enrolled in courses of the following CNFAE[4]: (5) Natural Science, Math and Statistics, (6) Information and Communication Technology and (7) Engineering, Manufacturing and Construction in the academic year 2023/24	Built from DGEEC

Table 8 - Independent Variables, explanations and sources

The first binary variable is a location variable. These are common in the literature (Agasisti, 2011; Agasisti et al., 2021; Martínez-Campillo & Fernández-Santos, 2020) but take different forms considering the exact sample we are working with. In the case of Portugal our main interest is in the two main cities of Lisbon and Porto, which comprise 40% of the country's population, and how the presence in these metropolitan areas may affect efficiency. We have 11 of our HEI that are located in either metropolitan

[3] Here, the Universities we previously mentioned which have polytechnic style internal organic units, have been classified as universities, as they still behave mostly as such.

[4] CNAEF: Classificação Nacional das Áreas de Educação e Formação (National Classification of Education and Training Areas).

area, which includes the two largest (U.Porto and U.Lisboa) and the four smallest (E.S.E. de Lisboa, do Porto, E.S.H.T. do Estoril, E.S.N. Infante D. Henrique) HEI. These 11 HEI account for 49.61% of enrolled students in the academic year of 2023/24. We would expect a positive effect as these HEI have access to bigger networks, more students, and a larger surrounding labor market, as well as a bigger international projection and prestige, which is relevant to attract foreign students and staff as well as to access research networks.

The second binary variable will denote the type of institution, dividing the sample into 13 universities and 19 remaining institutions, which are classified by DGES as polytechnic-style institutions. These will allow us to distinguish between the different missions of these HEI types. Universities concentrate 64.6% of students in 2023/24. We would expect a pronounced difference in the Research-focused regression, as polytechnics still focus little on research, but the teaching results are more ambiguous as both HEI focus on teaching as a primary goal.

The weight of students with DGES social scholarships, SAS, in the student body is a proxy of the socioeconomic structure of the latter, and, to a lesser extent, the measure of the impact of social third-mission goals in the efficiency of the other two. Whilst variables that account for the characteristics of the student body are common, this variable itself new in the literature as far as I'm aware. The expected result is quite ambiguous, but likely negative on both efficiencies as students may require greater institutional support and resources and are more likely to drop out. This is what similar variables in the literature (such as students with free lunch in the U.S.) find (Worthington, 2001).

To account for institutional complexity, we will use a ratio of the number of courses offered in the academic year of 2023/24 by the total number of internal organic units (that is faculties/schools). This will account for the level of internal fragmentation, whilst the use of any of these variables separately will be highly correlated with the size of the institution which will have separability issues. We would expect more fragmentation to imply less efficiency as the bureaucracy involved, and its costs, rise.

The private-public revenue ratio was built from data gathered in institutional financial reports. It is not uncommon in the literature (Agasisti & Ricca, 2015; Papadimitriou & Johnes, 2019; Wolszczak-Derlacz, 2017; Wolszczak-Derlacz & Parteka, 2011) and tells us the effect that greater financial self-reliance will have on efficiency. This is particularly relevant given the current trajectory of Portuguese HE as described in chapter 1. We expect a positive relation with both efficiencies as more self-reliance may lead to more autonomy to apply changes that positively reflect efficiency.

Two variables are meant to deal with the fact that some of the outputs are affected by the specific areas in which the HEI specializes. These are two ratios: the ratio of students enrolled in STEM programs and the ratio of students enrolled in Health programs (according to CNAEF classification), regardless of cycle. Measures to account for the field of medicine are more common, and tend to take the form of a binary variable (Agasisti et al., 2021; Agasisti & Ricca, 2015; Martínez-Campillo & Fernández-Santos, 2020; Wolszczak-Derlacz, 2017; Wolszczak-Derlacz & Parteka, 2011), although sometimes they appear as a ratio (Papadimitriou & Johnes, 2019). Focus on STEM is also present, if less common, and sometimes limited to engineering, normally in the form of a binary (Martínez-Campillo & Fernández-Santos, 2020; Wolszczak-Derlacz, 2017).

We expect that the first ratio (rtStemStu) affects efficiency positively, as these courses tend to generate highly cited publications in greater number, and also have strong results in the labor market. This is also the effect registered in the literature (Martínez-Campillo & Fernández-Santos, 2020; Wolszczak-Derlacz, 2017). The second ratio (rtMedStu) is more ambiguous, and the result may go either way, for teaching, these courses have excellent labor market results, but they tend to have far less students and be costly for a HEI to have, such that we may have an internal trade-off between quantity and quality in teaching, however we may expect a positive effect in terms of research, as this area produces highly cited research in high numbers.

The independent variables considered thus far are all institutional and either outside the HEI control, like the % of students with SAS scholarships, or very hard to change in the short run, such as the degrees offered or even the location, so it is clear that these variables are separable, they have no impact on the underlying technology.

The teacher-student ratio is primarily an intensity metric that also proxies the allocation choices of the HEI (such as the size of classes). It is a new addition that is not common in DEA literature; no other examples can be found as far as I know. It is also a metric often discussed in the Portuguese national context as a metric of efficiency, parroting the initial labor productivity ratios that Farrell (1957) criticized, and in this vein, it is sometimes cited as the main metric of efficiency. Its inclusion will allow us to test Farrel's initial suspicion of these types of metrics.

Should it prove a good measure of efficiency as it is interpreted traditionally, we may expect to find a trade-off, in which a lower ratio implies higher teaching efficiency, as one teacher is responsible for more students, but less research efficiency, as staff has less time to apply in research activities, this may harm both the quantity and quality of research. This variable is directly related to some of the inputs, the number

of academics (although the ratio uses the headcount and not the ETI measurements) and students enrolled, however it reflects internal choices of allocation by each HEI, it is hard to justify it impacting the frontier itself, the underlying technology, so we can assume separability, although weaker than the other variables. We will re-estimate the models without it to test for robustness. We present here the descriptive statistics and plots of these variables; they reinforce our conclusion of high heterogeneity between DMUs:

Variable	Obs	Mean	Std. dev.	Min	Max
Type	32	.40625	.4989909	0	1
Met	32	.34375	.4825587	0	1
TSRatio	32	.0955961	.0262305	.0575577	.2167883
StuSAS	32	.141649	.055335	.0435268	.281762
CFR	32	18.9852	8.658393	6.625	40.88889
rtPropPub	32	.2621707	.1213678	.0569486	.5877911
rtStemStu	32	.2848973	.1411726	0	.5412946
rtMedStu	32	.1937418	.2265642	0	1

Table 9 - Stata Output: descriptive statistics for the chosen independent variables

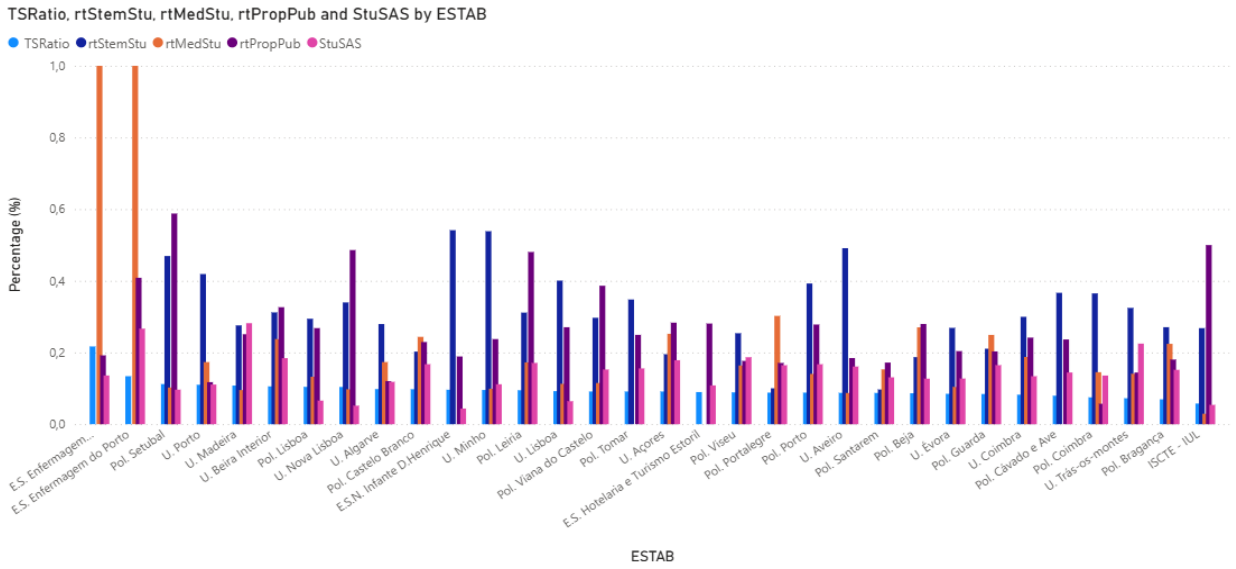


Figure 4 - Graph comparing TSRatio, rtStemStu, rtMedStu, rtPropPub and StuSAS by ESTAB

Figure 4 and Table 9 reinforce the heterogeneous character of the HEI in the sample.

We test multicollinearity issues in our variables making use of VIF metrics as well as Condition numbers. VIF values operate under the null hypothesis that a given variable is not redundant. Condition numbers operate under the null hypothesis that the independent variable matrix is orthogonal. We will make use of the “collin” command developed by Ender (2010).

Variable	VIF	SQRT VIF	Tolerance	R-Squared
Type	1.34	1.16	0.7457	0.2543
Met	2.05	1.43	0.4882	0.5118
TSRatio	2.84	1.69	0.3519	0.6481
StuSAS	1.96	1.40	0.5102	0.4898
CFR	1.53	1.24	0.6522	0.3478
rtPropPub	1.24	1.11	0.8094	0.1906
rtStemStu	1.91	1.38	0.5244	0.4756
rtMedStu	4.09	2.02	0.2446	0.7554
Mean VIF	2.12			

	Eigenval	Cond Index
1	6.7124	1.0000
2	0.8867	2.7514
3	0.6494	3.2149
4	0.3976	4.1088
5	0.1343	7.0693
6	0.1064	7.9440
7	0.0642	10.2265
8	0.0377	13.3392
9	0.0113	24.4101
Condition Number		24.4101
Eigenvalues & Cond Index computed		
Det(correlation matrix)		0.0556

Figure 5 - Stata Output: collin comand results

Our VIF value is below 5, both the mean VIF and individual VIF, so it does not indicate multicollinearity issues. Our condition number is above 10, which indicates moderate multicollinearity, but below 30, the value at which it would prove a problem. These values are also a result of a small sample size. So, this should not present a problem. We may estimate a model without the rtMedStu, which seems to be the main source of multicollinearity, to test robustness.

5. Results and Discussion:

5.1. Data Envelopment Analysis Results:

5.1.1. Teaching-Focused DEA:

The bias-corrected, technical efficiency measurements that result from the teaching-focused DEA (TE Scores) are presented below, as well as the scale efficiency metrics (Scale Eff) (some of the values presented in this category are greater than 1 due to the bootstrap procedure, in this case the DMU being scale efficient) and type of scale inefficiency from our normal DEA results (Scale Type (N-DEA)), divided between increasing and decreasing returns to scale (IRS and DRS):

ESTAB	Ranking	TE Scores	Scale Eff	Scale type (N-DEA)
U. Nova Lisboa	1	0.991848	0.925613	-
ISCTE – IUL	2	0.991384	0.861915	-
U. Açores	3	0.988308	0.717947	DRS
U. Lisboa	4	0.988179	0.864717	DRS
U. Madeira	5	0.987947	0.793481	IRS
E.S. Hotelaria e Turismo Estoril	6	0.987497	0.927449	-
U. Porto	7	0.986273	0.944219	DRS
E.S.N. Infante D. Henrique	8	0.986174	0.91617	-
U. Minho	9	0.984048	0.944284	-
U. Coimbra	10	0.98271	0.793508	DRS
Pol. Lisboa	11	0.982693	0.901041	DRS
E.S. Enfermagem de Lisboa	12	0.981139	1.001583	-
Pol. Viana do Castelo	13	0.981018	0.982456	IRS
Pol. Cávado e Ave	14	0.979153	0.88377	-
Pol. Setubal	15	0.978277	0.832127	DRS
U. Aveiro	16	0.97638	0.794627	IRS
Pol. Porto	17	0.973027	0.969261	-
Pol. Santarem	18	0.971685	0.859985	IRS
U. Évora	19	0.971505	0.487877	IRS
Pol. Coimbra	20	0.968741	0.966421	IRS
Pol. Leiria	21	0.96767	0.945243	DRS
U. Algarve	22	0.967661	0.830182	IRS
Pol. Beja	23	0.966272	0.764965	IRS
U. Beira Interior	24	0.965544	0.891484	IRS
Pol. Castelo Branco	25	0.961906	0.744582	IRS
E.S. Enfermagem do Porto	26	0.958628	1.018414	-
Pol. Viseu	27	0.954101	0.796907	IRS
Pol. Bragança	28	0.952222	0.705846	IRS
U. Trás-os-Montes	29	0.950681	0.741318	IRS
Pol. Portalegre	30	0.950532	0.720472	IRS
Pol. Tomar	31	0.950042	0.69981	IRS
Pol. Guarda	32	0.944358	0.803672	IRS

Table 10 - DEAt Results

We obtain an average of 0.9727 for the Technical Efficiency metric of our VRS Bias-corrected DEA. These results imply that in regard to the goal of teaching, Portuguese HEI are generally very efficient, particularly in terms of pure technical efficiency which is associated with managerial performance and choices (in comparison, Pedro et al. (2022) finds an average efficiency of 0.5422 for teaching in Portuguese HEI, which may be explained by a different sample, inputs and outputs, particularly because we consider quality, as well as different years taken into the sample).

Most inefficiency in teaching seems to derive from scale issues, with an average of 0.8447. While this value is still high, we note that only 2 HEI, E.S.E. de Lisboa and E.S.E. do Porto, the professional nursing schools, are considered optimally scaled. Using the results of our Normal DEAt (non-bias corrected) which are present in the last column of Table 10, we can attest that most HEI (half of the sample) were considered as too small (Increasing Returns to Scale), whilst 7 were considered too large (Decreasing Returns to Scale) which includes the bigger HEI in our sample U.Lisboa and U.Porto.

Differences between universities and polytechnics can be seen here as well, as Universities' average pure technical efficiency are higher than that of Polytechnics: 0.9794 against 0.9682. However, in terms of scale, Polytechnics prove to be quite more efficient with an average of 0.8653 against 0.8147. The first of these results lead us to expect a negative coefficient in our second-stage regression on the binary variable associated with University HEIs.

Lastly, we also calculated two different pure efficiency metrics, considering only one output and the three inputs. The one which maintains the number of graduates output is a quantity-focused metric, the one maintaining employment rates is a quality-focused metric. Whilst our quality-focused metric maintains a high degree of average technical efficiency (0.9720), the results of our quantity-focused metric vary more and indicate a lower level of average efficiency (0.8052). The two metrics have a positive correlation (0.4187). This can be seen in Figure 6.

