Benchmarking of Secondary Schools based on Students' Results in Higher Education

Maria C.A. Silva [1], Ana S. Camanho [2], Flávia Barbosa [2]

June 19, 2019

[1] CEGE - Católica Porto Business School (csilva@porto.ucp.pt)
[2] Faculdade de Engenharia da Universidade do Porto
(acamanho@fe.up.pt; flavia.barbosa@inesctec.pt)

Abstract

The performance of secondary schools is usually assessed based on students' results on national exams at the end of secondary education. This research uses data on academic achievements by first-year university students to benchmark secondary schools on their ability to lead students to success in higher education. The drivers' of success in early stages of tertiary education are also explored. The analysis is conducted using data of University of Porto and Catholic University of Porto, Portugal, for a three-year period, corresponding to more than 10.000 students from 65 degrees. The results show that the students grades on entry and the type of school attended have a significant role in students' success. Regarding school benchmarking, we found that the schools' ranking based on their ability to prepare students for university success is quite different from the ranking based on results on national exams. Given these findings, we propose complementing schools' performance assessments with indicators that account for the preparation of students for success in future challenges, which is indisputably a key objective of secondary education.

Keywords: Secondary Schools' Benchmarking; Higher Education; Composite Indicators; Data Envelopment Analysis.

1 Introduction

School benchmarking is a common practice in many countries worldwide. In a recent review of educational studies and applications of Data Envelopment Analysis (DEA) to this field, Thanassoulis et al. (2016) classified the studies according to the educational stage under assessment. Secondary education studies are typically concerned with the effectiveness of schools in making their pupils achieve good results on national exams given their initial ability levels and socio-cultural context. Studies with this purpose are usually called value-added assessments. Higher Education (HE) studies are typically concerned with cost efficiency, evaluating the extent to which the institutions minimise the resources used to produce their outputs. The outputs more often considered are research performance and teaching performance, given the dual role of HE institutions of producing scientific knowledge and passing it to society via students education.

The link between secondary education and higher education achievements remains understudied. This is probably due to the different missions of these educational stages, and to the unavailability of databases allowing researchers to trace the full educational history of students. However, as one of the aims of secondary education is to enable the students to enter HE, there is an inherent link between these two cycles of studies. In this paper, we assess secondary schools considering that their mission is based on three pillars: (i) to make their students achieve high grades in national exams given their ability levels and socio-economic background; (ii) to place as many students as possible in HE (which is linked with objective i); and (iii) to prepare students in a way that promotes success in further education and in life. The focus of our study in on upper secondary education (level 3 of the International Standard Classification of Education (ISCED) scale). Special types of secondary schools that prepare students for a profession (e.g., professional, technical or vocational schools) may have different missions, but these are not the subject of our analysis.

The objective of secondary schools stated in (i) is the main motivation behind the construction of league tables and rankings of schools based on national exams. This topic has attracted public interest in several countries, and has been widely researched by the scientific community and education authorities. The studies range from simple rankings of schools to more complex studies, where regression or frontier-based methods are used to compare schools.

Rankings of schools are also a concern of national education authorities in several countries. A few online platforms are available to the general public, where schools can be compared at national or regional level. Among the first tools available for school comparison are those provided by the UK Department of Education, called “School Performance Tables” (available since 1992). These tables have suffered many changes and updates over time but the UK can be considered a precursor in the development of value-added measures of school performance. The aim of these performance measures is to assess the progress that students make at a particular school, taking into account their initial levels of attainment and other socio-economic characteristics. The scores available today are simpler than in the past. As Leckie and Goldstein (2017) report, from 2002 to 2005 the comparisons of schools were based on value-added scores, which changed to contextual value-added up until 2010, and to expected progress up to 2015. Nowadays, the main figure provided by the Department for Education (among other statistics for each school) is called “Progress 8”. It aims to capture the progress a pupil makes from the end of primary school to the end of secondary school. To compute “Progress 8”, pupils’ results are compared to the actual achievements of other pupils with similar prior attainment.

The Portuguese Ministry of Education also has a website (Infoescolas) displaying for each school a number of statistics, including a measure of progress similar to the one used in the UK. This measure, called “Direct Paths of Success” (DPS) gives the difference in the percentage of students who obtain a positive score in national exams at the end of secondary education, after a non-withholding path of three-years in secondary education, and the national average for students of the same ability on entry (evaluated at the end of basic education).

In the academic community, studies on the topic of school performance and value-added have typically applied frontier techniques or multi-level regression. The data used in such studies are typically defined at the student level or aggregated at the school level. Examples of student-level studies include Portela and Thanassoulis (2001), who separated pupil effects from school effects in a DEA framework using UK data, Portela and Camanho (2010), who applied a similar approach to Portuguese schools, De Witte et al. (2010) who compared the results of a non-parametric DEA model to those of a multilevel regression model using British schools data, and Cherchye et al. (2010), who assessed the efficiency of Flemish students using DEA in a first stage and a regression-based approach in a second stage.

It is common practice in many countries to publicly disclose the schools’ results on national exames. This non-contextualised measure of students’ achievement underlies the construction of school rankings, with a strong impact on public opinion. When schools facing different contextual conditions are directly compared to each other based on raw exam results, the evaluation of performance is clearly unfair. Despite these limitations, these measures are often made public, and are enthusiastically discussed in the public sphere, given the importance of the results in national examinations to allow entry into higher education degrees and institutions with high demand. Thus, this type of assessments are directly related to the objective (ii).

The objective stated in (iii), concerning the promotion of successful paths in subsequent educational stages, is under-researched. It is our aim to shed some light on the way secondary schools prepare students for success in higher education. For that purpose, this paper is divided in two parts. In the first part we investigate the drivers of academic success during the first year in higher education. The explanatory variables considered represent the characteristics of the students and the characteristics of the school of origin. We conduct separate analysis for different Universities, as well as for specific degrees within each University. In the second part, we benchmark secondary schools based on their ability to prepare students for university success and provide a visual map of performance in the three objectives stated above.

From a methodological perspective, the most significant contribution of this paper concerns the benchmarking of schools based on students' results on higher education. For this purpose, we compare a sample of secondary schools (those that place a sufficiently large number of students at the universities under analysis) through the construction of a DEA-based composite indicator (CI). This overall indicator of students' performance aggregates individual indicators of students' outcomes at university. The final visualization of schools' performance reflecting the three objectives previously stated, includes, in addition to the CI proposed in this paper, the DPS indicator and the average school results in national exams.

This paper uses a sample of students who were enrolled in the University of Porto and Catholic University of Porto, Portugal, in the academic years 2013/14, 2014/15 and 2015/16. Our analysis is restricted to students in the first year at university, since we consider that this is the period when secondary education may have a stronger effect on students' achievements.

The Portuguese case presents some particularities that are worth exploring. The percentage of population with tertiary education in Portugal has been growing over the last years, but still lags behind the OECD average for the age group 25-34 (according to OECD data - data.oecd.org). In 2017 the percentage of Portuguese population with tertiary education was 34%, about seven percentage points below the OECD average (e.g, for France the percentage was 44%, for Spain was 43% and for the UK was 52%). This means that most of the young labour force in Portugal does not hold a university degree. Therefore, the study of the factors underlying students' success in Portuguese higher education is important, since this may trigger the design of policies to enhance the rates of success in HE, as well as give new insights on the most appropriate policies to foster admission of students with high academic potential in HE institutions .

2 Performance Assessment in Education

Witte and Lopez-Torres (2017) reviewed the literature on educational studies that applied frontier techniques and found that Data Envelopment Analysis (DEA) is the dominating frontier technique in the education field. Most of the studies reviewed have focused on one educational stage (e.g. basic education, secondary education or terciary education) using data at different levels of aggregation (e.g., the student, the classroom, the school, school district, HE Department, Faculty or University). None of the studies applying frontier techniques for benchmarking purposes explored the link between secondary education and higher education. This link was only addressed in studies concerned with the identification of the determinants of student's success in higher education.

This section reviews previous research addressing the determinants of student's success in HE and the evaluation of schools' performance using frontier techniques.

2.1 The determinants of university student's success

In several countries university access is conditioned by secondary school grades. This is also the case in Portugal, where applications for entry in HE are ordered by an entry score obtained as a weighted average between the secondary education grades (reflecting the achievements of the student at school for a period of three years in secondary education) and the grades obtained in national exams. Each HE degree defines the national exams required for admission and their relative weight in the computation of the entry score. The total weight of national exams in the entry score typically varies between 35% and 50%.

Clearly some schools may perform better at maximising student exam scores than others and some schools may be more benevolent in their grades than others. If that is the case, high school grades alone, or weighted with national examination grades, may be an unreliable predictor of university success. Academic achievements in HE education may also depend on other factors, some of which unobserved, like the motivation of the student for attending the course enrolled.

As a result, the analysis of the determinants of university students success is important not only for designing appropriate policies to monitor students progression in higher education, but also to help educational authorities in the design of fair policies for university access (that maximise the possibility of high potential students entering the HE degree of their choice). Access to tertiary education is becoming highly competitive, with highly reputed degrees showing a demand much higher than the supply. In the Portuguese context, Cabral and Pechincha (2018) report that in Portugal there were 50852 vacancies to higher public education in 2018, from which 86% were filled. For University of Porto (UP) degrees, from a total of 3976 vacancies 99.8% were filled. This example shows that for highly reputed Universities, such as UP, the supply of the different degrees is almost entirely met by the demand, implying a highly competitive process to enter a few of the degrees.

