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UNIVERSITIES' EFFICIENCY ANALYSIS: LITERATURE REVIEW OF DEA APPLICATION

Violeta Cvetkoska, PhD
Ss. Cyril and Methodius University in Skopje,
Faculty of Economics-Skopje
vcvetkoska@eccf.ukim.edu.mk

Abstract

The aim of the paper is to give a literature review of the evaluation of the relative efficiency of higher education institutions (HEIs), i.e. universities, by using the non-parametric approach Data Envelopment Analysis (DEA). By using Google Search, 30 studies published in the period 1989-2017 have been found. In this paper, 10 studies are analyzed. Through the analysis, it was found that universities in one country are considered in nine studies, while universities in seven European countries are considered in one study; the smallest sample of universities is 14, and the largest is 259; in most of the studies, DEA models are defined with a different input-output mix; output orientation and CRS assumption is most often specified for the DEA models; and in some studies, besides DEA, fuzzy DEA, bootstrapping procedures and regression analysis are used.

Keywords: universities, relative efficiency, DEA, literature review.

JEL classification: C44, C61, I23.

Introduction

Natural resources, people, management and government are the four pillars of a nation's value, while the key role of its future is played by education. In order for an organization to keep up with its time, it should constantly be adaptable to changes and open to lifelong learning. Higher education institutions (HEIs) should be able to create professionals that would enable organizations to face all the challenges they come across for the aim of the organization to become amply competititive across the country's borders. Bearing in mind the fact that the economic growth and development of a country depends on the vital role of education, there is one question that constantly crops up: how much does the state invest in the development of education and science?

Setting out from a quote by the management guru Peter F. Drucker: "*What gets measured gets improved*", in order for higher education institutions to improve their performance, they have to measure it first.

Why is it difficult to measure the efficiency of the higher education sector? Because it does not make profit, there is an absence of prices of inputs and outputs, and from multiple inputs, higher education institutions produce multiple outputs (Johnes, 2006, p. 273).

Data envelopment analysis (DEA) is a non-parametric methodology designed to measure the performances, i.e. the relative efficiency of homogenous entities (in its terminology known as Decision Making Units (DMUs) that use the same inputs in order to produce the same outputs). In the literature of the discipline of Operational Research, this methodology was introduced by Charnes, Cooper and Rhodes in 1978. A DMU that has an efficiency score of 1 (100%) is identified as efficient, as opposed to an inefficient one. With the application of DEA, the amounts of inefficiency and the sources of inefficiencies can be determined. More details for DEA can be found in Cvetkoska (2017).

This paper covers a literature review on the application of DEA for the evaluation of the universities' relative efficiency, with 30 studies published between 1989 and 2017 (found through Google Search).

Research Methodology

By using Google Search, 30 studies in which DEA is applied in the evaluation of the relative efficiency of universities are found (Table 1). The largest number of published studies is in 2011 (5), followed by 2008 with 4 studies, 2006 and 2010 with 3 studies, etc. Out of 30 studies, in 27 the conducted research is in 1 country, 1 study considers 2 countries, 1 study covers 7 European countries, and 1 study examines a hypothetical example. 4 studies are conducted in the UK, 3 studies in Australia, while 2 studies deal with Canada, China, Germany, Portugal, Poland and Turkey, etc. In the next Section, 10 selected studies are analyzed.

Table 1. *Studies in which DEA is applied to evaluate the efficiency of universities*

	Author(s)	**Country/State**
1.	Ahn, Arnold, Charnes and Cooper (1989)	Texas
2.	Athanassopoulos and Shale (1997)	UK
3.	McMillan and Datta (1998)	Canada
4.	Sarrico and Dyson (2000)	UK
5.	Avkiran (2001)	Australia
6.	Liu (2001)	China

