Efficiency Assessment of Universities with DEA Method Based on Public Data

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ABSTRACT

Assessment of efficiency in spending public funds for higher education is an important task of the Ministry of National Education. This paper illustrates the application of some models of Data Envelopment Analysis (DEA) to evaluate the relative efficiency of public universities from Romania using data collected from the official reports of the universities’ Rectors throughout the years 2012-2015. We use the constant returns to scale (CRS) model and the variable returns to scale (VRS) model to determine the output. Afterwards, we calculate the value of scale efficiency. Based on these results, universities can be grouped into several layers of efficiency. We conclude that public authorities would consider the application of DEA method to generate additional performance indicators in assessing higher education institutions for improving accuracy in public funds allocation and distribution.

Keywords: DEA, public universities, efficiency, analysis

1. INTRODUCTION

Universities and other higher education entities are complex organizations that together constitute one of the world’s largest industrial sectors even if operating in ways strange to the majority of companies (Birnbaum, 1988). They represent complex multi-structural entities that would ideally be that institutional arrangement that best enables functionality and reacts to the needs and expectations of the surrounding environment, as well as their stability and their strategies (Newton, Burgess, & Burns, 2010).

Quality assurance in higher education and scientific research is an obligation of a higher education institution and a fundamental task of the Ministry of National Education (Parliament, 2011). Accreditation is a part of universities’ never-ending efforts to assure interested parties that students will have adequate knowledge when they graduate, be able to find good jobs and to excel in their careers (Stanislav & Walter, 1999).

According to the National Education Law in Romania (no. 1/2011), accredited universities from Romania are divided into the following categories: universities of advanced research and education; universities of education and scientific research or universities of education and artistic creation; universities focused on education. This classification was made according to the methodology of the evaluation and hierarchy of the study programs in the universities from Romania. The evaluation is based on some of the following criteria: teaching and learning; scientific research; artistic creation in the case of arts universities; relationship of the university with the external environment; institutional capacity (Government, 2011).

Efficiency of public universities is important for getting performance at institutional level. There are several possibilities to assess efficiency of a process by calculating the normalized ratio between outputs and inputs. However, the same process can have different types of efficiency,
depending on the sets of inputs and outputs considered in the calculation; or, in other formulation, depending on the goals towards how efficiency is assessed. This is also the case of public universities. A highly pragmatic approach to examine the efficiency of a complex system is Data Envelopment Analysis Method (DEA). It has been designed to assess the relative efficiencies of units within a set where inputs and outputs are incommensurate so that simple efficiency measures are difficult to obtain (Thanassoulis, Dyson, & Foster, 1987).

The evaluation of relative efficiency of public universities from Romania using data collected from the reports released by the universities’ Rectors throughout the years 2012-2015 is considered in this study. The second section of this paper highlights basic elements regarding DEA application. The third section sets out the work done for the analysis of thirty accredited public universities using the software tool PIM-DEAssoft-V3.0. Results are discussed in the fourth section of the paper. The fifth section comprehends conclusions and possible future researches.

2. DATA DEVELOPMENT ANALYSIS METHODOLOGY

DEA was developed as a method for assessing the comparative efficiency of organizational units by Charnes, Cooper and Rhodes (1978). The original idea behind DEA was to provide a methodology by which, within a set of comparable decision making units (DMUs), the exhibiting best practice could be identified and would form an efficient frontier (Cook & Seiford, 2009). There are numerous ways in which efficiency can be measured. Most different exercises might involve the use of different combinations of inputs and outputs and hence yield different results. Differences can also exist in the methods of analysis used within studies. There are reasons therefore to believe that the choice of method matters (Geraint & Kaoru, 2016).

DEA is a linear programming method for a frontier analysis of inputs and outputs. DEA assigns a score of 1 to a unit only when comparisons with other relevant units do not provide evidence of inefficiency in the use of any input or output. DEA assigns an efficiency score less than one to (relatively) inefficient units. A score lesser than one means that a linear combination of other units from the sample could produce the same vector of outputs, using a smaller vector of inputs. The score reflects the radial distance from the estimated production frontier to the DMU under consideration (Rosenmayer, 2014).