One of the first studies that analysed the link between secondary education and higher education was that of Sear (1983), who found poor correlation between secondary school A-level scores and university scores in various degrees (this study used data of about 2000 students from Great Britain). Also in the UK, Smith and Naylor (2001) found that students who attended private fee-paying 'Independent' schools prior to university were likely to perform worse at university than students who attended state-sector schools (Local Education Authority - LEA) . This implies that the type of school attended had an impact on students achievements at the university. In addition, Smith and Naylor (2001) also found that financial constraints had a positive impact in dropout rates in university students. Later Smith and Naylor (2005) used data on all university students in the UK and an ordered probit regression model to explain students' classification at university. They found that prior A-level points had an important effect on success at university, as well as the type of school of origin of the student (on average, students who attended an independent school were about 6% less likely to be awarded a 'good' degree compared to a student who attended a state school, ceteris paribus). Kaighobadi and Allen (2008) also found evidence that the strongest predictor of university success (represented by the final grade on exit of HE) are the grades on two core courses of management and finance in the first year of studies). This result was obtained for the specific case of Business Schools in the US, with a sample with over 5000 students, based on a truncated regression model.

Mora and Escardibul (2008) used a sample of students from the University of Barcelona, observed over the period 1996-2003 (22364 students in 14 faculties). They used a generalised linear model to understand the main determinants of students' university performance. Mora and Escardibul (2008) dealt with the faculties diversity by running separate regressions for five groups of students (in Business and Economics degrees, in law degrees, in humanities degrees, in Psychology degrees, in Medical degrees and in Science degrees). They found that students from private schools perform better than those from public schools. They also concluded that high school peer effects (measuring the extent to which students from the same high school attend the same faculty) has a significant and negative impact on graduates' grades in all the faculties considered, suggesting that higher grades can be achieved by students who acquire new friends at university. Students' ability (measured by entry scores at university) is found to be also an important determinant of university students' final grades.

Cyrenne and Chan (2012) also corroborates the finding that students' high school entry grade is a good predictor of the university grade. These authors analysed 5136 students of the University of Winnipeg in Canada for the years 1997-2002 using two regression-based procedures: Least Squares Dummy Variable estimator (LSDV), which considers fixed effects by a separate dummy variable for each high school, and a Hierarchical Linear Model (HLM), which assumes that the high school effect (or the school intercept) is random. Cyrenne and Chan (2012) discuss the criteria for students admission to university, which in Canada, like in Portugal, is mainly determined by high school grades. Like Mora and Escardibul (2008), Cyrenne and Chan (2012) also found a significant private school positive effect.

Lasselle et al. (2014) analysed 1320 students that were enrolled in the University of St. Andrews in Scotland. They used a probit regression model to test the effects of high school classification and school environment (a dummy variable reflecting whether the school performed above or below average in high school results) on the performance of students at university (a binary variable set to one for students who achieved a first or upper second class degree at university). Results point to the importance of high school grades and the school environment in explaining university performance. The predicted probabilities of a good degree are slightly larger for those students from a less favourable school context. The authors discuss this result explaining that at "below average schools, those students obtaining three A grades are likely to be among the most well-motivated and brightest" (p.310).

Gosele et al. (2017) analysed 12000 students from Göttingen University and provide evidence that high school leaving grade is the best way to predict if the student will graduate. This effect however, varies widely depending on the field of study. In addition, the authors found that the socio-economic background of students (measured through parent's income or education) has a very small effect on university performance, suggesting that the impact of these variables fades away as a student moves on in his/her academic path.

Studies in the Portuguese context are scarce. In 2014, Cabral and Pechincha (2014) analysed the determinants of university success for UP students. Using regression analysis, they found that entry grade is not a very good predictor of university scores, while the type of school attended is the variable that influences the most university success. The influence of attending a private school is negative in the expected final graduation score of university students. The predictive power of the variables considered (gender, entry grades and type of secondary school attended) is very low as these variables can only explain about 6% of the variability around the mean of scores on exit (corresponding to the final year of the degree attended by the students).

Cerdeira et al. (2018) investigated the predictive power of internal grades and exam scores in the success of university students in Portugal. They used a sample of more than 20 thousand students and a regression model to predict their success, measured as the final grade at the end of the higher education degree. Results point to the higher importance of internal school grades in predicting student's success, but the two variables (results on national exams and internal school grades during secondary education) could only explain at most around 15% of student success (a value that is close to what we observe in our empirical study). Regarding other factors, public school students seem to have a slight advantage, gender appears non-significant, working students perform worse than non-working students, and students from social disadvantaged backgrounds seem to perform better (especially when enrolled in top courses).

In a recent study in the Portuguese context, Migueis et al. (2018) used data mining techniques to group and classify students in terms of their potential for academic success. The authors constructed an indicator of success corresponding to the average grade obtained by the student on graduation, corrected for the number of attempts to pass a course (the average grade of the student at the end of the degree is obtained by multiplying the grade obtained on each course by the number of ECTS the course is worth, and then dividing the result of the sum of these values for all courses approved by the total number of ECTS that the student has registered in whilst attending the degree). The conclusions of the study, considering several variables (e.g., entry grades, type of high school attended, parents' education), were that the entry grade and the grades obtained on national exams (also considered in the entry grade, which is a weighted average of national exam grades and internal school grades) are the best predictors of students' success in higher education.

2.2 Benchmarking Schools

The studies on school efficiency and effectiveness (or value-added) have frequently used frontier techniques for benchmarking purposes (see Witte and Lopez-Torres (2017)). According to Mayston (2003), two main perspectives of analysis have been adopted: value-added or value for money.

Value-added is related to the vast strand of the literature on school effectiveness, where the most effective schools are those that are able to add more value to their students. Taking into account students' ability levels on entry, schools are compared based on the extent to which they engage their students into successful academic paths, measured through attainment on exit (Portela and Camanho, 2010). Value for money, is related to the analysis of school efficiency. In this context, schools are seen as entities consuming resources (e.g. money, teacher's time, etc.) to allow the production of outputs (e.g. graduates, high grades in exams, etc.). In this process, efficient schools are those that consume the least inputs to achieve a given amount of outputs.

In effectiveness or efficiency studies, school inputs usually include three types of variables: (i) those reflecting characteristics of pupils (e.g., prior attainment or socioeconomic characteristics), (ii) those reflecting characteristics of the school (e.g., number of teaching and non-teaching staff, expenditure per pupil, size of school or class size), and (iii) those reflecting characteristics of teachers (e.g., teachers' salary, experience or level of education). Outputs are in general related to the results of students in standardized test scores, aggregated at the school level in various forms like the mean (Muniz (2002); Mizala et al. (2002),Portela et al. (2012)), or the proportion of pupils achieving more than a certain grade (Bradley and Taylor (1998)). Other relevant outputs also related to pupils' achievement are the number of approvals or success rates (Kirjavainen and Loikkanen (1998); Muniz (2002)), attendance rate (Bradley and Taylor (1998);Arnold et al. (1996)), number of graduates (Kirjavainen and Loikkanen (1998)), and percentage of students who do not drop out from school (Arnold et al. (1996)).

The use of standardized test scores done at the end of an education cycle is the main output used in school evaluations. This happens not only in studies done at the national level (in countries applying national exams), but also in studies comparing educational achievements in different countries. In this case, PISA, TIMSS and PIRLS results are often used (e.g., see Agasisti and Zoido (2018) who assessed 8500 schools in 30 countries). Some examples of recent educational efficiency/effectiveness studies can be found in Haelermans and Ruggiero (2017), Agasisti and Zoido (2018) or Aparicio et al. (2018).

The time component of educational achievements is often disregarded in empirical studies. In spite of the general agreement that pupils academic outcomes tell just a part of the story associated with their educational development, exam results are the only objectively measurable outcomes of secondary schools. Empirical evidence is, however, "inconclusive about the strength of the link between test scores and subsequent achievement outside the schools" (Hanushek (1986) p. 1154). However, for pupils that decide to pursue higher education studies, there is the possibility of measuring quantitatively their achievement at the next educational stage, reflecting an important outcome of schools: the preparation of students for success in further educational stages. This is a topic that we specifically address in this paper.

The purpose of this paper is to evaluate the performance of secondary schools considering different perspectives, ranging from value-added assessments (successful academic paths, without retention, given the prior ability levels of students), the results on national exams at the end of secondary education, and the results obtained in subsequent education stages. Although this study provides a wide-ranging evaluation of school performance, it leaves aside other objectives of schooling (e.g., to foster students' emotional development, social development, physical development or civil development) that eventually can only be measured in qualitative terms.

3 Methodology

The first issue addressed in this study concerns the determinants of success of first year students in higher education. This topic is evaluated using regression analysis. For the analysis of schools' performance based on higher education achievements of their students, we construct a composite indicator using a directional distance function model. These approaches are described in the following sections.