The size of the marks is directly proportional to the size of each HEI as measured through the number of students enrolled in 2023/2024 (StuEnrl). It is hard to see a direct relationship between any of this metrics and size, whilst bigger HEI such as U.Lisboa and U.Porto perform well, the best (E.S.E de Lisboa, do Porto, U.Madeira, U.Açores) and worst (U.Evora, U.Trás-os-Montes, Pol.Guarda and Pol.Tomar) results are obtained by smaller HEI. These and our scale results lead credence to the idea that the relation between size and efficiency in Teaching is more complex than a simple linear relationship, but little more can be said with this information.

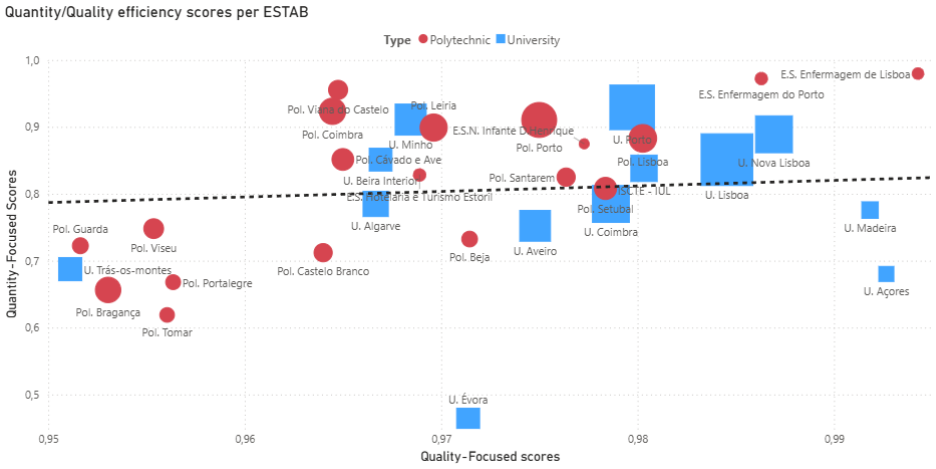


Figure 6 - Dispersion Graph comparing Quality and Quantity efficiency metrics (DEAt)

To test the sensitivity of these results, our pure technical efficiency scores (SW-VRS) will be compared to the results of other DEA, including: the quality (Qual) and quantity (Quant) focused results, the Bias-corrected CRS results (SW-CRS), normal DEA results, both CRS (N-CRS) and VRS (N-VRS) and a Bias-corrected VRS DEA metric without the students enrolled input (noStu), as the uniqueness of this input may lead to big alterations in results (Wolszczak-Derlacz, 2017). The small table below presents the correlation metrics between the TE scores of the supplementary DEA models with the baseline SW-VRS model:

ESTAB	N-CRS	N-VRS	noStu	Qual	Quant	SW-CRS
Correlation	0,52	0,88	0,88	0,77	0,45	0,45

Table 11 - Correlation Metrics (DEAt)

We obtain positive and generally elevated levels of correlation to all supplementary DEA metrics. Generally, we get high correlation with other VRS metrics and also with the noStu metric (so the inclusion of students as an input does not impact measurements drastically), implying robustness. With the CRS results we obtain a smaller correlation, which is to be expected, as these results do not separate scale efficiency. Lastly, our main measurements are more highly correlated with our Quality-focused metrics

than our Quantity-focused Metrics, reflecting the impact that accounting for quality may have on results and exposing the limits of purely quantitative studies.

5.1.2. Research-Focused DEAr:

We proceed in much the same way to our Research-Focused DEA. Below we present the Pure Technical efficiency (TE Scores) and Scale efficiency (Scale Eff) metrics, both bias-corrected, and the type of scale inefficiency as obtained from our normal DEAr results (Scale type (N-DEA)):

ESTAB	Ranking	TE Scores	Scale Eff	Scale type (N-DEA)
E.S. Enfermagem de Lisboa	1	0.862348	0.978641	DRS
U. Lisboa	2	0.859331	0.482837	DRS
U. Aveiro	3	0.844502	0.563756	DRS
U. Porto	4	0.812013	0.750464	DRS
U. Coimbra	5	0.805325	0.658834	DRS
U. Beira Interior	6	0.785566	0.922555	-
U. Açores	7	0.735029	1.055988	DRS
U. Minho	8	0.706732	0.581088	DRS
U. Madeira	9	0.699064	1.152598	-
E.S.N. Infante D. Henrique	10	0.6775	1.08591	-
E.S. Hotelaria e Turismo Estoril	11	0.671698	1.009485	-
U. Nova Lisboa	12	0.655073	0.542536	DRS
Pol. Portalegre	13	0.577123	1.028451	DRS
U. Trás-os-Montes	14	0.576464	0.666144	DRS
E.S. Enfermagem do Porto	15	0.572719	0.849478	-
Pol. Tomar	16	0.551074	0.797152	IRS
Pol. Bragança	17	0.545347	0.604021	DRS
U. Algarve	18	0.532674	0.562328	IRS
Pol. Cávado e Ave	19	0.526255	1.037543	IRS
Pol. Coimbra	20	0.512779	0.497241	DRS
Pol. Viana do Castelo	21	0.504998	0.865518	DRS
U. Évora	22	0.460099	0.530274	IRS
ISCTE – IUL	23	0.452427	0.725608	IRS
Pol. Leiria	24	0.452084	0.423486	DRS
Pol. Porto	25	0.439745	0.472375	DRS
Pol. Viseu	26	0.421048	0.862302	DRS
Pol. Lisboa	27	0.395051	0.413195	IRS
Pol. Santarem	28	0.360183	0.82855	DRS
Pol. Beja	29	0.347276	0.831475	IRS
Pol. Setubal	30	0.32887	0.577881	IRS
Pol. Castelo Branco	31	0.269357	1.075896	IRS

Table 12 - DEAr Results

Notice that only 31 DMUs are present on the table. As mentioned in chapter 4, Pol. Guarda has an outlier value in our AvCit metric. To attest to the impact of this outlier a Bias-corrected VRS DEA with and another without this HEI were calculated. What we find is that the absence of the outlier increases the efficiency scores of the remaining HEI by an average factor of 1.5722 (the value of the average ratio of our technical efficiency scores obtained without the outlier can be seen in table 12, by the scores with the

outlier, which can be seen in the appendix B.4.). Since this is a difference in proportion we cannot ignore, we decided to exclude the HEI from the sample for the DEAr.

Just by looking at the table we can see that there is a higher degree of variation than in our DEAt results, both in terms of pure technical and scale efficiency. On average we have a pure technical efficiency score of 0.5787, far lower than our DEAt, which signifies that management of HEI in Portugal are not effective in achieving Research goals. To add to this, no HEI is considered even near efficient in our scores, which indicates that in the multiple bootstrap regressions no HEI occupied consistently the frontier, with the highest score being below 0.9. This is on par with the results of Pedro et al. (2022) which also find a relatively smaller efficiency level to Portuguese HEI in research (0.3831) compared to teaching.

In terms of scale, the average score is 0.7559 which is still lower than our DEAt results, but closer. To note is that we have a higher variation as now we have 7 HEI that can be considered scale efficient (many have scores above 1 due to bootstrap procedures and due to the high variability of DEAr scores, these DMU should be taken as efficient). Whilst scale is still an issue, it appears that here managerial organization associated with pure technical efficiency is a bigger issue.

Most DMU in our normal DEA results present DRS (17 in 31) with IRS (9 in 31) being rarer. Even smaller DMU such as E.S.E. de Lisboa present DRS, as well as both U.Lisboa and U.Porto, which may indicate that the optimal scale for research is smaller than for teaching and may imply that research and teaching respond differently to issues of scale.

Starker here are the contrasts between universities and polytechnics, particularly in terms of pure technical efficiency with an average score of 0.6865 for the former against an average score of 0.5009 for the latter. This was expected and is clearly a result of the still lower focus on research of most polytechnics in Portugal. Unexpected is the fact that the average scale efficiency scores are still higher here: 0.7910 for polytechnics against 0.7073 for universities. This implies that the average polytechnic is better dimensioned to take advantage of their scale in research activity than the average university, should management assume this goal.

We also calculated quality and quantity focused metrics for research using much the same idea as before. One only took AvCit as output, the other only the number of publications. In this angle we have generally lower averages with an average score of 0.4464 for the Quantity-focused scores and an even lower 0.3790 for the quality-focused scores, with no HEI achieving efficiency in either dimension. These metrics have a low correlation (0.1558).

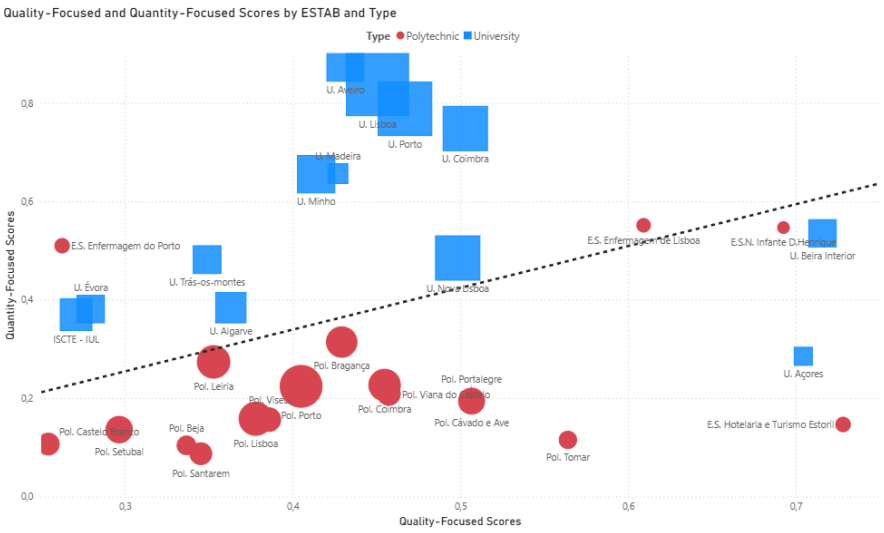


Figure 7 - Dispersion Graph comparing Quality and Quantity efficiency metrics (DEAr)

However, another pattern becomes apparent here, analyzing from left to right no pattern regarding size (as measured by the number of students enrolled in 2023/24) seems visible, that is size appears to have no significant influence on quality-focused efficiency, but analyzing from top to bottom it becomes apparent that size very much has an impact on achieving a high number of publications efficiently, there may be economies of scale associated with efficiency in research quantity, although the relation with quality may be more complex.

Lastly, we test the sensitivity of our results following the same procedure as before, inspired by Wolszczak-Derlacz (2017). The correlation levels between the auxiliary DEA (normal CRS and VRS, SW's CRS, SW's without student input and quantity/quality-focused scores) models and our main model can be found below (the models use the same tags as those used in the previous section):

ESTAB	N-CRS	N-VRS	NoStu	Qual	Quant	SW-CRS
Correlation	0,67	0,95	0,96	0,63	0,83	0,73

Table 13 - Correlation Metrics (DEAr)

In general, the correlation values are higher than in the previous section, reinforcing the robustness of these results. The N-VRS and NoStu metrics have correlation levels of 0.95 and 0.96. The latter implies that the Master and PhD students' input is not all that impactful in our ranking (and may not be a good input for future Research-focused DEA). The N-CRS and SW-CRS are lower, as expected, but still around 0.7, which is quite significant and reflects the lower importance of scale to attest for inefficiency compared to the DEAt, as we attested above. Lastly, in contrast to our DEAt, the DEAr ranking has higher correlation with our quantity metric than with the quality metric.

5.1.3. Comparisons:

Before advancing to the regressions, we can make a number of comparisons with this data. We start by comparing our main pure technical efficiency results for Research and Teaching:

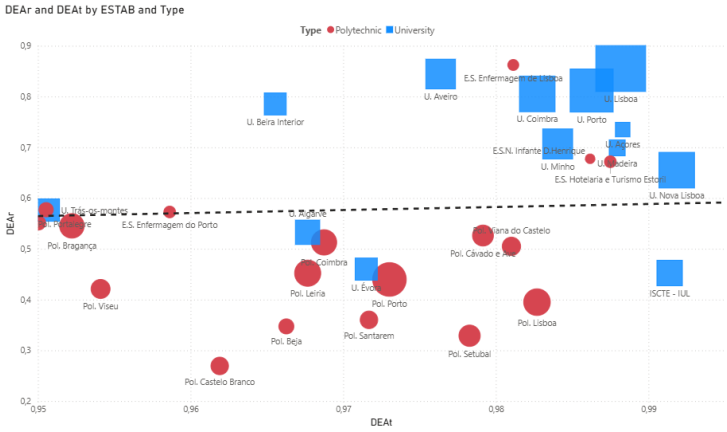


Figure 8 - DEAr and DEAt Comparison

We have a light positive correlation (0.382). It is interesting to note that both the biggest and smallest HEI in our sample are concentrated in the top right corner which denotes the HEI that are more efficient in both dimensions.

We may also compare how the quality and quantity focused metrics compare:

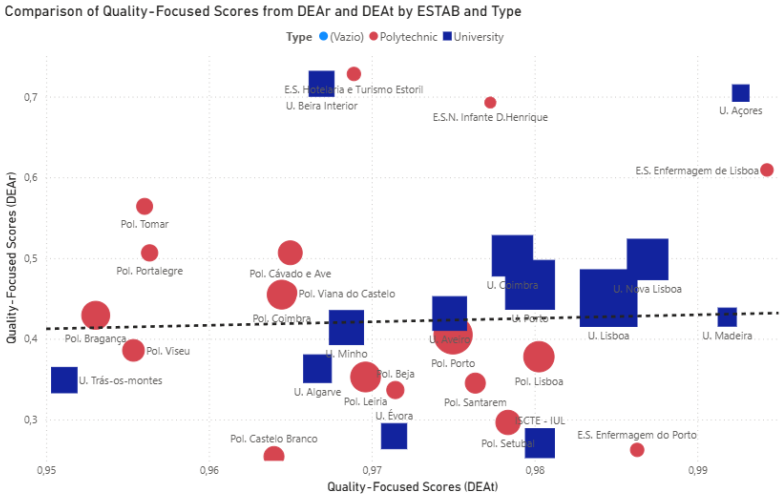


Figure 9 - Comparison of Quality-Focused Metrics

In terms of Quality, no relation can be seen (0.1109 correlation), one can note that the top right corner is quite empty, only U.Açores and E.S.E. de Lisboa seem to be able to be more efficient in achieving quality teaching and research. In relation to size there is no apparent relation either.

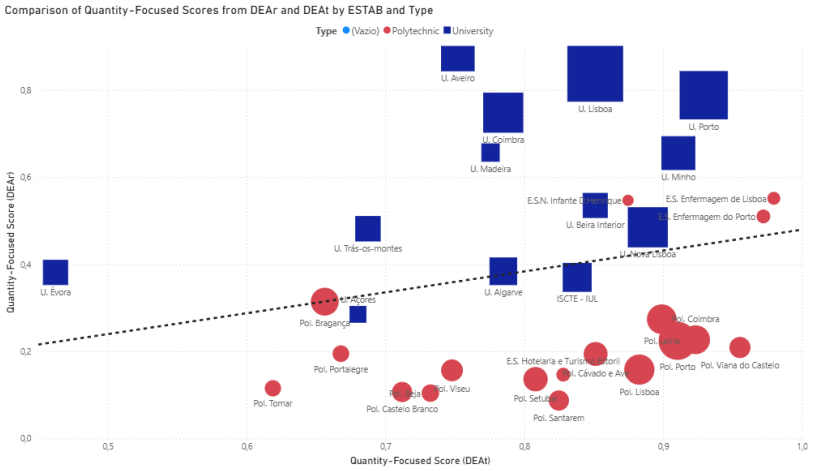


Figure 10 - Comparison of Quantity-Focused Scores

In terms of Quantity, there appears to be a clearer positive relation, however the correlation level, whilst positive, is still low (0.2039). There is a clear divide between universities and polytechnics, which seem to be due mostly to the DEAr scores. Likewise, size also seems to be relevant mostly due to the DEAr results, which we already have commented on.