7.	Abbott and Doucouliagos (2003)	Australia
8.	Flegg, Allen, Field and Thurlow (2003)	UK
9.	Johnes (2006)	UK
10.	Kempkes and Pohl (2006)	Germany
11.	McMillan and Chan (2006)	Canada
12.	Fandel (2007)	Germany
13.	Afonso and Santos (2008)	Portugal
14.	Garcia-Aracil and Palomares-Montero (2008)	Spain
15.	Worthington and Lee (2008)	Australia
16.	Johnes and Yu (2008)	China
17.	Agasisiti and Prerez-Esparrells (2010)	Italy and Spain
18.	Agasisti and Johnes (2010)	Italy
19.	Katharaki and Katharakis (2010)	Greece
20.	Baysal and Toklu (2011)	Turkey
21.	Kuah and Wong (2011)	hypothetical example
22.	Ulucan (2011)	Turkey
23.	Nazarko (2011)	Poland
24.	Wolszczak-Derlacz and Parteka (2011)	Austria, Finland, Germany, Italy, Poland, UK, and Switzerland
25.	Cunha and Rocha (2012)	Portugal
26.	Ramirez-Correa, Pena-Vinces and Alfaro -Perez (2012)	Chile
27.	Nazarko and Saparauskas (2014)	Poland
28.	Ramzi and Ayadi (2016)	Tunisia
29.	Mahmudah and Lola (2016)	Indonesia
30.	Alabdulmenem (2017)	Saudi Arabia

Source: Author.

Analysis of selected studies where DEA is applied to evaluate the efficiency of universities

McMillan and Datta (1998) have assessed the efficiency of 45 Canadian universities by using a data envelopment analysis. Inputs include: the total number of full-time faculty in the three professional ranks, the total expenditure less faculty salaries and benefits, and the total operating expenditure and research expenditure, while outputs include: the total full-time equivalent (fte) undergraduate student enrollment, fte graduate enrollment in master's level programs, fte graduate enrollment in doctoral programs, the total sponsored research expenditures and the number of active grants as a percentage of eligible faculty. From these inputs and outputs, alternative

variable sets are defined, for details see (McMillan and Datta, 1998, p. 494), while the data was collected within one year (1992-93). It was determined that the efficiencies are quite consistent across alternative classifications. In order for further determinants of efficiency to be identified, regression analysis is used.

Avkiran (2001) used DEA to examine the relative efficiency of Australian universities in 1995. The sample consists of 36 universities. In this study, three DEA models are developed including: model 1 – overall performance, model 2 – performance of educational service delivery, and model 3 – performance of fee-paying enrollments. In these three models, the same inputs are used: academic staff, FTE (full-time equivalence), and non-academic staff, FTE. Model 1 uses as outputs the following: undergraduate enrollments, EFTSU (equivalent full-time student unit), postgraduate enrollments, EFTSU, and research quantum. Model 2 includes as outputs: the student retention rate (%), the student progress rate (%) and the graduate full-time employment rate (%). Model 3 uses as outputs: overseas fee-paying enrollments, EFTSU, and non-overseas fee-paying postgraduate enrollments, EFTSU. These models are run with output orientation (maximization) and both constant returns to scale (CRS) and variable returns to scale (VRS) assumptions. The results obtained were compared and the presence of VRS assumption among the universities comprising the sample was confirmed. The average efficiency score is 95.53%, 96.67% and 63.39% in Models 1, 2, and 3, respectively. Based on performance model 1, 4 universities were operating at increasing returns to scale (IRS), 13 at a most productive scale size (MPSS), and 19 at decreasing returns to scale (DRS). Also, potential improvements for universities identified as most inefficient for each model are presented and described.

Abbott and Doucouliagos (2003) measured the technical efficiency and scale efficiency of 36 Australian public universities for 1995 by using the non-parametric technique DEA (DEA with input orientation and with VRS assumption was used). Outputs used include: the number of equivalent full-time students (EFTS), the number of post-graduate and undergraduate degrees enrolled, the number of post-graduate degrees conferred, the number of under-graduate degrees conferred, and research quantum, while inputs include: the total number of academic staff, the number of non-academic staff, expenditures on all other inputs, other than labor inputs and the value of non-current assets. The results obtained using a different output-input mix are compared and it is determined that they are not substantially different. As a whole, Australian public universities show a high level of efficiency. The results obtained by using all 4 as inputs, and teaching outputs measured as equivalent full-time students (EFTS) and research output measured as research quantum as outputs, are the preferred results.