3.1 Regression analysis to identify the determinants of good performance in higher education

A regression model (e.g. Gujarati and Porter (1999)) estimates the impact of a set of k explanatory variables (x_{ki}) observed for each observation i on a target or dependent variable usually denoted by y_i. The regression equation is defined in (1):

$$Y_i = \alpha + \sum_{k=1}^{K} \beta_k x_{ki} + \epsilon_i \tag{1}$$

α is the intercept and β_k is the estimated impact on the expected value of the dependent (or target) variable of unitary variations of the explanatory (or independent) variables k (ceteris paribus). ϵ_i is the disturbance term that reflects the difference between the expected and observed values of the target variable for observation i.

The standard method for estimating the parameters β_k is Ordinary Least Squares.

Independent variables may be of various types, including scale variables, categorical variables (represented through dummy variables) or interaction terms that consist in the multiplication of various independent variables. The use of interaction terms implies changes in the interpretation of the regression coefficients, since the impact of a certain variable x_k on the dependent variable needs to be added the amount of the coefficient β_{kp} associated with the interaction term between x_k and x_p. That is, the coefficient associated with the interaction term estimates the change in the slope of the regression on x_k given a one unit change in x_p (or, alternatively, the change in the slope of the regression on x_p given a one unit change in x_k, depending, on how the interaction is conceptualized). For details see Jaccard et al. (1990)).

When interaction terms are used, variables should be centered to avoid multicollinearity problems as advocated in Jaccard et al. (1990). Centering a variable is simply to take its difference from the mean.

3.2 Composite indicator to benchmark schools based on higher education achievements

Composite indicators are capable of aggregating several individual indicators, representing partial views of multi-dimensional processes, into a summary measure that provides an overall perspective of achievements. CIs have increasingly been accepted as a useful and relevant tool for performance comparisons, benchmarking, policy analysis and public communication in various fields, such as economy, environment and society (OECD, 2008). Flexible weighting systems can be implemented using DEA models, under the BoD approach, a term coined by Cherchye et al. (2007). It suggests the use of a dummy input equal to one and multiple outputs that represent individual performance indicators to be combined in the composite measure. In the absence of reliable and consensual information about the weights to be used in the aggregation stage, this method endogenously selects those weights that maximise the CI score for the unit under assessment. Thus, each unit can be assessed with its own weights, emphasising aspects with good performance.

This paper proposes the construction of a composite indicator using a directional distance function model (Zanella et al., 2015), whose innovative feature is to adopt a directional vector corresponding to the range of possible improvement for each unit (Portela et al., 2004). This advantage of this approach is the possibility to deal with indicators that may have negative data.

Consider a set of units $J = \{1, \ldots, n\}$, with indicators y_{rj} $(r = 1, \ldots, s)$ corresponding to output levels (in the sense that higher values correspond to better performance). For a given unit $o \in J$, the range of possible improvement for each indicator is as (Portela et al., 2004):

$$R_{ro} = \max_{J} \{y_{rj}\} - y_{ro},\ r = 1, \ldots, s \tag{2}$$

In order to benchmark the performance of unit o against its peers, we used model (3), specified according to the BoD paradigm. Note that model (3) is formally tantamount to the original Directional Distance Function model proposed by Chambers and Fare (1996), with a single input variable equal to one ($x_{ij} = 1\ \forall i, j$) and a directional vector whose components correspond to the range of possible improvement. In the context of the construction of composite indicators, the unitary input underlying the evaluation of every decision making unit can be interpreted as a "helmsman" attempting to steer the unit towards the maximization of outputs.

$$\begin{aligned} \max \quad & \beta_o \\ \text{s.t.} \quad & \sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{ro} + \beta_o R_{ro},\ r = 1, \ldots, s \\ & \sum_{j=1}^{n} \lambda_j \leq 1 \\ & \lambda_j \geq 0,\ \forall j \end{aligned} \tag{3}$$

From the optimal solution of model (3), we can obtain the values of the targets for each output indicator ($y_{ro}^{T}, r = 1, ..., s$) as shown in (4):

$$y_{ro}^{T} = \sum_{j=1}^{n} \lambda_j^* y_{rj}, \tag{4}$$

In the expression above, the symbol * signals the value of a decision variable at the optimal solution to model (3).

The value of β_o^* is equal to the minimum value of the distance between the value of the observed indicator y_{r0} and the target y_{ro}^{T} divided by the respective range, evaluated for $r = 1, \ldots, s$, as shown in (5):

$$\beta_o^* = \min_{r} \left\{ \frac{\left(y_{ro}^{T} - y_{ro}\right)}{R_{ro}} \right\} \tag{5}$$

Thus, β_o^* can be interpreted as the equi-proportional improvement that is possible in all output indicators of the unit o under evaluation, considering as reference the maximum improvement possible in each dimension observed in the sample under evaluation. Therefore, β_o^* is a proxy for the magnitude of inefficiency of unit o.

Since $y_{ro}^T - y_{ro}$ is always lower than the range R_{ro} (which defines the maximum potential for improvement) for each output r, it follows that β_o^* is always lower than 1. Values equal to 1 correspond to the worst possible performance, meaning that in all output dimensions the unit o under assessment has a potential for improvement equal to the maximum observed in the sample considered. In addition, as the target y_{ro}^T is always greater or equal to the value y_{ro} observed at unit o, the value of β_o^* is always greater or equal to zero.

Figure 1 illustrates the frontier estimated using the CI model (3) and the targets corresponding to projections on the frontier using the Range Directional Vector.

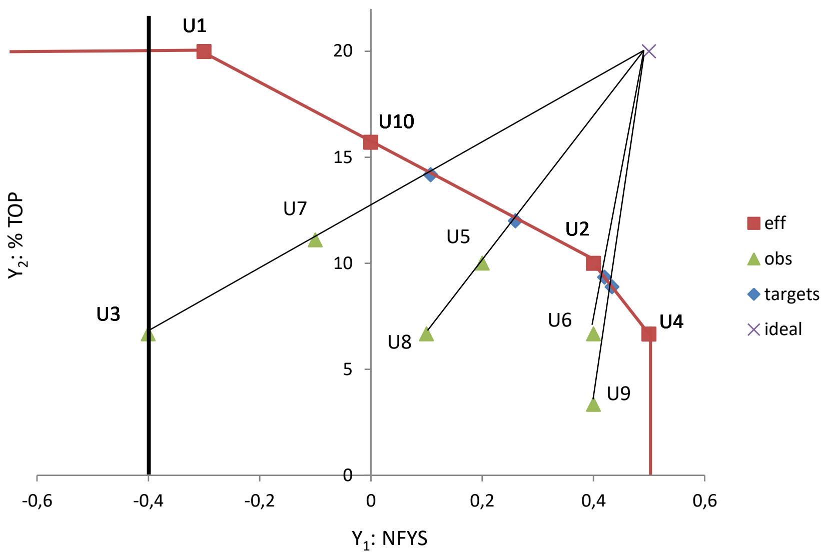

Figure 1: Graphical illustration of the CI with a range directional vector

The data corresponding to this pictorial illustration is provided in Table 1. Although this is a contrived example, the values Y_1 and Y_2 are within the ranges observed for the indicators used in the empirical study (described in detail in the next section). Y_1 corresponds to the Normalised First Year Score indicator (NFYS), representing the normalised values of the grade obtained for schools' students at the end of the first year in HE. Y_2 corresponds to the percentage of schools' students whose attainment in at the top level observed in the HE degree (% TOP).

	β	observed values Y_1	Y_2	target values Y_1^T	Y_2^T	partial efficiency E_{Y_1}	E_{Y_2}	overall efficiency
U1	0	-0.3	19.98	-0.3	19.98	1	1	1
U2	0	0.4	9.99	0.4	9.99	1	1	1
U3	0.56	-0.4	6.66	0.11	14.17	0	0.47	0.24
U4	0	0.5	6.66	0.5	6.66	1	1	1
U5	0.2	0.2	9.99	0.26	11.99	0.91	0.83	0.87
U6	0.2	0.4	6.66	0.42	9.324	0.98	0.71	0.84
U7	0.35	-0.1	11.09	0.11	14.16	0.59	0.78	0.69
U8	0.4	0.1	6.66	0.26	11.99	0.76	0.56	0.66
U9	0.33	0.4	3.33	0.43	8.88	0.96	0.37	0.67
U10	0	0	15.70	0	15.70	1	1	1

Table 1: Data for the illustration of the CI with a range directional vector

In order to estimate an efficiency score in this context, representing a ratio between the output observed and the target output level (i.e., a point on the frontier of the production possibility set), we propose the estimation of partial efficiency scores, each corresponding to a measures along the axis representing each output. In the particular case of output indicators with negative values, we must consider a fictitious origin, that coincides with the minimum value observed for that output indicator. This new origin is represented by the bold segment in Figure 1. The overall efficiency measure for each unit o under evaluation corresponds to the arithmetic average of the partial efficiency scores for all dimensions considered.