The models used for the measurement of efficiency can be with constant returns to scale (CRS) or variable returns to scale (VRS), oriented towards minimizing the inputs or maximizing the outputs (Charnes, et al., 1978). The efficiency scales are associated with each type of surface envelope caused by each DMU and this surface refers to the efficiency frontier (Charnes, Cooper, & Rhodes, 1978). Those elements which belong to this surface (or determine it) are considered efficient and those that do not belong to are considered inefficient. To make inefficient decision-making units becoming efficient, one can choose from the following variants: reducing inputs while outputs remain constant (input-oriented analysis); output increasing while inputs remain constant (output-oriented analysis); output increasing simultaneously with reducing input (the dual version). Input-oriented measurement equals output-oriented measurement of technical efficiency (TE) only in the case of constant returns to scales (CRS) (Fare & Lovell, 1978).

A model oriented to CRS input with constant returns to scale (CRS DEA) is obtained by the considering the following optimisation framework:

\[
\begin{align*}
\min \theta_i \theta \\
\text{st} \quad -y_i + Y\lambda &\geq 0 \\
\theta x_i - X\lambda &\geq 0 \\
\lambda &\geq 0,
\end{align*}
\]

(1)

where: \(x_i\) describes all inputs related to the \(i\)-th DMU, \(y_i\) describes all outputs related to the \(i\)-th DMU, \(X\) is the input matrix of size \(K\times N\) for all DMU units decision \(\lambda\) is the number of DMU decision units, \(K\) is the number of inputs for each DMU, \(M\) is the number of outputs for each DMU, \(Y\) is the output matrix of size \(M\times N\) for all DMUs, \(\theta\) is a scalar and \(\lambda\) represents a vector of constants by size \(N\times1\). The value obtained for \(\theta\) will be the efficiency score for the \(i\)-th DMU. It will satisfy \(\theta\)
≤ 1, where a value of 1 represents a point on the frontier and indicates a technically efficient DMU, according to the Farell’s (1957) definition. The linear programming problem must be solved $N$ times, for each DMU. A value of $\theta$ is then obtained for DMU (Coelli, n.d.).

Branker, Charnes and Cooper (1984) suggested an extension of the constant return to scale (DEA CRS) to account for variable return to scale (DEA VRS). The problem of linear programming to explain CRS to VRS, adding the condition of convexity, $N_1 \lambda = 1$ to (1) is the following:

$$\min \theta$$
$$\text{st} \quad -y_i + Y \lambda \geq 0$$
$$\quad \theta x_i - X \lambda \geq 0$$
$$\quad N_1 \lambda = 1$$
$$\quad \lambda \geq 0,$$

where $N_1$ is an $N \times 1$ vector of 1. If there are differences between technical efficiency determined with CRS ($TE_{CRS}$) and technical efficiency determined with VRS ($TE_{VRS}$), then DMU has a lack of scale obtained by difference between $TE_{VRS}$ and $TE_{CRS}$. It results that CRS technical efficiency measure is decomposed into “pure” efficient technique VRS and scale efficiency. This means that $TE_{CRS} = TE_{VRS} \times SE$.

A model oriented to VRS output with variable returns to scale (VRS DEA) is obtained by the linear programming model:

$$\max \phi \lambda$$
$$\text{st} \quad -\phi y_i + Y \lambda \geq 0$$
$$\quad x_i - X \lambda \geq 0$$
$$\quad N_1 \lambda = 1$$
$$\quad \lambda \geq 0,$$

where $\phi$ is a scalar and the other symbols have the same meaning as in (1) and (2). The obtained value of $\phi$ will be the efficiency score for the $i$-th DMU. It will satisfy $\phi \leq 1$, where a value of 1 represents a point on the frontier and indicates a technically efficient DMU, according to the Farell (1957) definition. $1 \leq \phi \leq \infty$ and $\phi - 1$ represents proportional increase in outputs with input quantities held constant for each $i$-th DMU. The linear programming problem must be solved $N$ times, for each DMU. A value of $\phi$ is then obtained for DMU (Coelli, n.d.).