From these results, we cannot conclude that greater efficiency in a given goal will lead to greater efficiency in the other, but we cannot also rule out the opposite either. Whilst our Regression results may provide some more clarity for the trade-offs and complementarities here associated, the deeper question of the relationship between teaching and research in HE will be touched here but not fully answered.

Size, here measured through the number of students enrolled in the academic year (StuEnrl) is the most important possible determinant that, due to the methodology followed, could not be carried through to the regression without breaking separability. Instead, it was used as a teaching input, and a more restricted version as a research input. We can still draw some brief conclusions.

The results of our scale efficiency metrics shift, from the majority being too small (IRS) in Teaching to the majority being too large (DRS) in Research, implying that the optimal scale might change according to the goal in question, however the 3 biggest HEI: U.Lisboa, U.Porto and U.Coimbra maintain DRS in both DEA, so it seems safe to assume that these HEI are larger than optimum, whilst the smallest: the E.S.E.s and E.S.H.T do Estoril and E.S.N. Infante D. Henrique are actually considered optimally sized most of the time, even in our bias-corrected scores. In terms of the relation between size and pure technical efficiency, there seems to be a generally positive relation, but this relation is more notable in quantity-focused Research efficiency, and particularly irrelevant in the case of Research quality efficiency, as seen in the table below. This, however, is the limit of what our methodology allows us to say.

Corr. With Students Enrolled	*Teaching*	*Research*
General	0.3631	0.3938
Quantity	0.2278	0.5767
Quality	0.2177	-0.0905

Table 14 - Correlation between size (StuEnrl) and DEA scores

5.2. Truncated Regression Results:

5.2.1. DEAt Regression Result:

Below we present the results for a series of regressions in order to identify what variables determine the scores we computed thus far and in order to identify relations between the two goals. First is our main regression, then we disaggregate by quantity and quality, lastly, we perform a series of other regressions to test sensitivity and possible multicollinearity issues. We do this by removing variables and testing how this impacts the remaining coefficients. We also add regressions on our CRS results, other models such as Tobit and OLS that are commonly used and alter the number of bootstrap repetitions to 500 and 2000 like Wolszczak-Derlacz and Parteka (2011).

Looking at our main result, we can identify 4 relevant variables: MET, which denotes if a HEI is located in the metropolitan areas of Lisbon or Porto, Uni, which denotes if a HEI is a University, TSRatio, the teacher student ratio, and rtMedStu, the ratio of students enrolled in a degree classified as medical by the CNAEF.

Met and Uni have a negative coefficient which implies they contribute positively to efficiency of teaching output of HEI. The result of Uni was already expected as we knew that the average pure technical efficiency of universities was higher than that of polytechnics, however when only quantity is considered, the coefficient is positive, whilst the negative coefficient is verified when quality is considered. This may imply that Polytechnics are actually more efficient than Universities in pumping out graduates, but these may have worse employability outcomes, therefore being perceived as of “worse” quality. There is little evidence in the literature to compare this to as most studies only consider universities and exclude polytechnics.

	Variables[5]							
Model – DEAt	MET	Uni	TSRatio	StuSAS	CFR	rtPropPub	rtStemStu	rtMedStu
SW Truncated Regression	**-0.01052***	**-0.01409*****	**-0.2682****	0.069141	0.000104	-0.02503	0.012839	**0.035909****
Quality-Focused Regression	**-0.00943****	**-0.12615*****	**-0.24212****	0.016769	0.0002768	**-0.0228456***	0.005964	0.0008212
Quantity-Focused Regression	**-0.50356***	**0.24286***	-6.858037	-0.947595	-0.008864	-0.2453715	-1.039812	-0.9388358
Without Students Input	**-0.0151*****	**-0.01322*****	**-0.29815****	0.035981	0.0000442	-0.0080773	0.0202949	0.0201997
SW TR - no TSRatio	**-0.01433****	**-0.01587*****	------	**0.090447***	0.0002	-0.02747	0.007588	0.011379
SW TR - no rtMedStu	-0.00956	**-0.01552*****	-0.081	**0.114028****	0.000221	-0.02923	-0.00682	------
SW TR - no TSRatio rtMedStu	**-0.0121****	**-0.016*****	------	**0.108516****	0.000232	-0.02908	-0.00228	------
SW TR - no rtStemStu	**-0.01044***	**-0.01363*****	**-0.25557****	0.068824	0.000157	-0.02551	------	**0.030434****
SW TR - no CFR	**-0.01038***	**-0.01354*****	**-0.27492****	0.06615	------	-0.02387	0.014874	**0.037136****
SW TR - no CFR rtStemStu	**-0.01014***	**-0.01262*****	**-0.26271****	0.063914	------	-0.02375	-------	**0.030615****
SW TR - no CFR rtStemStu rtPropPub	**-0.12944****	**-0.01251*****	**-0.25824****	0.055839	------	------	------	**0.032028****
SW TR CRS	**-0.62254***	**0.283362*****	-8.00675	-1.21953	-0.00968	-0.17454	-0.99351	-0.76128
OLS	-0.00924	**-0.0129*****	**-0.27****	0.057414	0.000142	-0.01974	0.010162	**0.034737***
Tobit	**-0.00924***	**-0.0129*****	**-0.27****	0.057414	0.000142	-0.01974	0.010162	**0.034737****
500 Bootstrap Repetitions	**-0.01052***	**-0.01409*****	**-0.2682****	0.069141	0.000104	-0.02503	0.012839	**0.035909****
2000 Bootstrap Repetitions	**-0.01052***	**-0.01409*****	**-0.2682****	0.069141	0.000104	-0.02503	0.012839	**0.035909****

Table 15 - DEAt Regression Results

The result of Met also aligns with our expectation described in the Data chapter, and with the literature which finds that more developed territories tend to affect efficiency positively (Agasisti & Ricca, 2015; Cantele et al., 2016; Lee, 2011; Martínez-Campillo & Fernández-Santos, 2020; Tran & Villano, 2017). The significance and signal are maintained in both the quantity and quality focused regressions, such that the presence in one of the main metropolitan areas, with large student pools and access to developed large labor markets seems to be a key factor in efficient production of highly employable graduates in large numbers.

The variable TSRatio also presents a significant negative coefficient. This implies that an increase in the Teacher-Student ratio, that is a lower number of students per teacher, will lead to an increase in efficiency. This is opposite to how the ratio is normally interpreted. This variable is new to the literature, as far as I am aware, so we have no point of comparison. This result seems to derive mainly from its impact on quality, which implies that a smaller number of students per teacher, normally represented by smaller classes, is effective in producing highly employable graduates, whilst the effect on quantity is not relevant:

[5] * Signals a variable relevant at a 10% confidence level, ** signals a variable relevant at a 5% confidence level and *** signals a variable relevant at a 1% level

a higher ratio implies less students per teacher and may lead us to conclude a higher inefficiency, as the ratio is normally interpreted, however the real output we considered is graduates, and larger classes may lead to a larger fail rates, therefore this justifies the ambiguous effect. This also implies using the Teacher-Student ratio as an indicator of efficiency in teaching is a flawed analysis. Those who use this ratio as an indicator for a school's teaching efficiency or productivity may be making a mistake with consequences for the outcomes of students.

The last significant variable in the main model is the rtMedStu, with a positive coefficient that implies it impacts pure technical efficiency negatively. This was expected in terms of teaching as medically associated classes are normally smaller and more costly to teach. To note is that this is the only variable relevant in the main model which isn't relevant in either the quality or quantity focused regressions, which limits our conclusions, and is unexpected, as the strong employability of medical degrees, particularly the nursing schools, led us to expect a positive effect on quality efficiency and a trade-off with quantity efficiency, but that isn't verified, even if the signals align the significance isn't there.

The relevance of these factors holds for most of the auxiliary models calculated, particularly Uni which remains significant at 1% in all models and Met which also maintains significancy in most models, but the significance levels fluctuate across models. When either rtMedStu or TSRatio are absent, StuSaS, the ratio of students with social scholarships, becomes relevant with a negative effect on efficiency as expected. The absence of rtMedStu also makes both Met and TSRatio lose relevance. This may be due to some multicollinearity issues with rtMedStu, as noted in our multicollinearity tests in the data chapter. This variable also loses significance if the number of students is removed as an input.

In the quality-focused regression, the rtPropPub gains relevancy and impacts efficiency positively. This implies that a higher financial autonomy marked by a higher reliance on internally generated revenue affects positively the efficiency of producing highly employable graduates, perhaps associated with more resources dedicated to teaching allowing a more up to date curriculum and institutional access to top of the line tools used in the labor market (e.g. AI tools), and more autonomy to develop partnerships with the labor market and events such as employment faIRS and conferences of important areas.

The remaining variables: rtStemStu, the ratio of students in Courses classified as Stem by the CNAEF, and CFR, the ratio of courses by internal organic units, are never relevant in any model.

5.2.2. DEAr Regression Result:

Moving to the DEAr, we follow the same procedure:

	Variables[5]							
Model – DEAr	MET	Uni	TSRatio	StuSAS	CFR	rtPropPub	rtStemStu	rtMedStu
SW TR	-0.3856391	**-0.852*** **	-11.20148	-2.55658	-0.0219594	**2.388823** **	-0.2652948	0.2509512
Quality-Focused Regression	-0.0006312	0.0128844	**-19.692** **	-0.2550254	-0.0098984	**1.99426***	0.7282854	**2.34861** **
Quantity-Focused Regression	**-2.735264***	**-5.747*** **	4.905339	-14.13042	**-0.156981** **	**8.25844** **	**-11.436*** **	**-8.002938** **
Without Students Input	**-0.7340952***	**-1.002*** **	-8.811527	-4.681935	-0.0091953	**2.492503** **	0.1213132	0.6749639
SW TR - no TSRatio	-0.5171364	**-0.843*** **	----	-2.524582	-0.0208671	**2.402884** **	-0.601735	-0.6267963
SW TR - no rtMedStu	-0.3700651	**-0.851*** **	-10.01445	-2.192462	-0.0217565	**2.379235** **	-0.3889537	----
SW TR - no TSRatio rtMedStu	**-0.64811** **	**-0.843*** **	----	-3.886849	-0.0219904	**2.510373** **	-0.2032079	----
SW TR - no rtStemStu	-0.3836997	**-0.859*** **	-11.69855	-2.518209	-0.0228733	**2.386201** **	----	0.3685167
SW TR - no TSRatio and Area Variables	**-0.631951** **	**-0.851*** **	----	-3.640756	-0.026314	**2.48315** **	----	----
OLS	-0.277503	**-0.574** **	-5.897624	-1.966572	-0.0139283	**1.544743***	-0.1517722	0.1201506
Tobit	-0.277503	**-0.574*** **	-5.897624	-1.966572	-0.0139283	**1.544743** **	-0.1517722	0.1201506
SW TR with Pol.Guarda (VRS)	-2.57117	**-4.633*** **	-13.5282	-17.4758	**-0.13013***	**8.013607***	-3.62221	-1.81187
SW TR with Pol.Guarda (CRS)	-0.54758	**-4.468*** **	3.837149	**-20.964** **	-0.0327	3.298697	0.312886	-2.17081
SW TR CRS	-0.3610775	-2.261***	-36.36513	-10.70449	0.0608575	3.5737704	2.873656	4.729689
500 Bootstrap Repetitions	-0.3856391	**-0.852*** **	-11.20148	-2.55658	-0.0219594	**2.388823** **	-0.2652948	0.2509512
2000 Bootstrap Repetitions	-0.3856391	**-0.852*** **	-11.20148	-2.55658	-0.0219594	**2.388823** **	-0.2652948	0.2509512

Table 16 - DEAr Regression Results

Here, in our main model, we have far more limited results. Only two variables are significant: Uni and rtPropPub. Both of these variables maintain their significance in the majority of models considered, so these results on these two variables are robust.

Uni affects pure technical efficiency positively, as expected. Whilst the situation is becoming muddier, most polytechnics in Portugal still mostly focus on teaching as a priority, while Universities put a lot of value on Research, so it is to be expected that these HEI are more efficient in achieving research goals. The lack of an effect on quality metrics however implies that most polytechnics can already efficiently produce highly cited publications on par with universities, this may be due to the participation in international projects that tend to accumulate high citations fast (as we saw in the case of Pol.Guarda) or it may be due to the individual characteristics of researchers. Like in the teaching regression we have no point of comparison in the literature.

The result of rtPropPub is less expected. Here, more financial autonomy is associated with less efficient research. This result is mirrored in both quantitative and qualitative regressions. This can be explained as research in Portuguese HE still being highly dependent on state and EU funding (both included in the denominator of rtPropPub) but may also imply that HEI more financially autonomous may be shifting

said resources for teaching in order to capture more student fees. This result is not unheard of in the literature (Tran & Villano, 2017), although what comparisons we have consider the two goals united and discard quality metrics, so comparisons are hard.

When both TSratio and rtMedStu are absent, Met becomes significant and contributes positively to efficiency. This may indicate multicollinearity issues associated with those variables, as we found something similar in the previous section, and aligns with our VIF testing in chapter 4. The remaining variables are not relevant in any model that considers the DEAr results.

When we look at our divide between quantity and quality we get good insights. Starting with our quality regression, TSratio and rtMedStu become significant, the first affecting efficiency positively, the second negatively. The effect of TSratio implies that having less students per teacher leads to a more efficient production of quality publications, this is easy to explain as academics with less students have more time to develop more innovative research. The bigger presence of medical students in the student population on the other hand implies less efficient production of highly cited publications, which may be due to this having less citations or accumulating them slower.

In the quantity focused regression, all variables apart from TSratio and StuSAS are significant to a degree. And all apart from rtPropPub affect efficiency positively. So, the presence in Lisbon/Porto, being a university, a higher portion of Stem or Med Students in the student population and a bigger internal fragmentation in organization all contribute positively to efficiently producing more publications, whilst higher financial autonomy contributes negatively.

Lastly, the exclusion of Pol.Guarda finds some justification in our result, when analyzing the VRS results with Pol.Guarda in our sample we see that both Uni and rtPropPub maintain relevancy and signal, and CFR becomes significant, but the magnitudes are 4 times higher than in our model.

5.2.3. Comparing Results:

Below we present a simplified table showing the sign of relevant factors affecting either our technical efficiency in terms of Teaching or Research and also divided between quality (QualT and QualR) and quantity (QuantT and QuantR). The goal is to answer our last research question and identify trade-offs and complementarities between the results.

We will also propose reasons for which may be able to explain these results, combining some possibilities we have already considered in the remaining chapter. These will be only suggestions, however, as our methodology does not allow us to determine causality, only relations, such that expanding the exact

way each variable affects efficiency goes beyond our scope, however by exposing possible explanations we trail possible paths for future research.

