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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

Joanna Wolszczak-Derlacz

Gdańsk University of Technology, Faculty of Management and Economics, Narutowicza 11/12, 80-233 Gdańsk, Poland

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ABSTRACT

In this study the technical efficiency of number of public European and American HEIs is assessed over a decade. Efficiency scores are determined using nonparametric DEA with different input-output sets and considering different frontiers: global frontier (all HEIs pooled together), regional frontier (Europe and the U.S. having their own frontiers) and country-specific ones. The external factors affecting the degree of HEI inefficiency are also investigated, e.g. institutional settings (size and department composition), location and funding structure. Specifically, the results indicate a positive association between both regional GDP per capita and number of departments and an institution's efficiency (for both the European and U.S. samples). On average, older European HEIs are more efficient, but this is not confirmed for American ones. Finally, government funding seems to have a negative effect on the efficiency of universities in Europe, which again is not confirmed for the U.S. However, some country heterogeneity at the European level is found through intensive sensitivity analysis.

1. Introduction

Numbers are meaningful: according to the Academic Ranking of World Universities[1] 2016 fifteen of the top twenty universities were in the U.S., Americans published 23% of the total number of scientific articles in the period 1996–2015, counting 33% of the total citations.[2] This is perceived in the literature as the transatlantic gap – referring to the differences between Europe and the U.S. in the quality of academic research (Bonaccorsi et al., 2017). Because of this, it is not surprising that the American system of higher education is perceived to be pre-eminent and when higher education institutions (hereafter, HEIs) around the world are searching to improve their performance they look to universities in the U.S. as their benchmark model, while scholars from the whole world are attracted to American academia (Clotfelter, 2010). However, from the internal American perspective, the higher education sector is not free of problems, and its worldwide dominance has also recently been challenged (Altbach et al., 2011). Nowadays, HEIs in both continents are under pressure due to declining public support, resulting in the need to seek external resources and to provide first-class teaching and research in order to survive amid local and global competition.[3]

This study has three main aims: firstly, to compare the technical efficiency of European and U.S. higher education institutions. Secondly, to evaluate the main factors that determine the efficiency of HEIs and to test whether these factors might have varying impacts on the European and U.S. efficiency. Thirdly, to address an evaluation problem, introducing DEA techniques as an analytic tool which can serve both HEI's managers and policymakers.

Data envelopment analysis (DEA) is used in this study – a methodology which constructs a production frontier in the multi-input/multi-output case – in order to evaluate the relative efficiency of a sample of 500 higher education institutions (in ten European countries and the U.S.) for the period between 2000 and 2012. Different models are estimated for different input-output sets and assumed frontier: global, regional and country-specific ones.

The research is motivated by the fact that most previous studies

E-mail address: jwo@zie.pg.gda.pl.

[1] http://www.shanghairanking.com/ARWU2016.html. It should be underlined that university rankings (among others, ARWU) are a different concept to efficiency analysis based on purely scientific methodology such as DEA or other nonparametric methods as used in our paper. Daraio et al. (2015b) discuss the main criticisms addressed to university rankings more thoroughly (e.g. monodimensionality, lack of statistical robustness etc.) and propose a new generation of rankings based on new ranking techniques. However, despite their methodological shortcomings global rankings are of great importance to university prestige as they receive a great deal of attention in media.

[2] http://www.scimagojr.com/countryrank.php?min=0&min_type=it.

[3] This can be also analysed from the cross-sectoral perspective of increasing competition for public resources between higher education and other public sector services (e.g. healthcare and public pensions, see Kwiek, 2015).

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have only considered one or a limited number of countries, mainly due to the fact that micro data on HEIs (at the level of individual institutions) are not easily obtainable and comparable across countries and time periods. Few studies have looked at the efficiency and productivity of HEIs from the international perspective. In particular, the efficiency of Italian universities has been compared to that of those in the U.K. (Agasisti and Johnes, 2009), Spain (Agasisti and Pérez-Esparrells, 2010), Germany (Agasisti and Pohl, 2012) and Poland (Agasisti and Wolszczak-Derlacz, 2016). However, as these authors admit, general conclusions cannot be drawn on the basis of comparisons between the performances of HEIs in only two countries. Some recent papers utilise European Tertiary Education Register (ETER)[4] database and its ancestors, the Aquameth and Eumida. Bonaccorsi et al. (2007a) cover universities in Italy, Spain, Portugal, Norway, Switzerland and the UK. Bonaccorsi et al. (2007b) compare universities by research field in four European countries. Still, they concentrate mainly on testing economies of scale and scope. Similarly, Daraio et al. (2015a) conduct the analysis of 400 HEIs from 16 European countries but only for the single year 2008/2009 and Daraio et al. (2015b) using the same data underline the aspect of country's differentiation affecting university efficiency. Finally, Bolli et al. (2016) examine the role of competitive funding on both the production frontier and university efficiency.

However, unlike the present paper, none of these studies compare the efficiency of European HEIs with their U.S. counterparts or examine differences in performance measured over a decade taking into account cross-country and cross-unit heterogeneity.[5]

In the present paper following the bootstrap procedures proposed by Simar and Wilson (2000, 2007) we calculate bias-corrected DEA scores and in a second stage the relationship between a given external variable and previously estimated efficiency scores is verified. The results of this quantitative exercise are tested in the numbers of robustness checks.