If all values of indicator r are positive (i.e., $y_{rj} \geq 0, \forall j$), we compute a partial efficiency score as usual:

$$\frac{y_{rj}}{y_{rj}^T} \tag{6}$$

If there exists at least one value of indicator r that is negative (i.e., $\exists j, y_{rj} < 0$), we compute a partial efficiency score as:

$$\frac{y_{rj} - \min_j \{y_{rj}\}}{y_{rj}^T - \min_j \{y_{rj}\}}. \tag{7}$$

The logic behind this procedure is to allow an interpretation of the efficiency score that can represent a proportional measure of improvement in relation to the observed values for each unit under assessment. This involves considering a proxy for a proportional interpretation in case the values of the indicators are negative. This requires switching the origin from 0 to the minimum value observed for that indicator.

As the overall efficiency score results from the aggregation of partial efficiency scores, it includes all sources of inefficiency, including both radial and non-radial adjustments to reach the frontier in all output dimensions considered. This is something that could not be achieved considering only the β_o factor, as it corresponds to equi-proportional adjustments associated to all outputs, disregarding slacks. Note that other authors have proposed alternative models to deal with negative data that maintained the proportional interpretation of the resulting efficiency score (e.g., Kerstens and de Woestyne (2011)) and others have addressed the issue of including all sources of inefficiency in the final efficiency score (e.g., Sharp et al. (2007)).

To illustrate how the partial efficiency measures and the overall efficiency measure are computed, consider the case of unit U3. As output Y_1 has negative values in our sample, we compute the partial efficiency score for y_{1U3} as $\frac{-0.4-(-0.4)}{0.11-(-0.4)} = 0$. Note that $\min_j \{y_{1j}\} = -0.4$. As all values of Y_2 are positive, we compute the partial score for y_{2U3} as $\frac{6.66}{14.17} = 0.47$. The overall score is $\frac{0+0.47}{2} = 0.24$.

4 Case study of two Portuguese Universities

4.1 Descriptive statistics of first year students

The data used in this paper were provided by University of Porto (UP), a public university, and Catholic University of Porto (UCP-Porto), a private university, covering a three year period (academic years of 2013/14, 2014/15 and 2015/16). The data includes entry grades to higher education (representing secondary education grades and results on national exams), as well as achievements of first year students attending first cycle degrees or integrated masters in these universities.

Table 2 presents the summary statistics of the data, organized by faculty. The sample includes 9184 students, 7626 students from UP and 1558 from UCP-Porto. These students attend 53 degrees from the 14 faculties of UP, and 12 degrees from the 7 faculties of UCP-Porto. The percentage of female students and students coming from private secondary schools is higher in UCP-Porto than in UP.

Faculties of UCP-Porto and UP	no. students	% female students	% students from private schools	no. degrees
School of Arts (CEA)	134	42%	36%	2
Faculty of Law (CFD)	496	68%	44%	1
Faculty of Biotechnology (CESB)	274	76%	42%	3
e Católica Porto Business School (CPBS)	375	51%	63%	2
Faculty of Education and Psychology (CFEP)	161	85%	43%	1
Faculty of Theology (CFT)	34	0%	50%	2
Institute of Health Sciences (CICS)	84	86%	35%	1
Total for UCP-Porto	**1558**	**64%**	**47%**	**12**
Faculty of Sport (FADEUP)	267	33%	35%	1
Faculty of Architecture (FAUP)	242	66%	24%	1
Faculty of Fine Arts (FBAUP)	257	79%	14%	2
Faculty of Nutrition and Food Science (FCNAUP)	117	94%	31%	1
Faculty of Sciences (FCUP)	1084	50%	20%	13
Faculty of Law (FDUP)	349	73%	24%	2
Faculty of Economics (FEP)	691	55%	34%	2
Faculty of Engineering (FEUP)	1713	29%	32%	10
Faculty of Economics (FFUP)	341	81%	28%	1
Faculty of Arts (FLUP)	1095	68%	15%	13
Faculty of Dental Medicine (FMDUP)	120	68%	49%	1
Faculty of Medicine (FMUP)	513	60%	48%	1
Faculty of Psychology and Education Science (FPCEUP)	309	88%	21%	2
Abel Salazar Institute of Biomedical Sciences (ICBAS)	528	68%	46%	3
Total for UP	**7626**	**56%**	**29%**	**53**

Table 2: Distribution of students per faculty

Data were collected at student level, and concerns the entry grade to the higher education degree and results at the end of the first year. Attainment on entry is measured through the variable "Entry score" (ES), which is a weighted average between secondary education grades obtained at school and national examination grades (in a scale 0-20). The specific formula is defined by each degree, but typically 50% is dedicated to specific national exams and the other 50% is dedicated to secondary school grades.

Attainment on exit is captured through two variables: "First year score" (FYS), which is the average classification (scale 0-20) obtained by the student in the courses that he/she was approved in the first year at university, and "ECTS", which is the number of European Credit Transfer and Accumulation System (ECTS) credits completed at the end of the first year. These two variables are used to compute the "Adjusted First Year Score" (AFYS), which is obtained multiplying the FYS by the percentage of ECTS credits to which the student was approved during the first year in higher education (from a total of 60 ECTS credits per academic year). In case the student enters the degree after having previously attended a different HE institution or degree, he/she may complete more than 60 ECTS in the first year (through creditation or enrollment in more than 60 ECTS). In the case the student completes more than 60 ECTS credits in the first year, the value of the AFYS is equal to the FYS.

Table 3 shows the descriptive statistics of the attainment variables for our sample per university and per faculty.

Faculties of UCP-Porto and UP	**Avg. ES**	**Avg. FYS**	**Avg. AFYS**	**Avg. ECTS**
School of Arts (CEA)	14.21	13.74	12.10	51.93
Faculty of Law (CFD)	14.84	12.47	7.48	35.32
Faculty of Biotechnology (CESB)	14.24	13.46	10.29	45.75
Católica Porto Business School (CPBS)	16.02	13.01	10.25	46.46
Faculty of Education and Psychology (CFEP)	13.55	13.37	11.40	50.06
Faculty of Theology (CFT)	13.24	13.57	8.72	38.15
Institute of Health Sciences (CICS)	12.98	13.49	13.05	58.01
Total for UCP-Porto	14.70	13.06	9.77	44.07
Faculty of Sport (FADEUP)	15.08	13.71	10.78	46.69
Faculty of Architecture (FAUP)	18.55	13.48	12.97	57.48
Faculty of Fine Arts (FBAUP)	16.77	13.94	11.64	49.72
Faculty of Nutrition and Food Science (FCNAUP)	16.44	13.85	11.77	50.22
Faculty of Sciences (FCUP)	15.26	12.88	9.54	43.16
Faculty of Law (FDUP)	17.03	12.37	10.46	49.67
Faculty of Economics (FEP)	17.47	13.87	12.64	53.87
Faculty of Engineering (FEUP)	16.62	13.41	10.92	47.96
Faculty of Economics (FFUP)	16.48	12.80	9.96	45.81
Faculty of Arts (FLUP)	15.57	13.51	11.44	49.73
Faculty of Dental Medicine (FMDUP)	17.57	13.69	7.71	33.25
Faculty of Medicine (FMUP)	18.79	13.23	11.72	52.65
Faculty of Psychology and Education Science (FPCEUP)	16.35	14.46	12.82	52.90
Abel Salazar Institute of Biomedical Sciences (ICBAS)	17.89	14.61	12.12	49.09
Total for UP	16.61	13.47	11.15	48.76

Table 3: Descriptive statistics of the attainment variables

Large differences in entry and exit scores happen between degrees, explained by factors such as the attractiveness of the degree and academic ability of the cohort of students enrolled, the structure and regulations of the degree or the culture of the faculty. Figure 2 illustrates the spread of Entry Scores per faculty (for UP and UCP-Porto).

Figure 3 illustrates the spread of First Year Scores per degree in one faculty of UP (Faculty of Engineering), for illustrative purposes. Variability across degrees implies their non-comparability in some cases. For example, medicine degrees in UP tend to have very high entry scores and very low variability among students (which is visible in Figure 2 for FMUP).

To allow comparisons among degrees, we normalised the Entry Score and the scores at the end of the first year (FYS and AFYS), and the resulting variables were used for inter-degree analysis. For this normalization we considered the mean and standard deviation of the variable (ES, FYS or AFYS) in each year and in each degree. The normalised variables are called Normalised Entry Score (NES), Normalised First Year Score (NFYS) and Normalised Adjusted First Year Score (NAFYS).