	MET	Uni	TSRatio	StuSAS	CFR	rtPropPub	rtStemStu	rtMedStu
DEAt	+	+	+	-*	...	...	...	-
QuantT	+	-	...	...	...	...	...	...
QualT	+	+	+	...	...	+	...	...
DEAr	+*	+	...	...	...	-	...	...
QuantR	+	+	...	...	+	-	+	+
QualR	...	...	+	...	...	-	...	-

Table 17 - Relevance and Sign of Independent Variables in different Models

A symbol "+" implies that the variable is significant and has a positive relation with the efficiency scores considered, a "-"symbol implies a negative significant relation with the given efficiency score, and a "…" symbol implies no significant relation. Two variables have a "*" next to their symbol, these variables are only relevant in a given specific case: in the DEAt results StuSAS is significant only when TSRatio or rtMEdStu are missing, in the DEAr MET is only significant when both rtMEdStu and TSRatio are absent.

Between the two main scores, DEAt and DEAr the only complementarity that can be identified is that being a university tends to imply a higher efficiency in achieving both Teaching and Research goals. Met presents another possible complementarity, but this variable is only relevant in the DEAr when both TSRatio and rtMEdStu are absent, so this relation is not as strong. However, when separating quality and efficiency the conclusions broaden.

Within the teaching goal, there is a trade-off: Universities, whilst more efficient overall, are less efficient than Polytechnics when it comes to producing a higher number of graduates (possibly because polytechnics may have to work with less inputs due to less funding associated with lack of research focus, and less attractiveness to both professors and students), but compensate for this by more efficiently producing more employable graduates (possibly due to better networks, more prestige associated with the name, etc…) which we associate with quality. This last effect seems to dominate in the DEAt resulting in a relevant positive sign.

There is also a complementarity associated with the variable Met: the presence in either Porto or Lisbon Metropolitan areas seems to be associated with higher efficiency in Teaching, in more efficiently graduating high numbers of students and more employable students. This may be associated with the access to a larger prospective student population and a bigger labor market ecosystem. This is also verified

in the literature as we already stated. It may also have a snowball effect, as HEI efficiency has positive effects in regional growth and development (Agasisti et al., 2021; Pedro et al., 2022), therefore deepening regional inequalities, but this is just a hypothesis we can't confirm as our method does not prove causality.

Within the DEAr results we also have one trade-off and one complementarity. The variable rtMedStu has a positive influence in efficiently achieving a high number of publications, but these publications may generate less citations on average (or take more time accumulating citations) hurting quality-focused efficiency. The result is that these two effects cancel out and DEAr is not relevantly influenced by rtMedStu. To this, we can add the negative effect that is registered on our DEAt, which, when combined with our QuantT results confirm our expected trade-off: more medical students hurt teaching efficiency because classes are smaller and more expensive, but affects research positively, the lack of effect in QualT is harder to explain. This may explain why we have such varying results when normal DEA papers that do not separate teaching and research and fail to consider quality, such that papers that register a positive effect (Papadimitriou & Johnes, 2019; Wolszczak-Derlacz & Parteka, 2011) are those in which the QuantR effect dominates, those who register a negative effect (Thai & Noguchi, 2021) are those in which DEAt effect dominates. This conclusion would be stronger with a significant negative effect on QuantT, but we find no such thing.

Meanwhile, rtPropPub affects negatively the quality and quantity efficiencies in Research. This means that more financial autonomy results in less efficient production of publications and on less cited publications, which, as we said, reflects the dependence of Portuguese HEI of European and National funding for conducting research projects, and that HEI may not take advantage of more financial autonomy to develop their own internal research projects. Whislt not unfindable in literature (Tran & Villano, 2017) the more common effect tends to be negative (Papadimitriou & Johnes, 2019; Wolszczak-Derlacz, 2017; Wolszczak-Derlacz & Parteka, 2011).

With the division between quality and quantity, more relations between the two goals can be identified. A higher TSRatio is associated with efficiently producing quality outcomes: a lower number of students per teacher seems to increase efficiency in producing both more employable students and more cited articles, whilst having no discernable impact on quantity. The first part of this result is quite comprehensible, smaller classes allow the teacher to more personally interact with the students and ease the transition of knowledge and accessibility and generating tighter networks, whilst being responsible for less students allows more time to focus on better and more innovative research. The lack of effects in quantity efficiency is unexpected if the ratio is interpreted in the traditional way, on the side of research

it might indicate that when faced with high student loads, academics may focus on less innovative, more formulaic research, without necessarily affecting output, on the teaching side, it and may be associated with a bigger drop-out rate generating less graduates per student. This confirms Farrell (1957) suspicion of simple ratios as efficiency metrics.

A trade-off appears associated with rtProbPub, whilst negatively affecting Research efficiency, more financial autonomy does positively affect Teaching efficiency, particularly in terms of quality. The reasons for this have already been touched, however this may not be a real trade-off, as public funding and internally generated revenues are composed of various factors, such as direct state transfers, research grants, social grants, student fees, etc… which clearly affect research and education differently. This does not explain our disparity from the literature like in the case of rtMedStu however, because most literature does not account for quality and so wouldn't register this effect, so either by the characteristics discussed of the Portuguese HE system or by the characteristics of our DEA the significance of this variable differs from the more common literature.

Lastly, three variables are only relevant in one case: StuSaS, rtStemStu and CFR. The first has a negative effect on DEAt but only when two other very relevant variables aren't present, but the effect is as we expected. The second has a relevant and large positive effect on quantitative research efficiency, but none in term of quality, and the quantitative effect does not cross to our mixed DEAr, this contradicts traditional two-stage DEAs which focus on quantitative metrics and mix research and teaching, which normally find a negative effect for this variable (Martínez-Campillo & Fernández-Santos, 2020; Thai & Noguchi, 2021), although they use a dummy and not a ratio as we do. The last variable, CFR, also has only a positive effect in efficiency on our quantity-focused DEAr which does not translate to the mixed DEAr, which may imply that bigger internal organic units lead to more efficient research production, this variable is new and a proxy for internal organization, so we have no point of comparison in the literature.

We can illustrate the usefulness of these results through an example: Politécnico de Viana do Castelo, an average polytechnic located outside either of the two metropolitan areas. It is ranked 13th in our DEAt results, with strong results in our quantity metric, where it ranks 3rd, and far weaker quality metric results, ranking 24th. In terms of Research, it is ranked 21st, it holds the same rank in our quantity-focused metric whilst ranking slightly higher in our quality metrics, 15th.

In this case, if Pol. Viana do Castelo adheres to the educational focus of polytechnics, it should seek to improve its efficiency in this goal, where the biggest hole is associated with quality, and this can be improved through a higher TSRatio or a higher financial autonomy. It also shows that, should the HEI chose

to also improve research efficiency it can improve its quantity efficiency through increasing the weight of STEM courses it offers and by having bigger internal organization units, it can also improve efficiency in achieving quality outcomes through a higher TSRatio, all this without affecting the efficiency of achieving the main teaching goal.

This same analysis can be done for any HEI in the sample. The results allow us to not only compare the efficiency of Portuguese HEI, the division between Teaching and Research, Quality and Quantity, allows us to see where each HEI is lacking, and what factors can be changed to improve efficiency as well as the expected effects on the remaining goals, therefore we can conduct analysis such as the example above, to each HEI and considering different priorities of goals.

6. Conclusions:

This thesis allows us, through the first-stage, to compare the efficiency of different Portuguese HEI in achieving different goals (teaching and research) and different dimensions (quality and quantity), which can be seen in Table 10 and Table 12, and to show that no overly apparent relation between different goals and different dimensions exists (as seen particularly in chapter 5.1.3.), although there is a small positive correlation.

In the second-stage, we identified possible determinants behind these scores and how they relate across goals and dimensions. Three trade-offs were registered overall: within education, universities (UNI) have better quality-efficiency scores but worse quantity-efficiency scores, within research, a higher ratio of medical degree students (rtMedStu) is associated with higher quantity-efficiency but lower quality-efficiency, lastly a higher ratio of internally generated revenue to public funding (rtPropPub) harms research efficiency but improves teaching-quality efficiency.

A Number of complementarities are also detected: the location of the HEI in either Porto or Lisbon (MET) is generally associated with better efficiency (apart from research quality), the ratio of internally generated revenue to public funding (rtPropPub) harms research efficiency in both quantity and quality efficiency metrics, and the ratio of teachers per students enrolled (TSRatio) contributes positively to higher quality-efficiency in both teaching and research.

The last three variables present neither trade-offs nor complementarities: the ratio of Stem students (rtStemStu) and the ratio of courses offered to internal organic units (CFR) affect research quantity efficiency positively, the ratio of SAS students (StuSAS) affects general teaching efficiency negatively (when either TSRatio or rtMedStu are not present).

These results allow us to question recent policy choices regarding Portuguese HE, which we glanced over in the introduction: the increasing financial autonomy of Portuguese HEI may be a positive sign for the efficient production of highly employable graduates, but may represent a negative development for Portuguese research overall, as its efficiency may suffer with the search for alternative revenue sources. The divide between polytechnics and universities still exists, although it is not one-sided in favor of universities particularly in terms of teaching output, but it is definitely still felt in terms of the employability of graduates and research, so the dual system of Portuguese HEI is still very much intact, despite the valorization of polytechnics.

The relevancy of location in HE efficiency (both teaching and to a lesser extent research) may contribute to deepening a problem in Portuguese society, the growing concentration of population and economic activity in the metropolitan areas. Since both Pedro et al. (2022) and Agasisti et al. (2021) agree that a higher efficiency of HEI leads to greater regional growth, the concentration of efficient HEI in these areas may aggravate division. The difference between HEI outside and inside Lisbon and Porto is starker than the difference between polytechnics and universities.

In terms of scale, our results are more limited, and the study of the exact relation between size and efficiency in Portuguese HE is our first recommendation for further research. However, recent Portuguese policy has focused in increasing the size of HEI, particularly with the full absorption of the professional nursing schools into the classic universities (E.S.E. de Lisboa into U.Lisboa, E.S.E. do Porto into U.Porto and E.S.E. de Coimbra into U.Coimbra) (Decreto Lei nº83/2024) however, according to our results it is hard to gage if this is the right path, as the professional nursing schools considered (Lisboa and Porto) were quite efficient, both in terms of scale and pure technical efficiency, whilst the classic universities had mixed results, particularly in terms of scale where they were always inefficient and under DRS. Further fragmentation of the bigger universities seems more efficient in this lens, however only a clear view of the relation between size and efficiency may confirm this.

These conclusions must be framed within the limitations of this thesis. These limitations may be associated with the methodology itself or from the choices undertaken in this thesis and therefore tend to originate avenues for future research which I will also make mention of.

The first limitation is the timeframe considered. We focused on the 2023/24 academic year; however, HE takes time, today's students may take 3 to 5 years to graduate, publications take time to accumulate citations and may start being written years before publication. Whilst the use of a single academic year is not flawed, particularly because we are using a relatively new framework, the most basic and best extension to this thesis would be to increase the timeframe considered to a couple of more academic years. This would allow for a bigger sample, particularly useful in the case of a small country like Portugal but may result in holes in data as not all variables are available for all academic years.

In the first step, the DEA, two limitations appear: the choice to only include the public HEI of Portugal, and the choice of inputs and outputs. Regarding the first, a more complex analysis will also include the relatively smaller but still relevant private side of Portuguese HE, however data here is more lacking so a trade-off with the richness of variables that said analysis may consider, as well as the inputs/outputs

chosen, may be inevitable. Such a study will also have to consider that these HEI will be profit-seeking and therefore follow a different rational from the public HEI.

In terms of inputs/outputs, this thesis partially covers the gap found in the literature of ignoring quality metrics by introducing a quality output to each of our DEAs, however quality was still ignored in the input side. To get a more accurate picture of the relation between quality and quantity, quality inputs should be added to the analysis, although these are hard to come by (this is the main reason why they were not included in the analysis). Additionally, the framework here presented can be incremented by including third mission goals as well, allowing it to acknowledge the three commonly accepted goals of HEI.

In the 2nd stage, the main limitations are lack of causality and weak generalization. Both of these do not result from the choices undertaken in the thesis but are endemic to frontier analysis itself. The first implies that, although we identified what factors are related to the efficiency scores and suggested possible explanations for the results, a more case by case analysis is still necessary to point out the exact relation between the factors and HE efficiency. The second makes our results harder to extend outside the sample considered and to compare with the remaining literature, a problem we acknowledged in chapter 2.4, although we still try to make some comparison throughout chapter 5. To allow for proper comparison between countries, HEI from different countries must be included in the same DEA with equivalent inputs/output. The extension of the framework applied to such international comparisons is another suggestion for future research.

Despite these limitations this thesis takes an important step in HE efficiency analysis, through the confirmation that different factors impact efficiency in achieving different goals of HEI, in achieving quantity results versus quality results and that increasing efficiency in either of the dimensions and goals considered may not imply increasing efficiency in the other. This must be kept in mind by both HEI managements that seek to increase the performance of their institutions, but also by policymakers when deciding on distribution of inputs, particularly funding.

Bibliography:

Afonso, A., & Santos, M. (2008). A DEA Approach to the Relative Efficiency of Portuguese Public Universities. *Portuguese Journal of Management Studies*, *13*(1). https://papers.ssrn.com/sol3/papers.cfm?abstract_id=981180

Agasisti, T. (2011). Performances and Spending Efficiency in Higher Education: A European Comparison through Non-parametric Approaches. *Education Economics*, *19*(2), 199–224. https://doi.org/10.1080/09645290903094174

Agasisti, T., Egorov, A., Zinchenko, D., & Leshukov, O. (2021). Efficiency of regional higher education systems and regional economic short-run growth: empirical evidence from Russia. *Industry and Innovation*, *28*(4), 507–534. https://doi.org/10.1080/13662716.2020.1738914

Agasisti, T., & Ricca, L. (2015). Comparing the Efficiency of Italian Public and Private Universities (2007–2011): An Empirical Analysis. *Italian Economic Journal*, *2*(1), 57–89. https://doi.org/10.1007/s40797-015-0022-7

Aigner, D., Lovell, C., & Schmidt, P. (1977). Formulation and Estimation of Stochastic Frontier Production Function Models. *Journal of Econometrics*, *6*(1), 21–37.

Almeida, J., Anjos, F., Moreira, M., Bermejo, P., Prata, D., & Rodrigues, W. (2025). University efficiency evaluation using data envelopment analysis: future research agenda. *Cogent Education*, *12*(1). https://doi.org/10.1080/2331186X.2024.2445964

Alvarez-Sández, D., Velázquez-Victorica, K., Mungaray-Moctezuma, A., & López-Guerrero, A. (2023). Administrative Processes Efficiency Measurement in Higher Education Institutions: A Scoping Review. *Education Sciences 2023, Vol. 13, Page 855*, *13*(9), 855. https://doi.org/10.3390/EDUCSCI13090855

Assembleia da República. (2023). "Lei n.º 16/2023, de 10 de abril". *Diário da República*, 1.ª série, 70 (abril): 2-5. https://diariodarepublica.pt/dr/detalhe/lei/16-2023-211573083

Assembleia da República. (2026). "Proposta de Lei n.º 30/XVII/1.ª — Altera o Regime Jurídico das Instituições de Ensino Superior (RJIES)". *Assembleia da República*. https://www.parlamento.pt/ActividadeParlamentar/Paginas/DetalheIniciativa.aspx?BID=315537

Badunenko, O., & Tauchmann, H. (2019). Simar and Wilson two-stage efficiency analysis for Stata. *Stata Journal*, *19*(4), 950–988. https://doi.org/10.1177/1536867X19893640

Banker, R., Charnes, A., & Cooper, W. (1984). Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis. *Management Science*, *30*(9), 1078–1092.