To measure the efficiency in higher education, Johnes (2006) used

DEA. The sample consists of 109 higher education institutions in England, of which 47 are pre-1992 universities, 34 are post-1992 universities, and 28 are Standing Conference of Principles Ltd (SCOP) HEIs. The full DEA model consists of 3 outputs and 6 inputs. Outputs used include: quantity and quality of undergraduate degrees, quantity of postgraduate degrees, and research, while as inputs, the following are used: quantity and quality of undergraduates, quantity of postgraduates, staff, the value of interest payments and depreciation, expenditures on library and computer facilities, and expenditure on administration. Data is collected for the 2000/01 academic year. The output-oriented approach is used and technical efficiency and scale efficiency are measured. Also, alternative DEA model specifications are defined regarding the variables, and the preferred model is the one in which the same 3 outputs are used, but with 4 inputs (where staff and expenditure on library and computer facilities are excluded). According to the results obtained, the average efficiency level of universities in England is high.

Johnes and Yu (2008) measured the research efficiency of 109 Chinese regular universities by using DEA. The following six inputs are included in the analysis: STAFFT- staff time (full-time staff to student ratio), STAFFQ – staff quality (percentage of the faculty with associate professor position or higher position), PG – postgraduate students (an index measuring the proportion of all students who are postgraduates), FUNDS – by using research expenditure, research funding is measured, BOOKS – an index of library books, and BLDG – an index of the area of the buildings, while as outputs, the following three are included: RESPP – an index of research output per person, RES – an index of volume of research output, and REPUT – an index of the university's prestige. Data is collected for 2003 and 2004, and alternative combinations of an input-output mix are chosen for 6 DEA models. The output-oriented DEA with VRS assumption is applied. According to Breu and Raab (1994), REPUT is a subjective measure because it is based on people's opinions, so in order to assess the impact of this variable on the results, DEA models are run with its inclusion and without it. When this variable is included in the model, efficiency is higher compared to when it is not included. Universities' rankings remain remarkably stable whether or not the reputation variable is included. Bootstrapping procedures are used to find the 95% of confidence intervals for the efficiencies of Chinese regular universities comprising the sample, and they indicate that there are significant differences between the best and worst performing Chinese regular universities. Also, an analysis is done of whether the significant differences between Chinese HEIs are associated with the following three criteria: regional (geographical) location, source of funding and type of university, and the results obtained are shown and interpreted.

Wolszczak-Derlacz and Parteka (2011) evaluated the relative efficiency of European public universities and examined the determinants

of efficiency scores using a two-stage DEA approach. The analysis includes several European countries, i.e. the following seven: Austria, Finland, Germany, Italy, Poland, the United Kingdom and Switzerland, and the observed period is 2001-2005. The initial sample consists of 266 European public universities. Inputs used are: the number of total academic staff, the number of students and total revenues, while outputs include: the number of graduations and the number of scientific publications. In order to detect observations that are atypical, the authors followed the procedure written by Willson (1993), and 7 universities (detected as outliers) were deleted from the initial sample, so the sample consists of 259 European public universities (8 from Austria, 15 from Finland, 66 from Germany, 51 from Italy, 31 from Poland, 11 from Switzerland and 77 from the UK). In the first step, DEA (output-oriented model with CRS assumption) is used, and according to the average efficiency scores obtained by country and by year, in the first year of the observed period (2001), the most efficient universities were in Austria, followed by Switzerland, Italy, the UK, Poland, Germany and Finland, while in all the years that follow, the best efficiency scores are identified in public universities from Switzerland. The efficiency scores obtained on European public universities across countries and within them exhibit a high variability, and authors found it interesting to discover the determinants of efficiency scores in public universities in Europe, so this is done in the second step by combining non-parametric and parametric methods. The crucial determinants (factors) of European public universities' efficiency include: the institution size, the number and composition of faculties, the funding structure and the gender structure of the academic staff.