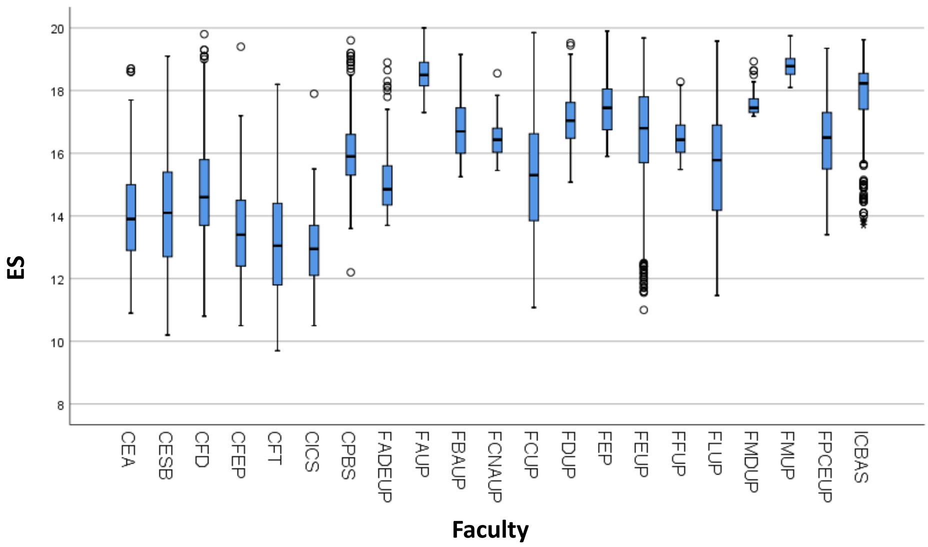

Figure 2: Boxplot of Entry Score per faculty for UP and UCP-Porto

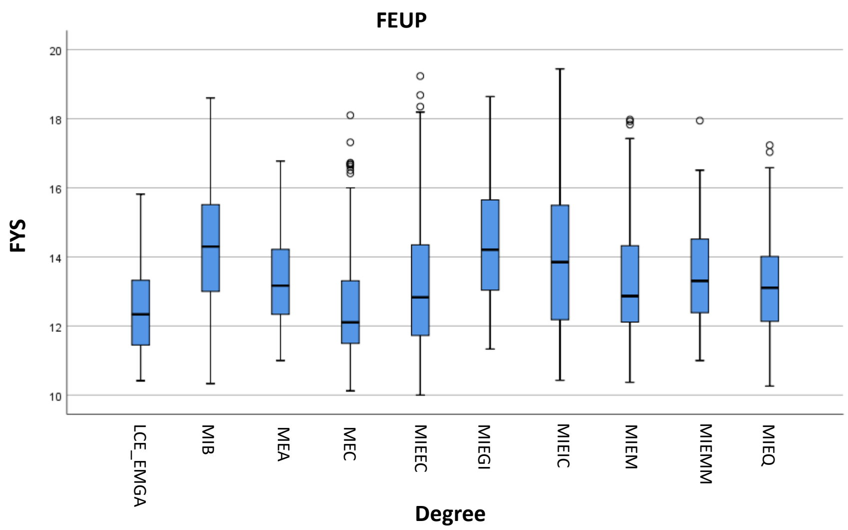

Figure 3: Boxplot of First Year Score for the degrees of FEUP

5 Results

5.1 Determinants of Success at the university

To identify the factors that have a significant influence on students' outcomes at the end of the first year in higher education (grades obtained in the courses attended and ECTS completed), we classified the factors in three different dimensions: (i) Characteristics of the student; (ii) Characteristics of the secondary school of origin; (iii) Characteristics of the degree/faculty.

Concerning the characteristics of the student, we consider the ES (that varies between 9.5 and 20) and gender (where the code 1 is used for females). The selection of students admitted in each higher education degree depends on their ES (corresponding to the classification considered in the national admission contest to public higher education, or the classification obtained in local admission contests organised by private universities). Therefore, we would expect that students with a higher ES (or entry grades above average when normalised values are used) perform better than students that enter with a lower ES.

Concerning the characteristics of the school of origin, we consider the type of secondary school (private or public, where the code 1 is used for private), school average grade on national exams (at the 8 most attended national exams in the period considered) and location of the school (a dummy variable that takes the value 0 for schools in the municipalities that belong to the district of Porto and have borders with Porto municipality (Porto, Matosinhos, Maia, Gondomar and Vila Nova de Gaia), and 1 otherwise).

Private schools in Portugal dominate the rankings of national exams results. This implies that students coming from these schools will have, on average, higher entry scores than their colleagues, and therefore have an advantage on entrance to HE. The school average grade on national exams (variable named "School Avg") was constructed based on the average of the 8 secondary exams that most students attended in the 3 academic years analysed (2013/14, 2014/15 and 2015/16). This variable accounts for school environment and peer effects of the student (since students from the same school will have the same value for this variable).

The location of the school may be relevant as it serves a as surrogate for the changes in life that the student experiences when entering university. If the student comes from a school located in the same municipality or in boardering municipalities of the HE faculty he/she attends, the adaptation efforts required may be less intense, as adjustments to living a different region and finding accommodation outside the family home may not be required.

Concerning the characteristics of the university attended, we run separate regressions for UP and UCP-Porto. The degree was indirectly considered in two ways: by running separate regressions per degree (on the assumption that the factors influencing attainment in HE may vary amongst degrees) and running a single regression with normalised variables to obtain overall trends for each University.

The information obtained from the regression analysis at the degree level is useful for managerial purposes. It allows those responsible for specific degrees to design the most appropriate procedures to enhance the outcomes of first year students.

In order to discover the factors that influence the results of first years students recruited by each university, we run a regression with the variables normalised around the mean of each degree for each particular year. This normalisation procedure was required for the independent variable ES and for the depend variables FYS and AFYS. The ECTS variable did not require any normalisation, as it is directy comparable across degrees. Using normalised scores per degree is equivalent to a fixed effects model for the degree (see Dranove (2012)).

In the regression models specified, we also considered some interation terms between variables. This implied the need to centralise the non-normalised variables around their mean - a common procedure to avoid problems of multicollinearity. The only variable that was centralised was the school average ("School-Avg") since all others were normalised variables whose mean is zero. The centralisation of this variables was done considering the mean and standard deviation within each university.

We start by analysing the determinants of student's success for the full sample of UP and UCP-Porto students (considering the two universities separately). So, for each university we run a Ordinary Least Squares (OLS) regression using as dependent variable the Normalised Adjusted First Year Score (NAFYS). Note that NAFYS considers simultaneously the number of ECTS undertaken by the student and the score obtained on the courses the student was approved. We also tested different specifications of the dependent variable (ECTS and NFYS), and the most important conclusions remained unchanged, irrespectively of the outcome variable considered.

The results are shown in Table 4 and Table 5. The total number of students used in the regressions are not coincidental with the numbers reported in Table 2 due to the missing values in some variables and to the exclusion from the regression analysis of students that did not complete any ECTS credit in the first year in HE.

Table 4 shows the significance of the regressions for UCP-Porto and UP for two modelling alternatives, with and without interactions among variables. The interaction terms considered are between the type of school and average exam grades, since it may happen that the impact of school average exam grades is differently relevant per type of school. In addition, the impact of the school average exam grades may also differ depending on the level of the student. As a result, we considered the interaction between the entry score of the student and the school average exam grade.

University	Model	R^2	Adjusted R^2	Std. Error Estimate	N
UCP-Porto	Without interaction	0.195	0.193	0.886	1489
	With interaction	0.196	0.192	0.886	
UP	Without interaction	0.131	0.130	0.923	7607
	With interaction	0.133	0.132	0.923	

Table 4: Determinants of student success

The adjusted R^2 for UCP-Porto is just 19.3% and the specification with two interaction terms did not imply an improvement in the adjusted R^2. For UP, the set of variables considered explains even less the variation in normalised scores, with an adjusted R^2 of just 13.0%. However, in this case, the consideration of the interaction terms improves slightly the adjusted R^2, which becomes 13.2%.

We also run a simple linear regression with only one predictor variable, corresponding to the normalised entry score (NES). In the case of UCP-Porto, this variable alone explains 13% of the variation in normalised first year scores, whereas for UP this percentage is 9.4%. Therefore, we can conclude that the Entry Score is the most important variable in both universities, although the predictive power of this variable is reduced in both cases.

Table 5 shows the coefficients obtained in the regressions for each university, considering NAFYS as the dependent variable and the best model in both cases (which for UCP-Porto does not include interaction terms, but for UP it does).

	UCP-Porto				UP			
Predictors	Coeff	Std Error	t	p value	Coeff.	Std Error	t	p value
(Constant)	0.086	0.052	1.668	0.096	0.043	0.025	1.707	0.088
NES	0.399	0.025	15.964	0.000	0.316	0.011	29.354	0.000
School Avg	-0.002	0.001	-1.647	0.100	0.000	0.002	0.180	0.857
Gender (1-female)	0.269	0.048	5.564	0.000	0.093	0.021	4.376	0.000
Municipality (1-out Porto)	-0.190	0.051	-7.293	0.000	0.023	0.023	0.973	0.331
Type of school (1-private)	-0.389	0.053	-7.293	0.000	-0.290	0.030	-9.660	0.000
Interactions:								
Type × School Avg	na	na	na	na	-0.007	0.002	-3.333	.001
NES × School Avg	na	na	na	na	0.002	0.001	2.456	.014

Table 5: Regression Results

Common findings for both universities is the positive impact of NES, the positive impact of gender (female students perform better) and the negative impact of private schools in the first year results of university students.

The main difference between the two universities concerns the impact of the location and the influence of the school average on national exams.

For UP students, the municipality where they attended secondary education does not have an impact on HE achievements. This can be interpreted as evidence that students who eventually have to move to a different city to attend a HE degree are able to adapt to the new context without repercussion on their first year results at university. However, for UCP-Porto, the fact that the student is dislocated has a negative impact on his/her performance.