Brandão, C., Reis, J., & Andrade, V. (2025). *Relatório de Atividades 2024*. https://www.eshte.pt/pt/artigos/139-informacao-institucional/planos-e-relatorios

Brzezicki, Ł. (2020). The Efficiency of Public and Private Higher Education Institutions in Poland. *Gospodarka Narodowa - The Polish Journal of Economics*, *304*(4), 33–51. https://doi.org/10.33119/gn/128218

Camanho, A., Silva, M., Piran, F., & Lacerda, D. (2024). A literature review of economic efficiency assessments using Data Envelopment Analysis. *European Journal of Operational Research*, *315*(1), 1–18. https://doi.org/10.1016/j.ejor.2023.07.027

Cantele, S., Guerrini, A., & Campedelli, B. (2016). Efficiency of Italian universities: the effect of controllable and non-controllable environmental and operational variables. *International Journal of Public Policy*, *12*, 243–260.

Cerdeira, L., Cabrito, B., & Mucharreira, P. (2021). Expansão e regionalização do ensino superior em Portugal nas últimas décadas: um percurso contraditório. *EccoS – Revista Científica*, (58), 1–22. https://doi.org/10.5585/eccos.n58.20848

Cerdeira, L., Cabrito, B., & Mucharreira, P. (2024). Os desafios da educação superior: os sucessos e as tensões dos 50 anos de democracia em Portugal. *CONTRIBUCIONES A LAS CIENCIAS SOCIALES*, *17*(13), e13965. https://doi.org/10.55905/revconv.17n.13-415

Charnes, A., Cooper, W., & Rhodes, E. (1978). Measuring the Efficiency of Decision Making Units. *European Journal of Operational Research*, *2*, 429–444.

Coelli, T., Prasada Rao, D., O'Donnel, C., & Battese, G. (2005). *An Introduction to Efficiency and Productivity Analysis* (2nd ed.). Springer.

Conde, J., Ferreira, A., & Matos, S. (2025). *Relatório de Gestão e Contas Consolidadas 2024*. https://www.ipc.pt/sobre/documentos/documentos-estrategicos-e-de-governacao/

Cooper, W., & Lovell, C. (2011). History lessons. *Journal of Productivity Analysis*, *36*(2), 193–200. https://doi.org/10.1007/s11123-011-0224-4

Cooper, W., Seiford, L., & Tone, K. (2007). Data envelopment analysis: A comprehensive text with models, applications, references and DEA-solver software: Second edition. In *Data Envelopment Analysis: A Comprehensive Text with Models, Applications, References and DEA-Solver Software: Second Edition* (2nd Edition, pp. 87–130). Springer US. https://doi.org/10.1007/978-0-387-45283-8

Cunha, M., & Rocha, V. (2012). *On the Efficiency of Public Higher Education Institutions in Portugal: An Exploratory Study* (468; FEP Working Papers). https://wps.fep.up.pt/wps/wp468.pdf

Ender, P. (2010). *Collinearity tests*. Https://Stats.Oarc.Ucla.Edu/Stat/Stata/Ado/Analysis/Collin.Hlp.

Escola Superior de Enfermagem do Porto. (2025). *Relatório de Atividades 2024*. https://www.up.pt/esep/documents/2/relatorio_atividades_2024.pdf

Escola Superior Náutica Infante D. Henrique. (2025). *Relatório de Atividades e Contas 2024*. https://www.enautica.pt/pt/enidh/documentos-de-gestao-88/documentos-de-gestao-173

ESEL - Divisão de serviços de Gestão Administrativa, & ESEL - Divisão de Recursos Financeiros e Patrimoniais. (2025). *Relatório de Atividades, Contas e Gestão da Escola Superior de Enfermagem de Lisboa 2024*. https://enfermagem.ulisboa.pt//sites/default/files/Ata_n%c2%ba_2-CG_-2025_Anexos.pdf

Farrell, M. (1957). The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society*, *120*(3), 253–281. https://academic.oup.com/jrsssa/article/120/3/253/7101561

Ferro, G., & D'elia, V. (2020). Higher education efficiency frontier analysis: A review of variables to consider. *Journal on Efficiency and Responsibility in Education and Science*, *13*(3), 140–153. https://doi.org/10.7160/eriesj.2020.130304

Grupo Instituto Politécnico de Beja. (2025). *Relatório de Contas 2024 Consolidado*. https://www.ipbeja.pt/RepositorioDocumentosOficiais/Paginas/ContasConsolidadas.aspx

Grupo Público Universidade do Minho. (2025). *Relatório de Atividades e Contas Consolidadas 2024*. https://www.uminho.pt/PT/uminho/Informacao-Institucional/Planos-e-Relatorios/Paginas/Relatorios-de-Atividades-e-Contas.aspx

Instituto Politécnico de Bragança. (2025). *Relatório e Contas 2024*. https://sggq.ipb.pt/files/F_documentos/RelatorioContas_2024_IPB.v0.pdf

Instituto Politécnico de Castelo Branco. (2025). *Relatório de Atividades e Contas Consolidado 2024*. https://www.ipcb.pt/media/divhjmfi/relatorio-de-atividades-e-contas_2024_consolidado_08-05-2025.pdf

Instituto Politécnico de Leiria. (2025). *Relatório de Atividades Instituto Politécnico de Leiria 2024*. https://www.ipleiria.pt/wp-content/uploads/2025/10/IPLeiria_Relatorio-Atividades-2024.pdf

Instituto Politécnico de Portalegre. (2025). *Relatório de Atividades 2024*. https://www.ipportalegre.pt/pt/sobre-nos/documentacao-e-legislacao/instrumentos-de-gestao/

Instituto Politécnico de Setúbal. (2025). *Relatório de Atividades 2024*. https://ips.pt/wp-content/uploads/2025/03/Relatorio-de-Atividades-IPS-2024.pdf

Instituto Politécnico de Tomar. (2025). *Relatório de Atividades e Contas 2024*. https://portal2.ipt.pt/pt/ipt/informacao_de_gestao/relatorio_de_atividades/

Instituto Politécnico de Viana do Castelo. (2025). *Relatório de Atividades e Contas Consolidadas 2024*. https://www.ipvc.pt/wp-content/uploads/2025/07/Relatorio-de-Atividades-e-Contas-Consolidadas-2024_compressed.pdf

Instituto Politécnico de Viseu. (2025). *Relatório de Atividades e Contas Consolidadas 2024*. https://ipv.pt/wp-content/uploads/2025/09/RACC_24_final.pdf

Instituto Politécnico do Cávado e do Ave. (2025). *Relatório de Atividades e Contas 2024*. https://ipca.pt/informacao-institucional/informacao-de-gestao/

Instituto Poltécnico de Santarém. (2025). *Relatório de Atividades 2024 | IPSantarém*. https://www.ipsantarem.pt/wp-content/uploads/2025/07/IPSANTAREM-RA-2024-vF_signed.pdf

Johnes, J. (2006). Data Envelopment Analysis and its Application to the Measurement of Efficiency in Higher Education. *Economics of Education Review*, *25*(3), 273–288. https://doi.org/https://doi.org/10.1016/j.econedurev.2005.02.005

Koopmans, T. (1951). Analysis of Production as an Efficient Combination of Activities. In T. Koopmans (Ed.), *Cowles Commision for Research in Economics - Monograph nº 13* (pp. 33–97).

Lampe, H. W., & Hilgers, D. (2015). Trajectories of efficiency measurement: A bibliometric analysis of DEA and SFA. *European Journal of Operational Research*, *240*(1), 1–21. https://doi.org/10.1016/j.ejor.2014.04.041

Lee, B. (2011). Efficiency of Research Performance of Australian Universities: A Reappraisal using a Bootstrap Truncated Regression Approach. *Economic Analysis & Policy*, *41*(3), 195–203.

Mammadov, R., & Aypay, A. (2020). Efficiency analysis of research universities in Turkey. *International Journal of Educational Development*, *75:102176*. https://doi.org/10.1016/j.ijedudev.2020.102176

Maral, M., & Çetin, M. (2024). Teaching, research, and third mission efficiency of universities: A data envelopment analysis and hybrid multi-criteria decision-making approach. *Managerial and Decision Economics*, *45*(4), 2171–2188. https://doi.org/10.1002/mde.4131

Martínez-Campillo, A., & Fernández-Santos, Y. (2020). The impact of the economic crisis on the (in)efficiency of public Higher Education institutions in Southern Europe: The case of Spanish universities. *Socio-Economic Planning Sciences*, *71*. https://doi.org/10.1016/j.seps.2019.100771

McDonald, J. (2009). Using least squares and tobit in second stage DEA efficiency analyses. *European Journal of Operational Research*, *197*(2), 792–798. https://doi.org/10.1016/j.ejor.2008.07.039

Ministério das Finanças e Ministério da Ciência, Tecnologia e Ensino Superior. (2024). "Portaria n.º 101/2024/1, de 13 de março". *Diário da República*, 1.ª série, 52 (março): 2-15. https://diariodarepublica.pt/dr/detalhe/portaria/101-2024-855215460 [1, 2, 3]

Moradi-Motlagh, A., & Emrouznejad, A. (2022). The origins and development of statistical approaches in non-parametric frontier models: a survey of the first two decades of scholarly literature (1998–2020). *Annals of Operations Research 2022 318:1*, *318*(1), 713–741. https://doi.org/10.1007/s10479-022-04659-7

Moreno-Gómez, J., Calleja-Blanco, J., & Moreno-Gómez, G. (2020). Measuring the Efficiency of the Colombian Higher Education System: a two-stage approach. *International Journal of Educational Management*, *34*(4), 794–804.

Papadimitriou, M., & Johnes, J. (2019). Does merging improve efficiency? A study of English universities. *Studies in Higher Education*, *44*(8), 1454–1474. https://doi.org/10.1080/03075079.2018.1450851

Pareto, V. (1906). *Manuale di economia politica*. Societa Editrice. https://books.google.pt/books/about/Manuale_di_economia_politica.html?id=oA6oZpaIQwoC&redir_esc=y

Pedro, E., Alves, H., Leitão, J., Alves, M., Raposo, M., Machado-Taylor, M., & Cerdeira, L. (2026). Towards More Effective Strategic Performance and Efficiency Measures in Portuguese Public Higher Education. *Trends in Higher Education 2026, Vol. 5, Page 18*, *5*(1), 18. https://doi.org/10.3390/HIGHEREDU5010018

Pedro, E., Leitão, J., & Alves, H. (2022). Do socially responsible higher education institutions contribute to sustainable regional growth and innovation? *International Journal of Sustainability in Higher Education*, *23*(8), 232–254. https://doi.org/10.1108/IJSHE-09-2021-0400

Politécnico de Lisboa - Planeamento e Controlo de Gestão. (2025). *Planos de Atividade 2025*. https://www.ipl.pt/politecnico/informacao-de-gestao/plano-de-atividades

Presidência do Politécnico da Guarda. (2025). *Relatório de Atividades 2024*. https://documental.ipg.pt/relatorios-de-atividades/

Presidência do PPORTO. (2024). *Plano de Atividades e Orçamento Consolidado 2025*.

Presidência do Conselho de Ministros. (2024). "Decreto-Lei n.º 83/2024, de 31 de outubro". *Diário da República*, 1.ª série, 212 (outubro): 21-25.

Quiroga-Martínez, F., Fernández-Vázquez, E., & Alberto, C. L. (2018). Efficiency in public higher education on Argentina 2004–2013: institutional decisions and university-specific effects. *Latin American Economic Review*, *27*(1). https://doi.org/10.1186/s40503-018-0062-0

Reitoria da Universidade de Aveiro. (2025). *Relatório de Gestão e Contas Grupo Universidade de Aveiro 2024*. https://www.ua.pt/pt/conselhogeral/page/15439

Reitoria da Universidade de Lisboa. (2025). *Relatório de Gestão e de Atividades 2024*. https://www.ulisboa.pt/info/documentos-de-gestao

Reitoria da Universidade do Porto, & Serviços Partilhados da Universidade do Porto. (2025). *Relatório de Atividades e Contas 2024*. https://www.up.pt/portal/documents/1964/Relatorio_de_Atividades_e_Contas_U.Porto_2024.pdf

Reitoria da Universidade Nova de Lisboa. (2025). *Relatório de Atividades e Contas 2024*. https://www.unl.pt/documentos-de-gestao-e-legislacao/prestacao-de-contas/

Reitoria ISCTE. (2025). *Relatório Integrado de Atividades e de Gestão 2024*. https://www.iscte-iul.pt/assets/files/2025/04/16/1744819454274_Relat_rio_Integrado_de_Atividades_e_de_Gest_o_2024.pdf

See, K. (2026). Higher education efficiency and productivity studies: a bibliometric analysis for future research. *Humanities and Social Sciences Communications 2026 13:1*, *13*(1), 100. https://doi.org/10.1057/s41599-025-06171-2

Simar, L., & Wilson, P. W. (2007). Estimation and inference in two-stage, semi-parametric models of production processes. *Journal of Econometrics*, *136*(1), 31–64. https://doi.org/10.1016/j.jeconom.2005.07.009

Slaughter, S., & Rhoades, G. (2009). Academic Capitalism and the New Economy - Markets, State and Higher Education. In *Academic Capitalism and the New Economy*. Johns Hopkins University Press. https://doi.org/10.56021/9780801879494

Soummakie, B., & Wegener, M. (2024). Two-Stage Research Performance Assessment of Turkish HEI using DEA and BETA Regression. *Journal of International Trade, Logistics and Law*, *10*(1), 159–177.

Sözen, A., Alp, I., & Kilinc, C. (2012). Efficiency assessment of the hydro-power plants in Turkey by using Data Envelopment Analysis. *Renewable Energy*, *46*, 192–202. https://doi.org/10.1016/j.renene.2012.03.021

Teodoro, A. (2026, April 27). O fim do modelo binário do ensino superior: por uma universidade compreensiva - Expresso. *Expresso*. https://expresso.pt/opiniao/2026-04-27-o-fim-do-modelo-binario-do-ensino-superior-por-uma-universidade-compreensiva-92430e70

Thai, K., & Noguchi, M. (2021). Investigating the Technical Efficiency of Japanesse National Universities following Corporatization: a two-stage Data Envelopment Analysis Approach. *International Journal of Educational Management*, *35*(6), 1297–1311.