3. RESEARCH DESIGN

This application explores the technical efficiency of public universities from Romania by DEA under various approaches. For this analysis, thirty accredited public universities were selected, namely: nine universities of advanced research and education, thirteen universities of education and scientific research or universities of educational and artistic creation and eight universities on education (Table 1). There are some important public universities that are not included in this study, such as Politehnica University of Bucharest or University of Medicine and Pharmacy Iuliu Hatieganu of Cluj Napoca. This is due to the fact they did not publish data or we failed in identifying the links to their reports.

For a correct choice of inputs and outputs in the analysis we took into consideration the universities with bachelor study programmes, master degree programs and PhD programmes. As for the staff, only the full-time employees have been taken into consideration and not the total number of positions of each university. In DEA, the homogeneity of DMUs must satisfy three rules. First, the DMUs must have similar activities and the same objectives. Secondly, they should utilize similar inputs to produce the same outputs and, thirdly, they should operate within similar environments (Dyson, et al., 2001). All the public universities that we have chosen are homogeneous decision units because they use similar inputs and produce the same outputs.
In this study we used the constant returns to scale (CRS) model (output oriented) and the variable returns to scale (VRS) model (output oriented) to determine the output maximization of the public universities from Romania. The next step was to calculate the value of scale efficiency (SE). Scale efficiency is the component of technical efficiency that can be attributed to the size of operations. Scale inefficiency represents deviations from the most productive scale size. It is the ratio of technical efficiency to pure technical efficiency (Avkiran, 2006).

In this study we have opted to use the software tool PIM-DEAsoft – V3.0 in order to apply the CRS and VRS models (Emrouznejad & Thanassoulis, 2011). Analysis has been done for the period 2012-2015.

The input and output variables used in this study are those contributing to performance and efficiency in higher education. The input variables taken into consideration are the number of academic staff (AS), the number of non-academic staff (NAS) and the number of accredited programs in universities (PR). The first input, the academic staff, includes the number of professors, lecturers, assistants who have contributed to teaching and research activities. The second input, non-
academic staff, includes the number of persons which work for academic staff and students. The first and second inputs were used in some other studies done by Avkiran (2001) and Abott & Doucouliagos (2003). The third input, namely: bachelor programmes, master programmes and doctoral programmes, is added for the first time in this paper.

The output variables are the total number of undergraduate enrolment (UG), the total number of graduate enrolment (GR) and the amount of money received from the state for basic institutional funding (B). The first output, the total number of undergraduate enrolment, represents all students enrolled in the university. This output was also used in previous researches by Avkiran (2001) and McMillan & Datta (1998). The second output, the total number of graduate enrolment, represents the number of MA students and PhD students. This output indicates the quality and quantity of teaching which is represented by the academic staff and it was also used in previous researches by Johnes (2006), McMillan & Datta (1998) and Avkiran (2001). The third output, basic institutional funding, represents the amount which a university receives from the state for equivalent students. This output is used for the first time in DEA analysis by this paper. In terms of analysing university efficiency, some researches found in the literature refer to other indicators such as the amount of research grants (Nur, Roziah, & Rasidah, 2013), or the value of the recurrent grants for research (Johnes, 2006).

The sample used in this study covers thirty universities from Romania for the period 2012-2015. All the necessary data were obtained from the reports of the university Rectors. Three models are presented to examine the possibility of measuring and comparing efficiency between universities. The first model uses three inputs (AS, NAS and PR) and two outputs (UG and GR), the second model includes two inputs (AS and NAS) and one output (B) and the last model includes only one input (AS) and one output (B).

4. RESULTS AND DISCUSSIONS

The results from Figure 1, Figure 2 and Figure 3 have been obtained after the application of the three models on the sample of public universities for the period under consideration (2012-2015).