The school average on national exams is statistically significant for UCP-Porto, with a negative impact on the NAFYS. This is counter intuitive, since we would expect that higher average results in the school of origin would contribute to better results in HE. Note, however, that a similar negative effect has been reported in the literature, where students from below average schools performed better than their colleagues (see Lasselle et al. (2014)).

Interestingly, in UP this effect *per se* is not significant, but the interaction effect between the school average and the type of school ownership is. This means that the school average has a negative impact on the performance of UP students when the students come from a private school. Since national data confirms that misalignment between internal grades and exam grades are higher in private than in public schools, this finding may imply that this effect may be associated with grade misalignment in private schools.

In UP the interaction term between the school average and the normalised entry scores (NES) is statistically significant and positive. This seems to imply that the positive impact of NES is fostered by high school averages.

Note that the above results considered all degrees together. As mentioned before, for managerial purposes it may be interesting to understand the extent to which these results are confirmed in a more specific analysis at the degree level. The regression models were run for all degrees of UP and UCP-Porto, and we concluded that the regressions were statistically significant for about 70% of the degrees in each university. For the degrees with statistically significant regressions, the variable NES had an important role in most of them (NES is not significant only in the degree in Nutrition Science of FCNAUP, degree in Environmental Sciences and Technology of FCUP, degree in Environmental Engineering of FEUP and degree in Aquatic Sciences in ICBAS). The impact of the other factors varies considerably among the different degrees.

Table 6 presents the detailed results for two degrees, one of UP and another of UCP-Porto, for illustrative purposes.

	UCP-Porto (N=242, R^2 =20.9%)				UP (N=150, R^2=15.1%)			
	Coeff.	Std. Error	t	p value	Coeff.	Std. Error	t	p value
(Constant)	0.154	0.117	1.316	0.189	0.227	0.169	1.347	0.180
NES	0.326	0.060	5.411	0.000*	0.364	0.077	4.724	0.000
School Avg	-0.015	0.004	-3.322	0.001	-0.003	0.007	-0.399	0.690
Gender (1-female)	0.400	0.115	3.485	0.001	0.077	0.156	0.497	0.620
Porto (1-out Porto)	-0.280	0.146	-1.922	0.056	0.030	0.182	0.166	0.869
Private (1-private)	-0.142	0.155	-0.911	0.363	-0.444	0.210	-2.116	0.036

Table 6: Regression results for the Management degree of UCP-Porto and Industrial Engineering and Management degree of FEUP

It is interesting to note the differences between these two degrees. In the management degree at UCP-Porto the main determinants of student success are the entry scores (with a positive impact), the gender (with an advantage for females), and the school average (with students from schools with higher averages in national exams performing worst). The type of secondary school that students attended in secondary education is not relevant in explaining the success of students in this degree (note that this is the degree that enrols more students from private schools in the sample analysed). The interaction terms were not statistically significant and therefore the regression model chosen (reported on Table 6) did not include them.

Regarding the Industrial Engineering and Management degree of the Faculty of Engineering of the University of Porto, the main determinants of success are the entry grades of the students and the type of school of origin (with students from private schools performing worse than their colleagues). Note that this is one of the degrees in UP with the highest average entry grades (together with medical degrees), meaning that the cohort of students is very homogeneous in terms of entry grades. Despite the small differences in entry grades, they do have some impact on achievements at the end of the first year.

5.2 Benchmarking of secondary schools based on university results

In this section we benchmark schools based on a composite indicator that aggregates three outputs representing students' university success. For this purpose, we consider only secondary schools that placed at least 45 students in UP and UCP-Porto. The final sample includes 64 schools (23.5% of them are private), comprising 6304 students (about 70% of the students in overall sample analysed, excluding the students that did not complete any ECTS).

Three indicators of student success at the university were constructed for each school, based on the average value of their students' achievements in HE: (i) the average normalised first year score, (ii) the average number of ECTS completed, and (iii) the percentage of students that the school placed at the top of the classifications of the HE degree. We consider "top students" those that complete more that 48 ECTS in the first year in HE and obtain a normalised first year score above 1.28 (meaning that their average grade is in percentile 90% for the cohort of students attending the same degree in a given academic year).

Using model (3) shown in section 3.2, we obtained a composite indicator representing the relative performance of the schools, providing a summary measure of schools achievements in terms of the three output indicators estimated at the school level (NFYS, Average ECTS, % students at the Top). The detailed results obtained for each school are shown in Table 7.

School name	Type of school	Municipality	No. of students	Avg. ECTS	% TOP	Avg. NFYS	CI
Escola Básica e Secundária Oliveira Júnior	Public	São João da Madeira	58	53.96	19%	0.44	1.00
Escola Secundária Dr. Mário Sacramento	Public	Aveiro	48	52.60	21%	0.43	1.00
Escola Secundária de Lousada	Public	Lousada	64	53.06	19%	0.31	0.94
Escola Secundária São Pedro	Public	Vila Real	54	53.66	17%	0.33	0.92
Escola Secundária D. Afonso Henriques	Public	Santo Tirso	49	48.41	20%	0.28	0.92
Escola secundária Ferreira de Castro	Public	Oliveira de Azeméis	47	53.49	17%	0.28	0.91
Escola Secundária Dr. Manuel Gomes de Almeida	Public	Espinho	113	48.93	18%	0.31	0.89
Escola Secundária Tomaz Pelayo	Public	Santo Tirso	47	51.82	15%	0.21	0.84
Escola Secundária Carolina Michaellis	Public	Porto	51	52.20	14%	0.25	0.83
Escola Básica e Secundária Rodrigues de Freitas	Public	Porto	52	44.57	17%	0.17	0.81
Escola Secundária de Santa Maria da Feira	Public	Santa Maria da Feira	108	49.01	14%	0.25	0.81
Escola Secundária de Fafe	Public	Fafe	68	49.69	15%	0.09	0.78
Escola Secundária de Almeida Garrett	Public	Vila Nova de Gaia	165	48.54	12%	0.19	0.76
Escola Artística Soares dos Reis	Public	Porto	90	50.79	10%	0.25	0.76
Escola Secundária Aurélia de Sousa	Public	Porto	153	49.98	11%	0.21	0.76
Escola Secundária D. Sancho I	Public	V. N. Famalicão	48	47.49	13%	0.17	0.76
Colégio Liceal de Santa Maria de Lamas	Private	Santa Maria da Feira	97	51.17	12%	0.08	0.75
Escola Secundária de Valongo	Public	Valongo	58	49.49	10%	0.22	0.75
Colégio Internato dos Carvalhos	Private	Vila Nova de Gaia	172	49.86	12%	0.11	0.75
Escola Secundária de Ermesinde	Public	Valongo	101	49.31	12%	0.12	0.74
Escola Secundária de Gondomar	Public	Gondomar	89	51.85	11%	0.08	0.74
Escola Secundária Augusto Gomes	Public	Matosinhos	89	50.00	10%	0.18	0.74
Escola Secundária da Maia	Public	Maia	176	50.55	10%	0.15	0.73
Escola Secundária Garcia de Orta	Public	Porto	200	48.93	10%	0.21	0.73
Escola Básica e Secundária Clara de Resende	Public	Porto	110	48.43	10%	0.18	0.72
Escola Secundária Francisco de Holanda	Public	Guimarães	45	47.93	11%	0.11	0.72
Escola Secundária de Rio Tinto	Public	Gondomar	125	50.83	10%	0.12	0.71
Colégio Luso-Francês	Private	Porto	100	51.23	8%	0.20	0.71
Escola Secundária Eça de Queirós	Public	Póvoa de Varzim	142	50.85	9%	0.10	0.70
Escola Básica e Secundária de Búzio	Public	Vale de Cambra	47	49.93	9%	0.15	0.70
Escola Secundária de Ponte de Lima	Public	Ponte de Lima	57	49.27	11%	0.05	0.70
Escola Secundária de Paredes	Public	Paredes	89	49.81	11%	-0.01	0.70
Escola Básica e Secundária de águas Santas	Public	Maia	52	49.53	8%	0.15	0.68
Escola Secundária Dr. Manuel Laranjeira	Public	Espinho	72	48.94	11%	-0.04	0.68
Escola Secundária Camilo Castelo Branco	Public	Vila Real	47	47.71	11%	0.00	0.67
Escola Secundária de Monserrate	Public	Viana do Castelo	85	51.22	9%	-0.02	0.67
Escola Secundária Filipa de Vilhena	Public	Porto	173	49.46	9%	0.04	0.67
Escola Secundária de Penafiel	Public	Penafiel	124	49.86	10%	-0.02	0.66
Escola Secundária João Gonçalves Zarco	Public	Matosinhos	97	48.94	7%	0.11	0.66
Escola Secundária Rocha Peixoto	Public	Póvoa de Varzim	54	47.37	11%	-0.07	0.66
Escola Secundária de Santa Maria Maior	Public	Viana do Castelo	123	48.75	10%	-0.06	0.65
Escola Secundária Camilo Castelo Branco	Public	V. N. Famalicão	69	49.18	9%	-0.03	0.64
Escola Secundária de Amarante	Public	Amarante	52	48.22	8%	0.02	0.63
Colégio Paulo VI	Private	Gondomar	136	46.58	9%	-0.03	0.63
Escola Secundária Alves Martins	Public	Viseu	83	50.83	6%	0.03	0.63
Escola Secundária José Régio	Public	Vila do Conde	84	48.14	6%	0.06	0.62
Escola Secundária Paços de Ferreira	Public	Paços de Ferreira	63	48.55	6%	0.03	0.62
Colégio Nossa Senhora do Rosário	Private	Porto	197	48.09	9%	-0.12	0.61
Colégio de Gaia	Private	Vila Nova de Gaia	46	48.34	7%	-0.01	0.61
Escola Secundária Inês de Castro	Public	Alcobaça	84	44.58	8%	-0.06	0.60
Escola Secundária António Sérgio	Public	Vila Nova de Gaia	62	47.70	6%	-0.09	0.58
Escola Secundária Latino Coelho	Public	Lamego	45	52.14	4%	-0.09	0.57
Escola Secundária Joaquim Gomes Ferreira Alves	Public	Vila Nova de Gaia	96	47.04	5%	-0.09	0.55
Escola Secundária de Marco de Canaveses	Public	Marco de Canaveses	84	51.56	4%	-0.12	0.54
Colégio D. Dinis	Private	Porto	133	46.11	3%	-0.14	0.49
Escola Secundária Fernão de Magalhães	Public	Chaves	45	40.62	7%	-0.24	0.49
Colégio Novo da Maia	Private	Maia	47	47.45	2%	-0.14	0.48
Colégio São Gonçalo	Private	Amarante	64	44.30	6%	-0.32	0.48
Externato Camões	Private	Gondomar	56	43.47	2%	-0.24	0.42
Externato Ribadouro	Private	Porto	911	42.47	2%	-0.37	0.39
Colégio D. Diogo de Sousa	Private	Braga	50	41.42	2%	-0.44	0.35
Externato D. Duarte	Private	Porto	66	36.36	2%	-0.46	0.31
Externato Académico	Private	Porto	46	38.99	2%	-0.57	0.30
Colégio da Trofa	Private	Trofa	86	41.37	1%	-0.63	0.28