Tran, C., & Villano, R. (2017). An empirical analysis of the performance of Vietnamese higher education institutions. *Journal of Further and Higher Education*, *41*(4), 530–544. https://doi.org/10.1080/0309877X.2015.1135886

Uniarea. (2026). Leiria e Porto perdem os politécnicos e ganham duas novas universidades à boleia do PTRR. *Uniarea*. https://uniarea.com/leiria-e-porto-perdem-os-politecnicos-e-ganham-duas-novas-universidades-a-boleia-do-ptrr/

Universidade Beira Interior. (2025). *Relatório de Atividades e Contas Consolidadas 2024*. https://www.ubi.pt/entidade/Docs_Estr

Universidade da Madeira. (2024). *Relatório de Gestão Consolidado 2023 Universidade da Madeira e Serviços Sociais da UMa*. https://www.uma.pt/en/documentacao-legal/

Universidade de Coimbra - Divisão de Planeamento Gestão e Desenvolvimento. (2025). *Relatório de Gestão e Contas Consolidado 2024*. https://www.uc.pt/dados/relatorios-de-gestao/

Universidade de Évora - Divisão de Planeamento e Garantia da Qualidade, Universidade de Évora - Divisão Financeira, & Universidade de Évora - Pró-Reitoria para a Qualidade Planeamento e Finanças. (2025). *Relatório de Atividades e Contas Separadas de 2024*. https://www.uevora.pt/universidade/documentos-institucionais/Planos-e-Relatorios-de-Atividades/Prestacao-de-Contas?folder=7663

Universidade de Trás-os-Montes e Alto Douro. (2024). *Plano de Atividades 2024*. https://www.utad.pt/wp-content/uploads/2024/03/Plano-de-Atividades-2024.pdf

Universidade do Algarve. (2025). *Relatório de Gestão Consolidado 2024*. https://www.ualg.pt/sites/default/files/inline-files/relatorio-de-gestao-consolidado_2024.pdf

Universidade dos Açores. (2025). *Relatório e Contas Consolidadas 2024*. https://uac.pt/sites/default/files/relatorio_e_contas_consolidadas_uac_2024_signed.pdf

Vasquez, M., Bilhim, J., & Pinto, R. (2012). *Eficiência e Produtividade no Ensino Superior Público* [PhD in Public Administration, Universidade Técnica de Lisboa]. https://repositorio.ulisboa.pt/entities/publication/6fdf3dda-c8d3-48e5-b777-c0e02ac6f923

Wolszczak-Derlacz, J. (2017). An evaluation and explanation of (in)efficiency in higher education institutions in Europe and the U.S. with the application of two-stage semi-parametric DEA. *Research Policy*, *46*(9), 1595–1605. https://doi.org/10.1016/j.respol.2017.07.010

Wolszczak-Derlacz, J., & Parteka, A. (2011). Efficiency of European public higher education institutions: a two-stage multicountry approach. *Scientometrics 2011 89:3*, *89*(3), 887–917. https://doi.org/10.1007/s11192-011-0484-9

Worthington, A. C. (2001). An Empirical Survey of Frontier Efficiency Measurement Techniques in Education. *Education Economics*, *9*(3), 245–268. https://doi.org/10.1080/09645290110086126

Appendix:

A. Stata Code (DO-File):

*Determinants of Technical Efficiency in Portuguese Public Higher Education Institutions taking Research and Teaching into Account – DoFile

use "DadosSimplificado.dta"

*Basics: these commands require the simarwilson, dea and teradial packages installed on Stata to work

rename ESTAB dmu

*Teaching-Focused DEA:

**Normal DEA:

dea StuEnrl StfETI TotFin = Grad PLOY, rts(vrs) ort(out) saving(DEAvrs)

**Simar-wilson Bias Corrected DEA and Regression:

***VRS:

simarwilson (Grad PLOY = StuEnrl StfETI TotFin) Met Type TSRatio StuSAS CFR PUBRP rtStemStu rtMedStu, algorithm(2) rts(vrs) base(output) tebc(deat2)

***CRS:

simarwilson (Grad PLOY = StuEnrl StfETI TotFin) Met Type TSRatio StuSAS CFR PUBRP rtStemStu rtMedStu, algorithm(2) rts(crs) base(output) tebc(deat2crs)

**Separating Quality and Quantity:

***Quantity-focused

simarwilson (Grad = StuEnrl StfETI TotFin) Met Type TSRatio StuSAS CFR PUBRP rtStemStu rtMedStu, algorithm(2) rts(vrs) base(output) tebc(deat2Quant)

***Quality-focused

simarwilson (PLOY = StuEnrl StfETI TotFin) Met Type TSRatio StuSAS CFR PUBRP rtStemStu rtMedStu, algorithm(2) rts(vrs) base(output) tebc(deat2Qual)

**Other Regressions for Sensitivity Analysis:

***Without StuEnrl Input variable

simarwilson (Grad PLOY = StfETI TotFin) Met Type TSRatio StuSAS CFR PUBRP rtStemStu rtMedStu, algorithm(2) rts(vrs) base(output) tebc(deat2noStu)

***Excluding TSRatio

simarwilson deat2 Met Type StuSAS CFR PUBRP rtStemStu rtMedStu, algorithm(1)

***Excluding rtMedStu

simarwilson deat2 Met Type TSRatio StuSAS CFR PUBRP rtStemStu, algorithm(1)

***Excluding TSRatio and rtMedStu

simarwilson deat2 Met Type StuSAS CFR PUBRP rtStemStu, algorithm(1)

***Excluding rtStemStu

simarwilson deat2 Met Type TSRatio StuSAS CFR PUBRP rtMedStu, algorithm(1)

***Excluding CFR

simarwilson deat2 Met Type TSRatio StuSAS PUBRP rtStemStu rtMedStu, algorithm(1)

***Excluding CFR and rtStemStu

simarwilson deat2 Met Type TSRatio StuSAS PUBRP rtMedStu, algorithm(1)

***Excluding CFR PUBRP and rtStemStu

simarwilson deat2 Met Type TSRatio StuSAS rtMedStu, algorithm(1)

***Tobit Regression

tobit deat2 Met Type TSRatio StuSAS CFR PUBRP rtStemStu rtMedStu, ll(1)

***OLS Regression

reg deat2 Met Type TSRatio StuSAS CFR PUBRP rtStemStu rtMedStu

***500 bootstrap repetitions full

simarwilson deat2 Met Type TSRatio StuSAS CFR PUBRP rtStemStu rtMedStu, algorithm(1) reps(500)

***500 bootstrap repetitions without CFR PUBRP and rtStemStu

simarwilson deat2 Met Type TSRatio StuSAS rtMedStu, algorithm(1) reps(500)

***2000 bootstrap repetitions full

simarwilson deat2 Met Type TSRatio StuSAS CFR PUBRP rtStemStu rtMedStu, algorithm(1) reps(2000)

***2000 bootstrap repetitions without CFR PUBRP and rtStemStu

simarwilson deat2 Met Type TSRatio StuSAS rtMedStu, algorithm(1) reps(2000)

*Research-focused DEA:

**Normal DEA:

dea TotFin Mdenrl AFFTEstf = NumPub AvCit , rts(vrs) ort(out) saving(DEArvrs)

**Simar-wilson Bias-corrected DEA:

***VRS

simarwilson (NumPub AvCit = AFFTEstf TotFin Mdenrl) Met Type TSRatio StuSAS CFR PUBRP rtStemStu rtMedStu, algorithm(2) rts(vrs) base(output) tebc(dear2)

***CRS

simarwilson (NumPub AvCit = AFFTEstf TotFin Mdenrl) Met Type TSRatio StuSAS CFR PUBRP rtStemStu rtMedStu, algorithm(2) rts(crs) base(output) tebc(dearcrs2)

**Testing an Outlier:

drop if dmu == "Pol. Guarda"

***Normal DEA

dea TotFin Mdenrl AFFTEstf = NumPub AvCit , rts(vrs) ort(out) saving(DEArvrs2)

***SW Bias-corrected DEA VRS

simarwilson (NumPub AvCit = AFFTEstf TotFin Mdenrl) Met Type TSRatio StuSAS CFR PUBRP rtStemStu rtMedStu, algorithm(2) rts(vrs) base(output) tebc(dearPGO)

***SW Bias-corrected DEA CRS

simarwilson (NumPub AvCit = AFFTEstf TotFin Mdenrl) Met Type TSRatio StuSAS CFR PUBRP rtStemStu rtMedStu, algorithm(2) rts(crs) base(output) tebc(dearcrsPGO)

****Since notable differences were detected, we continue without the outlier

**Separating Quantity and Quality

***Quantity-focused

simarwilson (NumPub = AFFTEstf TotFin Mdenrl) Met Type TSRatio StuSAS CFR PUBRP rtStemStu rtMedStu, algorithm(2) rts(vrs) base(output) tebc(DEArQuant)

***Quality-focused

simarwilson (AvCit = AFFTEstf TotFin Mdenrl) Met Type TSRatio StuSAS CFR PUBRP rtStemStu rtMedStu, algorithm(2) rts(vrs) base(output) tebc(DEArQual)

***Without AFFTEstf Input variable

simarwilson (NumPub AvCit = TotFin AFFTEstf) Met Type TSRatio StuSAS CFR PUBRP rtStemStu rtMedStu, algorithm(2) rts(vrs) base(output) tebc(DEArNS)

***Excluding TSRatio

simarwilson dearPGO Met Type StuSAS CFR PUBRP rtStemStu rtMedStu, algorithm(1)

***Excluding rtMedStu

simarwilson dearPGO Met Type TSRatio StuSAS CFR PUBRP rtStemStu, algorithm(1)

***Excluding rtMedStu and TSRatio

simarwilson dearPGO Met Type StuSAS CFR PUBRP rtStemStu, algorithm(1)

***Excluding rtStemStu

simarwilson dearPGO Met Type TSRatio StuSAS CFR PUBRP rtMedStu, algorithm(1)

***Excluding TSRatio rtMedStu and rtStemStu

simarwilson dearPGO Met Type StuSAS CFR PUBRP, algorithm(1)

***Tobit Regression

tobit dearPGO Met Type TSRatio StuSAS CFR PUBRP rtStemStu rtMedStu, ll(1)

***OLS Regression

reg dearPGO Met Type TSRatio StuSAS CFR PUBRP rtStemStu rtMedStu

***500 bootstrap repetitions full

simarwilson dearPGO Met Type TSRatio StuSAS CFR PUBRP rtStemStu rtMedStu, algorithm(1) reps(500)

***2000 bootstrap repetitions full

simarwilson dearPGO Met Type TSRatio StuSAS CFR PUBRP rtStemStu rtMedStu, algorithm(1) reps(2000)

B. Auxiliary Tables:

B.1. Normal DEAt:

ESTAB	CRS_TE	CRS-OEF	VRS_TE	VRS-OEF	SCALE	RTS
U. AÇORES	0.734672	1.361152	0.997491	1.002515	0.736519	DRS
U. ALGARVE	0.821983	1.21657	0.972458	1.028322	0.845264	IRS
U. AVEIRO	0.815006	1.226985	0.981749	1.01859	0.830157	IRS
U. BEIRA INTERIOR	0.891006	1.122327	0.975101	1.025535	0.913757	IRS
U. COIMBRA	0.842953	1.186306	0.9881	1.012043	0.853105	DRS
U. ÉVORA	0.497822	2.00875	0.975752	1.024851	0.510193	IRS
U. NOVA LISBOA	1	1	1	1	1	-
U. MINHO	1	1	1	1	1	-
U. PORTO	0.967386	1.033714	1	1	0.967386	DRS
U. TRÁS-OS-MONTES	0.748425	1.336139	0.956095	1.045921	0.782794	IRS
U. MADEIRA	0.800867	1.248647	0.996736	1.003275	0.803489	IRS
U. LISBOA	0.883981	1.131246	1	1	0.883981	DRS
POL. BEJA	0.759473	1.316703	0.976446	1.024122	0.777793	IRS
POL. CÁVADO E AVE	1	1	1	1	1	-
POL. BRAGANÇA	0.731477	1.367097	0.957964	1.043881	0.763575	IRS
POL. CASTELO BRANCO	0.731106	1.367791	0.968584	1.032435	0.75482	IRS
POL. COIMBRA	0.991057	1.009024	0.991515	1.008558	0.999538	IRS
POL. GUARDA	0.785037	1.273825	0.956614	1.045354	0.820642	IRS
POL. LEIRIA	0.933901	1.070777	0.979254	1.021186	0.953686	DRS
POL. LISBOA	0.914756	1.093188	0.991923	1.008143	0.922205	DRS
POL. PORTALEGRE	0.70882	1.410795	0.961283	1.040276	0.737368	IRS
POL. PORTO	1	1	1	1	1	-
POL. SANTAREM	0.855948	1.168295	0.981301	1.019055	0.872258	IRS
POL. SETUBAL	0.82931	1.205822	0.983506	1.016771	0.843218	DRS
POL. VIANA DO CASTELO	0.995082	1.004942	0.995207	1.004816	0.999874	IRS
POL. VISEU	0.774277	1.291527	0.960035	1.041629	0.80651	IRS
POL. TOMAR	0.687814	1.453881	0.961055	1.040523	0.715686	IRS
ISCTE – IUL	1	1	1	1	1	-
E.S.E. DE LISBOA	1	1	1	1	1	-
E.S.E. DO PORTO	1	1	1	1	1	-
E.S.N. INFANTE D. HENRIQUE	1	1	1	1	1	-
E.S. HOTELARIA E TURISMO ESTORIL	1	1	1	1	1	-

Table 18 - Normal DEAt Results

Columns:

- CRS-TE: technical efficiency metrics from our Normal, Teaching-focused output-oriented CRS DEA;
- CRS-OEF: output expansion factor metrics from our Normal, Teaching-focused output-oriented CRS DEA;
- VRS-TE: technical efficiency metrics from our Normal, Teaching-focused output-oriented VRS DEA;
- VRS-OEF: output expansion factor metrics from our Normal, Teaching-focused output-oriented VRS DEA;
- SCALE: scale efficiency metrics from our Normal, Teaching-focused output-oriented DEA;
- RTS: type of return to scale registered in our Normal, Teaching-focused output-oriented DEA;

B.2. Normal DEAr (with Pol. Guarda):

ESTAB	CRS_TE	CRS-OEF	VRS_TE	VRS-OEF	SCALE	RTS
U. AÇORES	0.502826	1.98876	0.504178	1.983426	0.997318	IRS
U. ALGARVE	0.328203	3.046895	0.498693	2.005242	0.658127	IRS
U. AVEIRO	0.545364	1.833638	1	1	0.545364	DRS
U. BEIRA INTERIOR	1	1	0.778052	1.285261	1.285261	DRS
U. COIMBRA	0.587757	1.701383	0.867315	1.152984	0.677675	DRS
U. ÉVORA	0.286813	3.486592	0.469292	2.130869	0.61116	IRS
U. NOVA LISBOA	0.396901	2.51952	0.574327	1.741168	0.691072	DRS
U. MINHO	0.464543	2.152653	0.756526	1.321832	0.614048	DRS
U. PORTO	0.698821	1.430982	1	1	0.698821	DRS
U. TRÁS-OS-MONTES	0.439141	2.277173	0.606046	1.65004	0.724599	DRS
U. MADEIRA	1	1	1	1	1	-
U. LISBOA	0.46935	2.130606	1	1	0.46935	DRS
POL. BEJA	0.206272	4.847968	0.206272	4.847968	1	-
POL. CÁVADO E AVE	0.337138	2.966144	0.337138	2.966144	1	-
POL. BRAGANÇA	0.314209	3.182595	0.472921	2.114518	0.664401	IRS
POL. CASTELO BRANCO	0.179149	5.581946	0.181289	5.516054	0.988192	IRS
POL. COIMBRA	0.221969	4.505134	0.361627	2.76528	0.613807	IRS
POL. GUARDA	1	1	1	1	1	-
POL. LEIRIA	0.18911	5.287928	0.393956	2.538355	0.480028	IRS
POL. LISBOA	0.135501	7.380019	0.251488	3.976333	0.538797	IRS
POL. PORTALEGRE	0.319946	3.125527	0.343812	2.908566	0.930583	IRS
POL. PORTO	0.206735	4.83711	0.312001	3.205118	0.662609	IRS
POL. SANTAREM	0.163278	6.124524	0.190153	5.258923	0.858663	IRS
POL. SETUBAL	0.148673	6.726171	0.238601	4.191097	0.623102	IRS
POL. VIANA DO CASTELO	0.348441	2.869926	0.384759	2.59903	0.905608	IRS
POL. VISEU	0.251061	3.983096	0.300625	3.326403	0.835128	IRS
POL. TOMAR	0.260316	3.841485	0.260316	3.841485	1	-
ISCTE – IUL	0.381775	2.619344	0.490207	2.039955	0.778803	IRS
E.S.E. DE LISBOA	0.447405	2.235111	0.507819	1.969206	0.881032	IRS
E.S.E. DO PORTO	0.414069	2.415056	0.414069	2.415056	1	-
E.S.N. INFANTE D. HENRIQUE	0.231674	4.31641	0.231674	4.31641	1	-
E.S. HOTELARIA E TURISMO ESTORIL	0.329781	3.032315	0.329781	3.032315	1	-