Figure 1: Results from data analysis using model 1

Based on the first model of analysis (three inputs: AS, NAS, PR; two outputs: UG, GR) the results show that, out of nine universities of the first category (advanced), three universities are efficient in the period 2012-2014 (DM3, DMU5 and DMU6) and two universities (DMU3 and DMU5) in 2015 under CRS approach. Using the VRS approach, five universities (DMU2, DMU3, DMU4, DMU5 and DMU6) look to be efficient in the period 2012-2015. For the second category of universities (education and research) three universities (DMU 9, DMU18 and DMU25) have been identified as being efficient under CRS approach and seven universities (DMU 9, DMU10, DMU13,
DMU17, DMU18, DMU23 and DMU25) under VRS approach in the period 2012-2015. For the last category (education) a single university was identified as being efficient (DMU15) under CRS and five universities (DMU14, DMU15, DMU20, DMU21, DMU22) under VRS, for the same period of time. The scale efficiency is presented in Figure 1 and shows that only five from all categories of universities are efficient during the four-year period (DMU5, DMU9, DMU18, DMU25 and DMU15). The most inefficient for all categories are DMU 4 and DMU23.

![Figure 2: Results from data analysis in Model 2](image1)

In the second model we analysed the efficiency of universities from a different point of view, namely: the number of academic staff and the number of non-academic staff as inputs and the public funds for equivalent students as output. The results show that only two universities (DMU1 and DMU7) from the first category, one (DMU30) from the second category and one (DMU 21) from the last category are efficient for the period 2012-2015. The most inefficient ones for all categories of universities over 2012-2015 seem to be DMU4, DMU17 and DMU20.

In the last model we analysed the efficiency of universities considering only the number of academic staff as input and the public funds for equivalent students as output. The results show that DMU7, DMU18 are efficient for all four years. The most inefficient DMUs seem to be DMU4, DMU10, DMU17 and DMU 29 during the four years of analysis (2012-2015).

In the particular case of DMU1 (the university where the authors are employed), certain observations can be drawn. In the model 1, where three inputs and two outputs were taken into
consideration, the efficiency average was 95.28% for the period 2012-2015, out of 100% efficiency. It must be compared with an efficient peer for the analysed period, which in this case is DMU5. Thus, in comparison with its peers, DMU1 should manage outputs better, particularly by increasing the number of postgraduates (GR) on average by 33% and undergraduates by 5% (output UG).

In what regards model 2, DMU1 is efficient throughout all four years of analysis, making it a benchmark for all other inefficient DMUs, such as DMU5 or DMU28.

In model 3, only a single input and a single output are taken into account (the academic staff and the basic funds received from the state). Throughout the four years of analysis, DMU1 reported an average of 91% efficiency; the efficient peer being DMU7 for the period 2012-2014 and DMU6 for 2015. As a result of this analysis, the gap in output was as follows: 22% for 2012, 8% for 2013, and 10% for 2014, whereas for 2015 the lack was merely 3%.

These results can be compared with other ranking systems, such as U-Multirank. In the case of DMU1, U-Multirank shows a medium-level in terms of expenditure on teaching, a medium level for the percentage of graduate and postgraduate students and a broad range of the subjects/areas offered; a low level in terms of the relations with the private sector, as well as the attraction of foreign students; a low-medium level relating to the expenditure on research; and a medium-high level in terms of involvement in attracting regional students (U-Multirank, 2017). In the case of DMU5, U-Multirank evaluation shows a high level in terms of expenditure on teaching, a medium level for the percentage of graduate and postgraduate students, but rather oriented to a more limited range of subjects/areas (U-Multirank, 2017). Putting together the two types of rankings, one remark is that DMU1 has many specialisations, but not so well dimensioned and lower salaries for the academic staff, whereas DMU5 succeeded to have a better calibration of both number and size of specialisations, with a better remuneration of its staff.

5. CONCLUSIONS

The purpose of this paper was to investigate the application of DEA method for analysing the relative efficiency of public universities from Romania. This type of investigation enables to know how efficient universities can be in utilizing various resources comparing with their peers and can help them to improve their performance by reallocating resources to maximize some key outputs. The results of this study show that DEA is a reliable approach by providing quantitative indicators for comparative analysis among public universities in a certain country. Three models are proposed to examine the possibility of measuring and comparing efficiency between universities. They use publicly available data from the annual reports of university Rectors. This research encourages us to say that the Ministry of National Education might consider DEA approach as a tool for better allocation of funds for higher education and to encourage universities to optimise their educational offer (number of specialisations, size of specialisations, etc.) and the structure and size of academic and non-academic staff.

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