The results indicate that European and U.S. institutions are relatively inefficient, with a high heterogeneity of efficiency scores both between and within countries. The inefficiency is lower for U.S. institutions compared to the mean value for the whole Europe, although higher in relation to some specific examples of European countries (e.g. the U.K.) what is confirmed in the model with country-specific frontier. The main findings of the second-stage analysis are: (a) universities located in wealthier regions of Europe and the U.S. are more efficient; (b) the number of different departments is positively associated with efficiency – indicating the presence of economies of scope and/or economies of scale; (c) funding structure matters for technical efficiency but the direction of the effect varies between the European and U.S. sample; (d) a greater inefficiency of universities with a larger proportion of revenue obtained from government resources is confirmed only in the case of the European sample with some cross-country heterogeneity.

The remainder of this paper is structured as follows: in Section 2 the methodological basis for the non-parametric analysis of technical efficiency is briefly presented together with literature review of empirical studies in which DEA has been applied to evaluating the efficiency of HEIs in cross-country studies. Next, in Section 3, we describe the panel and data, along with key descriptive statistics on the HEIs in the sample. In Section 4, different versions of DEA models are evaluated for different input-output sets and assumed frontiers. In Section 5, the second-step analysis is conducted, in which we treat the (previously estimated) efficiency scores as dependent variable in a regression equation. Finally, Section 6 is dedicated to the discussion of the findings from a policy perspective and conclusion.

We argue that DEA techniques (with full knowledge of the methodology utilized e.g. its limitations) can be used as an additional tool to help strategic planning and/or evaluation of HEIs. The results of the second step of our analysis where we look for the determinants of the HEI's inefficiency can be informative both to management and policy-makers. Specifically, it is shown that funding mechanisms (e.g. through pressure on the competitive resources) have the potential to significantly alter the nature and efficiency of higher education providers.

2. Using two-stage DEA to evaluate technical efficiency and its determinants – method and literature review

In the empirical part of this study the technical efficiency of HEIs will be evaluated through non-parametric DEA analysis, and then by regressing efficiency scores on potential covariates. There is much support for DEA methodology for the empirical evaluation of the production of multi-input/multi-output units, which is in fact a characteristic of the activities carried out by HEIs (Bougnol and Dula, 2006). The formal presentation of the method following closely the notation of Simar and Wilson (2000, 2007) is presented in the Appendix A in Supplementary material. First, we calculate DEA efficiency scores ($\hat{\lambda}$) by maximizing achievable output for a given level of the inputs. If the DEA efficiency score is , then the DMU is said to be efficient, if $\hat{\lambda} > 1$ (or 100%) then the unit is inefficient and the magnitude of the inefficiency is determined by the distance to the benchmark units called frontier (the greater the difference between the DEA score and 1, the greater the inefficiency).

The second step of our analysis involves examination of (the direction and magnitude of) the potential determinants (Z) of the previously estimated bias-corrected efficiency scores $\left(\hat{\hat{\lambda}}_i\right)$.

$$\hat{\hat{\lambda}}_i = \alpha + Z_i\beta + \varepsilon_i, \quad (1)$$

where ε_i is a statistical noise with distribution restricted by $\varepsilon_i \geq 1 - \alpha - z_i\beta$. The bootstrap procedure is employed to obtain bias-corrected beta coefficients to overcome the problems arising from the serial correlation of previously estimated scores and a possible correlation of the error term (ε_i) with environmental variables (Z_i) – see Appendix A in Supplementary material.

Since the 80 s the DEA method has been applied to assess the efficiency of entities operating in various sectors of the economy. In this steam of the literature, examination of the higher education sector is also present, albeit with a quantitatively lower representation.[6] Due to the nature of the present empirical analysis, the following literature review is restricted to works considering the evaluation of the efficiency of HEIs in more than one country (Table B1 in the Appendix B in Supplementary material).

In particular, Agasisti and Johnes (2009) examine universities in Italy and the UK between the years 2002/2003 and 2004/2005, finding that UK universities were more efficient, but the Italian ones were improving their technical efficiency. Italian universities have also been compared to Spanish universities (Agasisti and Pérez-Esparrells, 2010) and to German ones (Agasisti and Pohl, 2012) In the latter publications, the authors conduct also a second-stage analysis employing tobit regression and find evidence that medical faculties and operating in regions with a higher unemployment rate were negatively associated with efficiency and the regional share of employees working in science and technology was positively related.

[4] Aquameth and Eumida were projects funded by the European Commission with intention to create the foundations of a regular data collection on individual HEIs in the EU-27 Member States. As far as the author is aware, these datasets were not freely available to researchers outside the consortium (for a detail description of these databases see e.g. Bonaccorsi et al., 2010 and Daraio et al., 2011). The following project ETER (https://eter.joanneum.at/) give open access to the data at the level of individual HEIs. Currently data are available for 2465 HEIs in 32 countries and for three academic years: 2011, 2012 and 2013. Its detail coverage and comparison with our data will be discussed more thoroughly in the section dedicated to data collection.

[5] Wolszczak-Derlacz (2016) use the analogous data for European and American universities, but her analysis is focused on the productivity changes measured by Malmquist indices.

[6] Emrouznejad and Yang (2017) cover DEA-related studies for the period 1978–2016. They refer to more than 10 000 studies with only about 150 dedicated to education sector.