Cunha and Rocha (2012) evaluated the relative efficiency of 3 groups of HEIs in Portugal in 2008 by using the methodology data envelopment analysis. The first, second and third group consisted of public universities (a total of 14), public polytechnics (a total of 20) and faculties of the University of Porto (a total of 14), respectively. Their inputs include: total funding per student, total expenditure per student, and academic staff per student, while the outputs used are: the total number of graduate students, the total number of PhD degrees awarded and the total number of courses. 3 inputs are used in all of the groups, while 3 outputs are used for the first group, for the second group the output "total number of PhD degrees awarded" is excluded, because public polytechnics do not offer PhD courses, and for the third group, the output "total number of courses" is excluded. A DEA with input orientation is used and authors point out that their MatLab code is designed to allow CRS and VRS assumption, but they focus on the efficiency scores obtained with VRS assumption as more reasonable. According to the efficiency scores obtained for public universities, only two are relatively efficient, and the average efficiency is 83.21%. 5 public polytechnics are identified as relatively efficient and the average efficiency is 77.93%, while 6 faculties of

the University of Porto are relatively efficient and the average efficiency is 82.5%. According to the results obtained, a great portion of HEIs in Portugal were inefficient in their work, contributing to a significant waste of resources (Cunha and Rocha, 2012, p. 21). In their future research, they mention that they could include additional inputs and/or output variables, and as one output variable they stated "the number of publication records in international high quality journals in all scientific fields", then several years could be observed and also determinants could be discovered on HEI efficiency scores.

Nazarko and Saparauskas (2014) evaluated the efficiency of 19 public higher education institutions, i.e. Polish universities of technology, by using DEA. The following 15 were considered as variables: input variables: government budget subsidy (I_1), number of academic teachers (I_2), number of other employees (I_3), number of licenses to award PhD degrees (I_4), and number of licenses to award doctoral degrees (I_5); output variables: weighted number of full-time students (O_1), weighted number of full-time PhD students (O_2), percentage of students studying abroad (O_3), percentage of international students (O_4), percentage of students with university scholarships (O_5), percentage of students with government Ministry scholarships (O_6), employer preference for hiring alumni (O_7), and parametric assessment of scholarly achievements of the faculty (O_8); environmental variables: population of the city where the university is located (E_1) and percentage of students with need-based financial aid (E_2). In each group of variables a correlation analysis was carried out and for the DEA model (CCR output-oriented), I_1, O_1, O_2, O_7, O_8, E_1 and E_2 were selected. Frontier Analyst v. 4.1.0, Statistica 9 and Excel 2007 software were used for calculations.

Mahmudah and Lola (2016) measured the efficiency of 25 Indonesian universities (both public and private) in 2015 by using DEA and Fuzzy DEA (FDEA). Four inputs have been used and they are the following: the number of lecturers, the number of students, the number of departments and A-accredited programs by the Higher Education of Indonesia, and the following five are used as outputs: world rank, presence rank, impact rank, openness rank and excellence rank. Models under CRS and VRS assumptions have been used. Based on the results obtained for both the DEA and FDEA, better results are achieved based on the VRS assumption. 9 universities (36%) are identified as relatively efficient based on the CRS, while 13 universities (52%) are identified as relatively efficient according to the model under VRS assumption.

Alabdulmenem (2017) measured the efficiency of 25 public universities in Saudi Arabia by using the DEA. As inputs, faculty and administrators are used, while as outputs the following are used: number of new entrants, number of enrollees and number of graduates. According to the results obtained, 15 universities are identified as efficient, and due to the poor utilization of available resources, some of the public universities in Saudi

Arabia are inefficient.