Table 19 - Normal DEAr Results (with Pol. Guarda)

Columns:

- CRS-TE: technical efficiency metrics from our Normal, Research-focused output-oriented CRS DEA (including Pol. Guarda);
- CRS-OEF: output expansion factor metrics from our Normal, Research-focused output-oriented CRS DEA (including Pol. Guarda);
- VRS-TE: technical efficiency metrics from our Normal, Research -focused output-oriented VRS DEA (including Pol. Guarda);
- VRS-OEF: output expansion factor metrics from our Normal, Research-focused output-oriented VRS DEA (including Pol. Guarda);
- SCALE: scale efficiency metrics from our Normal, Research-focused output-oriented DEA (including Pol. Guarda);
- RTS: type of return to scale registered in our Normal, Research-focused output-oriented DEA (including PolGuarda);

B.3. Bias-corrected DEAt:

ESTAB	TEDEAT	OEFDEAT	TEDEATCRS	OEFDEATCRS	SCALE
U. AÇORES	0.988308	1.011831	0.709552039	1.40934	0.717947
U. ALGARVE	0.967661	1.033419	0.803335062	1.244811	0.830182
U. AVEIRO	0.97638	1.024191	0.775858511	1.288895	0.794627
U. BEIRA INTERIOR	0.965544	1.035686	0.860766537	1.161755	0.891484
U. COIMBRA	0.98271	1.017594	0.779788019	1.2824	0.793508
U. ÉVORA	0.971505	1.029331	0.47397469	2.109817	0.487877
U. NOVA LISBOA	0.991848	1.008219	0.918067523	1.089245	0.925613
U. MINHO	0.984048	1.016211	0.929220961	1.07617	0.944284
U. PORTO	0.986273	1.013918	0.931257548	1.073817	0.944219
U. TRÁS-OS-MONTES	0.950681	1.051878	0.704757146	1.418929	0.741318
U. MADEIRA	0.987947	1.0122	0.783917524	1.275644	0.793481
U. LISBOA	0.988179	1.011963	0.854494388	1.170283	0.864717
POL. BEJA	0.966272	1.034905	0.739163858	1.35288	0.764965
POL. CÁVADO E AVE	0.979153	1.02129	0.865346091	1.155607	0.88377
POL. BRAGANÇA	0.952222	1.050176	0.672122148	1.487825	0.705846
POL. CASTELO BRANCO	0.961906	1.039603	0.716218122	1.396223	0.744582
POL. COIMBRA	0.968741	1.032267	0.936211685	1.068135	0.966421
POL. GUARDA	0.944358	1.05892	0.758954352	1.317602	0.803672
POL. LEIRIA	0.96767	1.03341	0.914683283	1.093275	0.945243
POL. LISBOA	0.982693	1.017611	0.88544745	1.129373	0.901041
POL. PORTALEGRE	0.950532	1.052042	0.684831503	1.460213	0.720472
POL. PORTO	0.973027	1.027721	0.943116583	1.060314	0.969261
POL. SANTAREM	0.971685	1.02914	0.835634322	1.196696	0.859985
POL. SETUBAL	0.978277	1.022206	0.814050578	1.228425	0.832127
POL. VIANA DO CASTELO	0.981018	1.019349	0.963807208	1.037552	0.982456
POL. VISEU	0.954101	1.048107	0.760330169	1.315218	0.796907
POL. TOMAR	0.950042	1.052585	0.664848881	1.504101	0.69981
ISCTE – IUL	0.991384	1.008691	0.854488547	1.170291	0.861915
E.S.E. DE LISBOA	0.981139	1.019224	0.982691655	1.017613	1.001583
E.S.E. DO PORTO	0.958628	1.043157	0.976280103	1.024296	1.018414
E.S.N. INFANTE D. HENRIQUE	0.986174	1.014019	0.903503887	1.106802	0.91617
E.S. HOTELARIA E TURISMO ESTORIL	0.987497	1.012661	0.915852985	1.091878	0.927449

Table 20 - SW Bias-corrected DEAt Results

Columns:

- OEFDEAT: output expansion factor metrics from our Bias-Corrected, Teaching-focused output-oriented VRS DEA;
- TEDEAT: technical efficiency metrics from our Bias-Corrected, Teaching-focused output-oriented VRS DEA;
- OEFDEATCRS: output expansion factor metrics from our Bias-Corrected, Teaching-focused output-oriented CRS DEA;
- TEDEATCRS: technical efficiency metrics from our Bias-Corrected, Teaching-focused output-oriented CRS DEA;
- SCALE: scale efficiency metrics from our Bias-Corrected, Teaching-focused output-oriented DEA;

B.*4. Bias-Corrected DEAr (with Pol. Guarda):*

ESTAB	TEDEAR	OEFDEAR	TEDEARCRS	OEFDEARCRS	SCALE
U. AÇORES	0.350846	2.850255	0.3678071	2.718817	1.048344
U. ALGARVE	0.416968	2.398268	0.267111	3.743762	0.640604
U. AVEIRO	0.867249	1.153071	0.455454	2.195611	0.525171
U. BEIRA INTERIOR	0.626395	1.596437	0.5182982	1.929391	0.827431
U. COIMBRA	0.761615	1.312999	0.5139041	1.945888	0.674755
U. ÉVORA	0.4016	2.490039	0.2340277	4.272998	0.582738
U. NOVA LISBOA	0.484956	2.062044	0.3452811	2.896191	0.711985
U. MINHO	0.651092	1.53588	0.394133	2.537215	0.605341
U. PORTO	0.802048	1.246808	0.5912207	1.691416	0.737139
U. TRÁS-OS-MONTES	0.512259	1.952138	0.3724581	2.684866	0.727089
U. MADEIRA	0.762554	1.311383	0.7578268	1.319563	0.993801
U. LISBOA	0.841033	1.189014	0.3990098	2.506204	0.474428
POL. BEJA	0.147733	6.768971	0.1428813	6.998815	0.96716
POL. CÁVADO E AVE	0.312697	3.197982	0.2305589	4.337287	0.737323
POL. BRAGANÇA	0.371766	2.689868	0.2417987	4.135672	0.650406
POL. CASTELO BRANCO	0.127574	7.8386	0.1330446	7.516275	1.042884
POL. COIMBRA	0.279182	3.581898	0.1637245	6.107822	0.586444
POL. GUARDA	0.597045	1.674917	0.5798178	1.72468	0.971147
POL. LEIRIA	0.32012	3.123833	0.1420799	7.038292	0.443834
POL. LISBOA	0.186822	5.352691	0.0990845	10.0924	0.530369
POL. PORTALEGRE	0.237738	4.206317	0.2237048	4.470177	0.940973
POL. PORTO	0.23675	4.223863	0.1645251	6.078102	0.694931
POL. SANTAREM	0.128607	7.775657	0.1104859	9.050928	0.8591
POL. SETUBAL	0.179445	5.572732	0.108986	9.175492	0.60735
POL. VIANA DO CASTELO	0.273961	3.650154	0.2489448	4.016955	0.908687
POL. VISEU	0.218504	4.576573	0.1872362	5.340848	0.8569
POL. TOMAR	0.193582	5.165779	0.164956	6.062223	0.852126
ISCTE - IUL	0.398713	2.508071	0.3189912	3.134883	0.800053
E.S.E. DE LISBOA	0.686155	1.457397	0.3155546	3.169024	0.459888
E.S.E. DO PORTO	0.533207	1.875445	0.3252504	3.074554	0.609989
E.S.N. INFANTE D. HENRIQUE	0.554203	1.804395	0.1375437	7.270416	0.248183
E.S. HOTELARIA E TURISMO ESTORIL	0.549321	1.820428	0.1954106	5.117431	0.355731

Table 21 - SW Bias-corrected DEArResults (with Pol. Guarda)

Columns:

- OEFDEAR: output expansion factor metrics from our Bias-Corrected, Research-focused output-oriented VRS DEA (including Pol. Guarda);
- TEDEAR: technical efficiency metrics from our Bias-Corrected, Research-focused output-oriented VRS DEA (including Pol. Guarda);
- OEFDEARCRS: output expansion factor metrics from our Bias-Corrected, Research-focused output-oriented CRS DEA (including Pol. Guarda);
- TEDEARCRS: technical efficiency metrics from our Bias-Corrected, Research-focused output-oriented CRS DEA (including Pol. Guarda);
- SCALE: scale efficiency metrics from our Bias-Corrected, Research-focused output-oriented DEA (including Pol. Guarda);

B.5. Normal DEAr (without Pol. Guarda):

ESTAB	CRS_TE	CRS-OEF	VRS_TE	VRS-OEF	SCALE	RTS
U. AÇORES	0.948252	1.054572	1	1	0.948252	DRS
U. ALGARVE	0.349476	2.861427	0.619802	1.6134185	0.56385	IRS
U. AVEIRO	0.545364	1.833638	1	1	0.545364	DRS
U. BEIRA INTERIOR	1	1	1	1	1	-
U. COIMBRA	0.587757	1.701383	0.919791	1.0872035	0.639012	DRS
U. ÉVORA	0.286813	3.486592	0.536118	1.865261	0.53498	IRS
U. NOVA LISBOA	0.396901	2.51952	0.757533	1.3200745	0.523939	DRS
U. MINHO	0.464543	2.152653	0.80174	1.2472872	0.579418	DRS
U. PORTO	0.698821	1.430982	1	1	0.698821	DRS
U. TRÁS-OS-MONTES	0.439141	2.277173	0.692767	1.4434868	0.633894	DRS
U. MADEIRA	1	1	1	1	1	-
U. LISBOA	0.46935	2.130606	1	1	0.46935	DRS
POL. BEJA	0.381	2.624672	0.457235	2.1870592	0.83327	IRS
POL. CÁVADO E AVE	0.697494	1.433704	0.711723	1.405041	0.980007	IRS
POL. BRAGANÇA	0.396865	2.519749	0.666053	1.501382	0.595846	DRS
POL. CASTELO BRANCO	0.333924	2.994693	0.35436	2.8219889	0.942331	IRS
POL. COIMBRA	0.321027	3.115003	0.615112	1.6257202	0.5219	DRS
POL. GUARDA	-	-	-	-	-	-
POL. LEIRIA	0.23237	4.303482	0.540114	1.851461	0.430225	DRS
POL. LISBOA	0.206786	4.835917	0.483682	2.0674741	0.427525	IRS
POL. PORTALEGRE	0.714709	1.399171	0.737479	1.3559708	0.969125	DRS
POL. PORTO	0.247814	4.035285	0.536335	1.8645063	0.462051	DRS
POL. SANTAREM	0.374085	2.673189	0.471548	2.1206749	0.793312	DRS
POL. SETUBAL	0.23312	4.289636	0.408689	2.4468483	0.570408	IRS
POL. VIANA DO CASTELO	0.553254	1.807488	0.671515	1.48917	0.823889	DRS
POL. VISEU	0.422046	2.36941	0.539452	1.853733	0.78236	DRS
POL. TOMAR	0.615253	1.625348	0.745696	1.3410291	0.825072	IRS
ISCTE - IUL	0.382492	2.614434	0.562697	1.7771554	0.679747	IRS
E.S.E. DE LISBOA	0.994744	1.005284	0.995386	1.0046354	0.99935	DRS
E.S.E. DO PORTO	0.571785	1.748909	0.571785	1.7489091	1	-
E.S.N. INFANTE D. HENRIQUE	1	1	1	1	1	-
E.S. HOTELARIA E TURISMO ESTORIL	1	1	1	1	1	-

Table 22 - Normal DEAr Results (without Pol. Guarda)

Columns:

- CRS-TE: technical efficiency metrics from our Normal, Research-focused output-oriented CRS DEA (excluding Pol. Guarda);
- CRS-OEF: output expansion factor metrics from our Normal, Research-focused output-oriented CRS DEA (excluding Pol. Guarda);
- VRS-TE: technical efficiency metrics from our Normal, Research-focused output-oriented VRS DEA (excluding Pol. Guarda);
- VRS-OEF: output expansion factor metrics from our Normal, Research-focused output-oriented VRS DEA (excluding Pol. Guarda);
- SCALE: scale efficiency metrics from our Normal, Research-focused output-oriented DEA (excluding Pol. Guarda);
- RTS: type of return to scale registered in our Normal, Research-focused output-oriented DEA (excluding Pol. Guarda);

B.6. Bias-corrected DEAr (without Pol. Guarda):