Table 7: CI results for the schools analysed

Table 8 shows the average values for the 15 schools located on the top of the ranking, as well as for the bottom 15 schools and schools in the middle positions of the ranking (the top 23% and bottom 23% of the ranking in descending order of the CI score). This table also reports the statistical significance (p value) of the ANOVA test on the differences among the groups for the values of the indicators reported.

	Avg. ECTS	Avg. %TOP	Avg. NFYS	Avg. NES	Avg. nat. exams	DPS	Alignment	No. schools	% private schools
Top	50.71	15.87%	0.27	0.00	10.27	0.01	0.45	15	0%
Middle	49.31	9.49%	0.07	-0.02	10.62	0.01	0.55	34	18%
Bottom	44.37	3.80%	-0.27	-0.04	10.72	0.04	1.44	15	60%
p value	0.00	0.00	0.00	0.86	0.57	0.31	0.01		

Table 8: Summary of performance indicators for groups of schools

Other indicators that can explain some of the differences in schools performance are also reported in the Table 8, despite not having been included in the CI model. These indicators correspond to the normalised entry score, the average score computed for all students of the school on the 8 national exams with more students enrolled, the DPS indicator and the "Alignment" indicator. This latter is computed by the Portuguese Ministry of Education and is available in the site Infoescolas (http://infoescolas.mec.pt/) . This variable indicates whether internal grades assigned by the school to its students are aligned with the internal grades assigned by the other schools in the country to students with similar test scores. This alignment score varies between -2 and 2, with a value of -2 indicating under-scoring and a value of 2 indicating grade inflation. For example, if the internal classifications assigned by School A are systematically higher than the internal classifications assigned by School B to students who subsequently obtain the same results on the national examinations, then it is possible that School A is making an evaluation of their students' performance with very different criteria from those used by School B, eventually signaling the existence of grades inflation at the School A.

Top schools place on average 16% of their students at the top of the HE degrees, and their students are aproved, on average, to 51 ECTS (the maximum for the first year is 60). These students also have classifications that are about 0.3 standard deviations above the mean of their degree.

Contrasting these values with those of bottom schools, it is evident that our CI was able to distinguish between the schools that assured the HE success of their students and those that did not. Note also that the differences observed are statistically significant, except the indicators not related to success in higher education. The NES cannot be differentiated among the 3 groups of schools, the average in national exams obtained by the students from these schools is also not statistically different among groups, and the indicator DPS indicator is also similar among schools.

An additional characteristic that seems to be different among the three groups is the indicator of "Alignment", with bottom schools showing positive values with higher magnitude. This signals an eventual grade inflation in bottom schools. Combined with the regression results discussed in the previous section, this seems to provide evidence that the inflation of grades has a negative impact on the subsequent success of students in HE.

The dicotomy between public and private school attendance in secondary education and its impact on HE achievment (observed in the regression results) can also be seem at the school level. In Table 8, we observe that according to our CI there is no private school performing at the top level, meaning that private schools are not among the best in terms of the preparation of their students for university success. However, private schools are better than public schools in terms of the direct paths of success, and in the average grades obtained in national exams. Therefore, they are more likely to guarantee entrance of their students in HE than public schools, although their students, on average, perform significantly worse in higher education than their colleagues coming from public schools.

In order to obtain a better overview of schools performance, we complement the information revealed by the composite indicator (representing students' achievements in HE) with other information encapsulating the different aims of schools.

One of these aims is to lead students to enter the HE degrees of their choice. To reflect the achievements associated with this objective, we use the average school grade in national exams. In principle, as the entry grade to HE weights the results on national exams by approximately 50% (with school internal grades assigned the remaining weight), schools with higher grades on national exams have a higher percentage of students that are able to enter university.

The other aim of schools is to foster good achievements throughout the students educational path, given their previous achievements and contextual conditions. This objective is usually evaluated in the literature based on value-added measures. In this study we use the DPS indicator for this purpose.

In Figure 4 we compare these three dimensions considered important for the performance evaluation of secondary schools: success in higher education (measured through the CI proposed in this paper) in shown in the x-axis, guaranteeing entrance to university (measured through the average grades obtained in national exams) is shown in the y-axis, and adding value to their students given attainment on entry (measured through the indicator DPS) is illustrated using the size of bubbles. We use a colour scheme for signaling public and private schools.

School performance

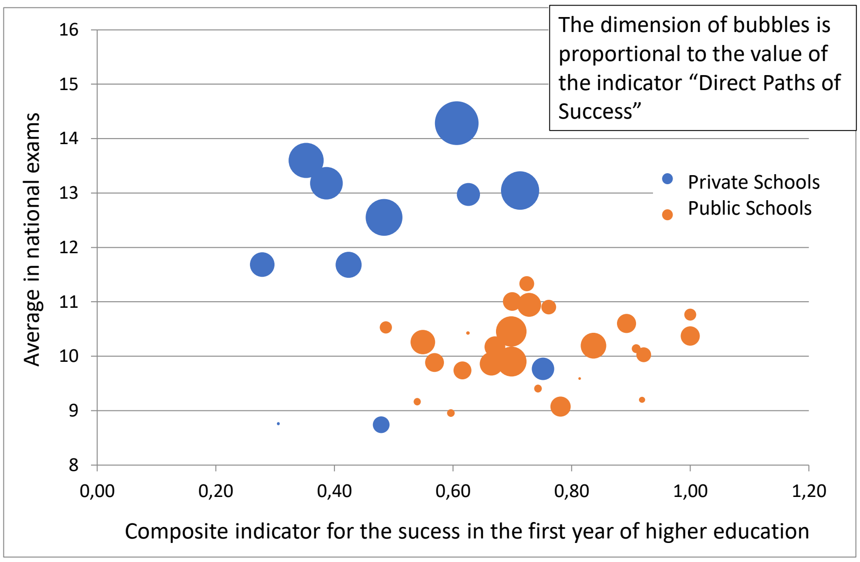

Figure 4: Overview of schools performance in three dimensions

It is clear from this figure that there is a negative relationship between students' performance in higher education (proxied by the CI proposed in this paper) and the average in the national examinations obtained by the schools' students. Private schools (blue) are located above the median national exam scores (60% of private schools are above the sample median), as well as in the indicator of "Direct Paths of Success" (83% of private schools are above the sample median). However, in the composite indicator representing performance in higher education, only 20% of the private schools are above the sample median.

Thus, it seems clear that schools have distinct profiles and the performance of their students in HE exhibits can be quite different. This difference appears largely related to the type of school (public vs private) since schools that perform best in our CI tend to be public.

Thus, we have schools that provide to the majority of their students ways to succeed throughout secondary education and finish this educational path with high classifications in national exams. This enhances the probability of entrance in higher education. However, these schools are generally not able to create the conditions to guarantee the best performance of their students in higher education.

Unfortunately, the three indicators of success of schools appear to be in conflict rather than complementing each other, as we do not find in our sample schools that perform well on all indicators. Therefore it is our conviction that the various objectives should be analysed in complementary way, as they offer very different perspectives regarding school quality and achievements. Clearly, in the ideal world, all the indicators should move hand-in-hand on the same direction. A good school should be able to show good performance simultaneously in the three objectives, and this is the target that should be pursued by all schools.