Based on the 10 studies analyzed regarding the application of DEA in measuring the efficiency of universities, it can be concluded that:

- The studies analyzed were published in the period between 1998 and 2017;
- Nine studies include universities from one country (Australia (2 studies), Canada (1 study), China (1 study), England (1 study), Indonesia (1 study), Poland (1 study), Portugal (1 study) and Saudi Arabia (1 study)), and one study includes universities from 7 European countries (Austria, Finland, Germany, Italy, Poland, the United Kingdom, and Switzerland);
- The period covered is one year and two years, while in one study, a period of five years is covered (2001-2005);
- The smallest sample of universities (14 public universities in Portugal) is covered in the study of Cunha and Rocha (2012), and the largest sample (259 European public universities) is covered in the study of Wolszczak-Derlacz and Parteka (2011);
- The following are most often used as inputs: academic staff (total number, per student, percentage of the faculty with associate professor position or higher position (staff quality), full-time staff to student ratio (staff time); expenditures (on administration, research expenditures, on all other inputs, other than labor inputs, total expenditures per student); number of students (total, quantity of postgraduates, quantity and quality of undergraduates); non-academic staff; the value of non-current assets; etc.;
- The following are most often used as outputs: number of enrollees (undergraduate, postgraduate); research (RES – an index of volume of research, RESPP – an index of research output per person, research quantum, the number of scientific publications); number of graduates; number of equivalent full-time students (EFTS), etc.
- In all studies, the non-parametric methodology DEA is used, and for DEA models, the output orientation and CRS assumption are usually specified; then, in most studies, the DEA models are defined with a different input-output mix; in one DEA model, two environmental variables (population of the city where the university is located and percentage of students with need-based financial aid) are included, and in some studies, besides DEA, the following are used: fuzzy DEA, bootstrapping procedures and regression analysis.

Conclusion

For the purpose of measuring the relative efficiency of higher education institutions, Data Envelopment Analysis has proven to be quite a useful tool in practice. When DEA is used, the choice of inputs and outputs is given a key role because the results received by solving the model depend on it. Rosenmayer (2014, p. 49) points out that firstly, the objectives of universities should be determined so as to look for an optimal mix of variables (inputs and outputs) afterwards. According to him, certain universities prepare students for labor market participation, while others are directed more towards basic research, thus adapting the curricula, while in the field of innovations, technical universities work together with the industry.

What can be measured with DEA is the efficiency of universities, faculties within universities and departments within faculties in the process of choosing a faculty Dean, etc. Information received through the application of the DEA in higher education institutions is especially important for their management since the areas in need of further improvement can be determined, and strategies in that direction can be developed regarding the allocation of funds among the organizational units of these institutions, so as to determine the optimal size of HEI organizational units (Nazarko and Saparauskas, 2014, pp. 2-3).

This paper covers a literature review of the application of the DEA for the evaluation of universities' relative efficiency. At the same time, the country where the research was done is mentioned, as well as the analysis sample, inputs and outputs used, the model and the results obtained.

In the upcoming research, it is planned for DEA to be applied to evaluate the efficiency of faculties in the framework of Ss. Cyril and Methodius University in Skopje, and to give recommendations for improving their efficiency in accordance with the results and qualitative analysis applied.

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АНАЛИЗА НА ЕФИКАСНОСТ НА УНИВЕРЗИТЕТИ: ПРЕГЛЕД НА ЛИТЕРАТУРА ЗА ПРИМЕНА НА DEA

Доц. д-р Виолета Цветкоска
Универзитет Св. Кирил и Методиј во Скопје
Економски факултет - Скопје, Р. Македонија
vcvetkoska@eccf.ukim.edu.mk

Апстракт

Целта на трудот е да се даде преглед на литература за оценување на релативната ефикасност на високообразовни институции, поточно универзитети со користење на непараметарскиот пристап анализа на обвиени податоци (DEA). Со користење на Google Search, најдени се 30 студии кои се објавени во периодот 1989-2017 година. Во овој труд се анализирани 10 студии. Преку анализата најдено е дека во девет студии предвид се земени универзитети од една држава, а во една студија примерокот го сочинуваат универзитети од седум Европски држави; најмалиот примерок на универзитети е 14, а најголемиот 259; во најголем дел од студиите, DEA моделите се дефинирани со различен инпут-аутпут микс; за DEA моделите, најчесто е специфицирана излезна ориентација и CRS претпоставка; и во некои студии, покрај DEA користени се и fuzzy DEA, bootstrapping процедури и регресиона анализа.

Клучни зборови: универзитети, релативна ефикасност, DEA, преглед на литература.

JEL класификација: C44, C61, I23.