ESTAB	TEDEAR	OEFDEAR	DIFFVRS	TEDEARCRS	OEFDEARCRS	DIFFCRS	SCALE
U. AÇORES	0.735029	1.36049	2.09502	0.776182	1.288358	2.110296	1.055988
U. ALGARVE	0.532674	1.87732	1.277495	0.299538	3.338477	1.121398	0.562328
U. AVEIRO	0.844502	1.18413	0.973771	0.476094	2.100427	1.045316	0.563756
U. BEIRA INTERIOR	0.785566	1.272967	1.254107	0.724728	1.379829	1.398283	0.922555
U. COIMBRA	0.805325	1.241734	1.057391	0.530576	1.884745	1.032441	0.658834
U. ÉVORA	0.460099	2.173447	1.145664	0.243978	4.098723	1.042519	0.530274
U. NOVA LISBOA	0.655073	1.526548	1.350789	0.355401	2.813726	1.029308	0.542536
U. MINHO	0.706732	1.414963	1.085456	0.410674	2.435022	1.041968	0.581088
U. PORTO	0.812013	1.231508	1.012425	0.609387	1.640994	1.030727	0.750464
U. TRÁS-OS-MONTES	0.576464	1.734713	1.125338	0.384008	2.60411	1.031011	0.666144
U. MADEIRA	0.699064	1.430484	0.916741	0.80574	1.241095	1.063225	1.152598
U. LISBOA	0.859331	1.163696	1.021757	0.414917	2.410121	1.039866	0.482837
POL. BEJA	0.347276	2.879551	2.350704	0.288752	3.463184	2.020919	0.831475
POL. CÁVADO E AVE	0.526255	1.900218	1.682955	0.546013	1.831459	2.368213	1.037543
POL. BRAGANÇA	0.545347	1.833696	1.46691	0.329401	3.035814	1.362294	0.604021
POL. CASTELO BRANCO	0.269357	3.712543	2.111383	0.2898	3.450652	2.178218	1.075896
POL. COIMBRA	0.512779	1.950159	1.836721	0.254975	3.921957	1.557341	0.497241
POL. GUARDA	-	-	-	-		-	-
POL. LEIRIA	0.452084	2.211976	1.412236	0.191451	5.223255	1.347491	0.423486
POL. LISBOA	0.395051	2.53132	2.114585	0.163233	6.126219	1.64741	0.413195
POL. PORTALEGRE	0.577123	1.732733	2.427562	0.593543	1.684799	2.65324	1.028451
POL. PORTO	0.439745	2.274046	1.857422	0.207724	4.814071	1.26257	0.472375
POL.SANTAREM	0.360183	2.776368	2.800658	0.29843	3.350874	2.701065	0.82855
POL. SETUBAL	0.32887	3.040714	1.832705	0.190048	5.261833	1.743782	0.577881
POL. VIANA DO CASTELO	0.504998	1.980207	1.84332	0.437085	2.287885	1.75575	0.865518
POL. VISEU	0.421048	2.375028	1.926955	0.36307	2.754288	1.939103	0.862302
POL. TOMAR	0.551074	1.81464	2.846724	0.43929	2.276403	2.663071	0.797152
ISCTE - IUL	0.452427	2.210302	1.134719	0.328284	3.046139	1.029133	0.725608
E.S.E. DE LISBOA	0.862348	1.159625	1.256783	0.843928	1.184935	2.674428	0.978641
E.S.E. DO PORTO	0.572719	1.746056	1.074104	0.486513	2.055445	1.495809	0.849478
E.S.N. INFANTE D. HENRIQUE	0.6775	1.476015	1.222477	0.735704	1.359242	5.348874	1.08591
E.S. HOTELARIA E TURISMO ESTORIL	0.671698	1.488764	1.222778	0.678069	1.474776	3.469972	1.009485

Table 23 - SW Bias-corrected DEAr Results (without Pol. Guarda)

Columns:

- OEFDEAR: output expansion factor metrics from our Bias-Corrected, Research-focused output-oriented VRS DEA (excluding Pol. Guarda);
- TEDEAR: technical efficiency metrics from our Bias-Corrected, Research-focused output-oriented VRS DEA (excluding Pol. Guarda);
- DIFFVRS: ratio between the VRS Technical Efficiency Scores without Pol. Guarda by the scores with Pol. Guarda;
- OEFDEARCRS: output expansion factor metrics from our Bias-Corrected, Research-focused output-oriented CRS DEA (excluding Pol. Guarda);
- TEDEARCRS: technical efficiency metrics from our Bias-Corrected, Research-focused output-oriented CRS DEA (excluding Pol. Guarda);
- DIFFCRS: ratio between the CRS Technical Efficiency Scores without Pol. Guarda by the scores with Pol. Guarda
- SCALE: scale efficiency metrics from our Bias-Corrected, Research-focused output-oriented DEA (excluding Pol. Guarda);

B.7. Comparison of DEAt scores:

ESTAB	N-CRS	N-VRS	SW-CRS	SW-VRS	QUANT	QUAL	NOSTU
U. AÇORES	0.734672	0.997491	0.709552	0.988308	0.680233053	0.992661945	0.993517
U. ALGARVE	0.821983	0.972458	0.803335	0.967661	0.784909272	0.966666628	0.968727
U. AVEIRO	0.815006	0.981749	0.775859	0.97638	0.752184079	0.974781715	0.977419
U. BEIRA INTERIOR	0.891006	0.975101	0.860767	0.965544	0.851127429	0.966917498	0.969144
U. COIMBRA	0.842953	0.9881	0.779788	0.98271	0.78486085	0.978640582	0.983158
U. ÉVORA	0.497822	0.97572	0.473975	0.971505	0.462367451	0.971372298	0.972522
U. NOVA LISBOA	1	1	0.918068	0.991848	0.888989325	0.98694265	0.992835
U. MINHO	1	1	0.929221	0.984048	0.911006839	0.968448809	0.975561
U. PORTO	0.967386	1	0.931258	0.986273	0.929288401	0.979721528	0.99117
U. TRÁS-OS-MONTES	0.748425	0.956095	0.704757	0.950681	0.687421716	0.951115878	0.952341
U. MADEIRA	0.800867	0.996736	0.783918	0.987947	0.775702395	0.99183295	0.992728
U. LISBOA	0.883981	1	0.854494	0.988179	0.851108667	0.984547914	0.990033
POL. BEJA	0.759473	0.976446	0.739164	0.966272	0.732385899	0.971448828	0.97234
POL. CÁVADO E AVE	1	1	0.865346	0.979153	0.851403014	0.964994534	0.971837
POL. BRAGANÇA	0.731477	0.957964	0.672122	0.952222	0.65629954	0.953044816	0.954043
POL. CASTELO BRANCO	0.731106	0.968584	0.716218	0.961906	0.712031119	0.963991542	0.964886
POL. COIMBRA	0.991057	0.991515	0.936212	0.968741	0.923410402	0.964467103	0.973104
POL. GUARDA	0.785037	0.956614	0.758954	0.944358	0.722393915	0.951632697	0.952476
POL. LEIRIA	0.933901	0.979254	0.914683	0.96767	0.899054922	0.96961752	0.973661
POL. LISBOA	0.914756	0.991923	0.885447	0.982693	0.882910057	0.980265203	0.984925
POL. PORTALEGRE	0.70882	0.961283	0.684832	0.950532	0.66793454	0.956354377	0.957138
POL. PORTO	1	1	0.943117	0.973027	0.910426588	0.974990233	0.978487
POL. SANTAREM	0.855948	0.981301	0.835634	0.971685	0.824933517	0.976360363	0.976982
POL. SETUBAL	0.82931	0.983506	0.814051	0.978277	0.808125149	0.97836598	0.979891
POL. VIANA DO CASTELO	0.995082	0.995207	0.963807	0.981018	0.955363689	0.964752106	0.960835
POL. VISEU	0.774277	0.960035	0.76033	0.954101	0.747963072	0.955364419	0.956407
POL. TOMAR	0.687814	0.961055	0.664849	0.950042	0.618950187	0.956048354	0.956979
ISCTE – IUL	1	1	0.854489	0.991384	0.838147091	0.980326417	0.989203
E.S.E. DE LISBOA	1	1	0.982692	0.981139	0.97974994	0.9942719	0.995286
E.S.E. DO PORTO	1	1	0.97628	0.958628	0.972253915	0.9862999	0.978978
E.S.N. INFANTE D. HENRIQUE	1	1	0.903504	0.986174	0.874760381	0.977280668	0.985991
E.S.H.T. ESTORIL	1	1	0.915853	0.987497	0.828117984	0.968902775	0.986935
CORRELATION LEVELS	0.51585	0.876485	0.453125		0.450858528	0.771633513	0.882479

Table 24 - Comparison of DEAt Results

Columns:

- N-CRS: Normal, output-oriented CRS Technical Efficiency Scores from a Teaching-Focused DEA;
- N-VRS: Normal, output-oriented VRS Technical Efficiency Scores from a Teaching-Focused DEA;
- SW-CRS: Bias-Corrected, output-oriented CRS Technical Efficiency Scores from a Teaching-Focused DEA;
- SW-VRS: Bias-Corrected, output-oriented VRS Technical Efficiency Scores from a Teaching-Focused DEA (main scores);
- Quant: 3-input, 1-ouput (Number of Graduates) output-oriented VRS Technical Efficiency Scores;
- Qual: 3-input, 1-ouput (Employment Rate) output-oriented VRS Technical Efficiency Scores;
- NoStu: 2-input, 2-ouput (excludes Students Enrolled) output-oriented VRS Technical Efficiency Scores;

B.8. Comparison of DEAr Scores (part 1):

ESTAB	SW-VRS (PG)	SW-VRS	DIFF	SW-CRS	N-VRS	N-CRS
U. AÇORES	0.350846	0.735029	2.09502	0.776182	1	0.948252
U. ALGARVE	0.416968	0.532674	1.277495	0.299538	0.619802	0.349476
U. AVEIRO	0.867249	0.844502	0.973771	0.476094	1	0.545364
U. BEIRA INTERIOR	0.626395	0.785566	1.254107	0.724728	1	1
U. COIMBRA	0.761615	0.805325	1.057391	0.530576	0.919791	0.587757
U. ÉVORA	0.4016	0.460099	1.145664	0.243978	0.536118	0.286813
U. NOVA LISBOA	0.484956	0.655073	1.350789	0.355401	0.757533	0.396901
U. MINHO	0.651092	0.706732	1.085456	0.410674	0.80174	0.464543
U. PORTO	0.802048	0.812013	1.012425	0.609387	1	0.698821
U. TRÁS-OS-MONTES	0.512259	0.576464	1.125338	0.384008	0.692767	0.439141
U. MADEIRA	0.762554	0.699064	0.916741	0.80574	1	1
U. LISBOA	0.841033	0.859331	1.021757	0.414917	1	0.46935
POL. BEJA	0.147733	0.347276	2.350704	0.288752	0.457235	0.381
POL. CÁVADO E AVE	0.312697	0.526255	1.682955	0.546013	0.711723	0.697494
POL. BRAGANÇA	0.371766	0.545347	1.46691	0.329401	0.666053	0.396865
POL. CASTELO BRANCO	0.127574	0.269357	2.111383	0.2898	0.35436	0.333924
POL. COIMBRA	0.279182	0.512779	1.836721	0.254975	0.615112	0.321027
POL. GUARDA	0.597045	-	-	-	-	-
POL. LEIRIA	0.32012	0.452084	1.412236	0.191451	0.540114	0.23237
POL. LISBOA	0.186822	0.395051	2.114585	0.163233	0.483682	0.206786
POL. PORTALEGRE	0.237738	0.577123	2.427562	0.593543	0.737479	0.714709
POL. PORTO	0.23675	0.439745	1.857422	0.207724	0.536335	0.247814
POL. SANTAREM	0.128607	0.360183	2.800658	0.29843	0.471548	0.374085
POL. SETUBAL	0.179445	0.32887	1.832705	0.190048	0.408689	0.23312
POL. VIANA DO CASTELO	0.273961	0.504998	1.84332	0.437085	0.671515	0.553254
POL. VISEU	0.218504	0.421048	1.926955	0.36307	0.539452	0.422046
POL. TOMAR	0.193582	0.551074	2.846724	0.43929	0.745696	0.615253
ISCTE – IUL	0.398713	0.452427	1.134719	0.328284	0.562697	0.382492
E.S.E. DE LISBOA	0.686155	0.862348	1.256783	0.843928	0.995386	0.994744
E.S.E. DO PORTO	0.533207	0.572719	1.074104	0.486513	0.571785	0.571785
E.S.N. INFANTE D. HENRIQUE	0.554203	0.6775	1.222477	0.735704	1	1
E.S. HOTELARIA E TURISMO ESTORIL	0.549321	0.671698	1.222778	0.678069	1	1
AV DIFF/CORRELATION			1.572182	0.729424	0.947756	0.665135

Table 25 - Comparison of DEAr scores (part 1)

B.9. Comparison of DEAr Scores (part 2):

ESTAB	SW-VRS	QUANT	QUAL	NOSTU
U. AÇORES	0.735029	0.28525328	0.704465019	0.770172453
U. ALGARVE	0.532674	0.38403627	0.36308785	0.432436846
U. AVEIRO	0.844502	0.88203824	0.43140726	0.70594946
U. BEIRA INTERIOR	0.785566	0.53529646	0.715950504	0.789877873
U. COIMBRA	0.805325	0.74832185	0.502915906	0.768107973
U. ÉVORA	0.460099	0.3813746	0.279487972	0.38319911
U. NOVA LISBOA	0.655073	0.48512328	0.498390572	0.657952784
U. MINHO	0.706732	0.65549214	0.413963262	0.608253082
U. PORTO	0.812013	0.78844238	0.466941826	0.825406882
U. TRÁS-OS-MONTES	0.576464	0.4817881	0.348945127	0.570404809
U. MADEIRA	0.699064	0.65669006	0.426958064	0.742957782
U. LISBOA	0.859331	0.83755587	0.450541411	0.853664783
POL. BEJA	0.347276	0.1042381	0.336623639	0.343454915
POL. CÁVADO E AVE	0.526255	0.19419586	0.506658429	0.519485242
POL. BRAGANÇA	0.545347	0.31426545	0.429207981	0.466042533
POL. CASTELO BRANCO	0.269357	0.1068467	0.254239566	0.277275462
POL. COIMBRA	0.512779	0.22686852	0.454780783	0.428535364
POL. LEIRIA	0.452084	0.27392291	0.3527948	0.34004615
POL. LISBOA	0.395051	0.15827165	0.377898043	0.367825833
POL. PORTALEGRE	0.577123	0.19488085	0.506494629	0.446138442
POL. PORTO	0.439745	0.22422224	0.40499175	0.456990499
POL. SANTAREM	0.360183	0.08725802	0.345191537	0.373823293
POL. SETUBAL	0.32887	0.13621843	0.296493141	0.276707657
POL. VIANA DO CASTELO	0.504998	0.20902073	0.457315811	0.501077919
POL. VISEU	0.421048	0.15656629	0.385728166	0.375255037
POL. TOMAR	0.551074	0.11537619	0.564104465	0.553149264
ISCTE – IUL	0.452427	0.37006927	0.270821245	0.479713883
E.S.E. DE LISBOA	0.862348	0.55166579	0.609251793	0.767757502
E.S.E. DO PORTO	0.572719	0.51010565	0.262487467	0.565714051
E.S.N. INFANTE D. HENRIQUE	0.6775	0.54696139	0.692656909	0.666579567
E.S. HOTELARIA E TURISMO ESTORIL	0.671698	0.14668482	0.728179271	0.650804098
AV DIFF/CORRELATION		0.82540521	0.627574409	0.95525493

Table 26 - Comparison of DEAr scores (part 2)

Columns (both parts):

- N-CRS: Normal, output-oriented CRS Technical Efficiency Scores from a Teaching-Focused DEA;
- N-VRS: Normal, output-oriented VRS Technical Efficiency Scores from a Teaching-Focused DEA;
- SW-CRS: Bias-Corrected, output-oriented CRS Technical Efficiency Scores from a Teaching-Focused DEA;
- SW-VRS (PG): Bias-Corrected, output-oriented VRS Technical Efficiency Scores from a Teaching-Focused DEA (includes Pol. Guarda);
- DIFF: ratio between the VRS Technical Efficiency Scores without Pol. Guarda by the scores with Pol. Guarda;
- SW-VRS: Bias-Corrected, output-oriented VRS Technical Efficiency Scores from a Teaching-Focused DEA (main scores);
- Quant: 3-input, 1-ouput (Number of Graduates) output-oriented VRS Technical Efficiency Scores;
- Qual: 3-input, 1-ouput (Employment Rate) output-oriented VRS Technical Efficiency Scores;
- NoStu: 2-input, 2-ouput (excludes Students Enrolled) output-oriented VRS Technical Efficiency Scores;