6 Conclusion

This paper has analysed students' success in the first year of higher education and established a link between HE achievements and the school of origin of the student. This analysis had two main aims. The first was to understand the drivers of student success in higher education. We concluded that for the sample analysed, the main drivers are the entry grades, the gender and the type of school attended during secondary education. The second was to understand how schools compare in terms of fostering the success of their students in higher education. For that purpose, we constructed a composite indicator that can complement existing indicators, which are mainly based in exam outcomes at the end of secondary education, ignoring "what comes next".

Our results bring new insights in comparison with the traditional rankings of schools' achievements. For the sample of schools analysed in this study, it was concluded that the best schools concerning the probability of placing their students at the degrees of their choice in HE are not the best in terms of promoting students' success at university.

However, these results need to be read carefully. In the first place, our CI only analysed a sample of students from each school, while the other two indicators of school performance consider all schools' students. The students considered in our CI are only those that entered the two universities analysed. Nevertheless, these are two representative universities in Portugal: UP is the second largest university in Portugal and UCP is the largest private university in Portugal.

In addition there are some regional differences (e.g. concentration of private schools, dimension of schools, misalignment of grades or DPS) between schools in the country, and therefore it would certainly be a very interesting avenue for future research an extension of this study to the national level.

To sum up, our analysis signals that the common perception that the educational role of secondary schools finishes when their students are placed at a university is debatable. Some schools' focus excessively on national exam results, which can have an immediate positive effect regarding university entrance but it may also have a negative effect on students' overall development. This can limit students' ability to succeed in later stages of their academic career or professional life, which is certainly not desirable or intentional on the part of schools, and must be carefully considered by schools administrators.

References

Agasisti, T. and Zoido, P. (2018). Comparing the efficiency of schools through international benchmarking: Results from an empirical analysis of oecd pisa 2012 data. *Educational Researcher*, 47(6):352–362.

Aparicio, J., Cordero, J. M., Gonzalez, M., and Lopez-Espin, J. J. (2018). Using non-radial dea to assess school efficiency in a cross-country perspective: An empirical analysis of oecd countries. *Omega*, 79:9–20.

Arnold, V. L., Bardhan, I. R., Cooper, W. W., and Kumbhakar, S. C. (1996). New uses and statistical regressions for efficiency evaluation and estimation - with an illustrative application to public secondary schools in Texas. *Annals of Operations Research*, 66:255–277.

Bradley, S. and Taylor, J. (1998). The effect of school size on exam performance in secondary schools. *Oxford Bulletin of Economics and Statistics*, 60(3):291–324.

Cabral, J. A. S. and Pechincha, P. (2014). Análise do percurso dos estudantes admitidos pelo regime geral em licenciatura - 1^o ciclo e mestrado integrado na universidade do porto em 2008/09, 2009/10 e 2010/11. *Reitoria da Universidade do Porto*.

Cabral, J. A. S. and Pechincha, P. (2018). Acesso ao ensino superior 2018: Análise descritiva. *Reitoria da Universidade do Porto, Gabinete de estudos estratégicos e melhoria contínua*.

Cerdeira, J. M., Nunes, L. C., Reis, A. B., and do Carmo Seabra, M. (2018). Predictors of student success in higher education: Secondary school internal scores versus national exams. *Higher Education Quarterly*, 72(4):304–313.

Chambers, R. G., C. Y. and Fare, R. (1996). Benefit and distance functions. *Journal of Economic Theory*, 70(2):407–419.

Cherchye, L., De Witte, K., Ooghe, E., and Nicaise, I. (2010). Efficiency and equity in private and public education: a nonparametric comparison. *European Journal of Operational Research*, 202(2):563–573.

Cherchye, L., Moesen, W., Rogge, N., and Puyenbroeck, T. V. (2007). An introduction to âbenefit of the doubt composite indicators. *Social indicators research*, 82(1):111–145.

Cyrenne, P. and Chan, A. (2012). High school grades and university performance: A case study. *Economics of Education review*, 31:524–542.

De Witte, K., Thanassoulis, E., Simpson, G., Battisti, G., and Charlesworth-May, A. (2010). Assessing pupil and school performance by non-parametric and parametric techniques. *Journal of the Operational Research Society*, 61:1224 –1237.

Dranove, D. (2012). Practical regression: Fixed effects models. *Case Number: 7-112-005, Kellogg School of Management.*

Gosele, K. D., Lerche, K., Meya, J., and Schwager, R. (2017). Determinants of students' success at university. *Education Economics*, 25(5):513–532.

Gujarati, D. N. and Porter, D. C. (1999). *Essentials of econometrics.* McGraw-Hill, New York.

Haelermans, C. and Ruggiero, J. (2017). Non-parametric estimation of the cost of adequacy in education: the case of dutch schools. *Journal of the Operational Research Society*, 68(4):390–398.

Hanushek, E. (1986). The economics of schooling: production and efficiency in public schools. *Journal of Economic Literature*, XXIV:1141–1177.

Jaccard, J., Wan, C., and Turrisi, R. (1990). The detection and interpretation of interaction effects between continuous variables in multiple regression. *Multivariate Behavioral Research*, 25(4):467–78.

Kaighobadi, M. and Allen, M. T. (2008). Investigating academic success factors for undergraduate business students. *Decision Sciences Journal of Innovative Education*, 6(2):427–436.

Kerstens, K. and de Woestyne, I. V. (2011). Negative data in dea: a simple proportional distance function approach. *Journal of the Operational Research Society*, 62(7):1413–1419.

Kirjavainen, T. and Loikkanen, H. A. (1998). Efficiency differences of Finnish senior secondary schools: An application of DEA and Tobit analysis. *Economics of Education Review*, 17(4):377–394.

Lasselle, L., McDougall-Bagnall, J., and Smith, I. (2014). School grades, school context and university degree performance: evidence from an elite scottish institution. *Oxford Review of Education*, 40(3):293–314.

Leckie, G. and Goldstein, H. (2017). The evolution of school league tables in england 1992â2016: 'contextual value-added', 'expected progress' and 'progress 8'. *British Educational Research Journal*, 43(2):193â212.

Mayston, D. (2003). Measuring and managing educational performance. *Journal of the Operational Research Society*, 54:679–691.

Migueis, V., Freitas, A., Garcia, P., and Silva, A. (2018). Early segmentation of students according to their academic performance: A predictive modelling approach. *Decision Support Systems*, 115:36–51.

Mizala, A., Romaguera, P., and Farren, D. (2002). The technical efficiency of schools in Chile. *Applied Economics*, 34:1533–1552.

Mora, T. and Escardibul, J.-O. (2008). Schooling effects on undergraduate performance: evidence from the university of barcelona. *Higher Education*, 56:519–532.

Muniz, M. A. (2002). Separating managerial inefficiency and external conditions in data envelopment analysis. *European Journal of Operational Research*, 143:625–643.

OECD (2008). *Handbook on Constructing Composite Indicators: Methodology and User Guide*. Joint Research Centre-European Commission, OECD publishing, Paris.

Portela, M. and Camanho, A. (2010). Analysis of complementary methodologies for the estimation of school value-added. *Journal of the Operational Research Society*, 61:1122–1132.

Portela, M., Camanho, A., and Borges, D. (2012). Performance assessment of secondary schools: the snapshot of a country taken by dea. *Journal of the Operational Research Society*, 63:1098–1115.

Portela, M. C. A. S. and Thanassoulis, E. (2001). Decomposing school and school type efficiency. *European Journal of Operational Research*, 132(2):114–130.

Portela, M. C. A. S., Thanassoulis, E., and Simpson, G. (2004). Negative data in dea: a directional distance approach applied to bank branches. *Journal of the Operational Research Society*, 55(10):1111–1121.

Sear, K. (1983). The correlation between a level grades anddegree results in england and wales. *Higher Education*, 12(3):609–619.

Sharp, J. A., Meng, W., and Liu, W. (2007). A modified slacks-based measure model for data envelopment analysis with natural negative outputs and inputs. *Journal of the Operational Research Society*, 58(12):1672–1677.

Smith, J. and Naylor, R. (2001). Determinants of degree performance in uk universities: A statistical analysis of the 1993 student cohort. *Oxford Bulletin of Economics and Statistics*, 63(1):29–60.

Smith, J. and Naylor, R. (2005). Schooling effects on subsequent university performance: evidence for the uk university population. *Economics of Education Review*, 24(5):549–562.

Thanassoulis, E., De Witte, K., Jhones, J., Jhones, G., Karagiannis, G., and Portela, M. (2016). Applications of data envelopment analysis in education. In Zhu, J., editor, *Data Envelopment Analysis: A handbook of empirical studies and applications*, pages 367–428. Springer, New York.

Witte, K. D. and Lopez-Torres, L. (2017). Efficiency in education: a review of literature and a way forward. *Journal of the Operational Research Society*, 68(4):339–363.

Zanella, A., Camanho, A. S., and Dias, T. G. (2015). Undesirable outputs and weighting schemes in composite indicators based on data envelopment analysis. *European Journal of Operational Research*, 245(21):517–530.