Abstract
The present paper evaluates the Romanian public universities from funding efficiency point of view over the past 7 years, respectively 2012-2018. In order to evaluate the funding efficiency, we employed a nonparametric method, namely data envelopment analysis (DEA) for three-cycle system (technical efficiency from constant return to scale, technical efficiency from variable return to scale and scale efficiency). Based on our empirical findings 11 universities showed to be efficient when we applied VRS and only two universities with CRS approach. When scale efficacy was applied, our sample reduced to only two public universities as being efficient. This study identifies characteristics that describe differences within the public universities efficiency based on funding in higher education system in Romanian

Keywords: efficiency, DEA, higher education, Romania.

JEL Classification: I21, I23.
Introduction

Universities have an important role in a country economic development through generating and transferring knowledge (Abd Aziz et al., 2013). Funding is correlated with universities mission, vision and objectives to be achieved. The lack or the insufficient funds affect the results attained and therefore the universities efficiency (Visbal-Cadavid et al., 2017). Therefore, the relation between higher educational system and its funding sustainability has attracted a lot of attention mainly from the efficiency point of view (Visbal-Cadavid et al., 2017). Many authors have focused not only on the efficiency level of higher education institutions but as well on the factors that need to be accounted when calculating efficiency rates (Quiroga-Martinez et al., 2018). DEA is a technique used to estimate the efficiency and to explain the influence of inputs and outputs when obtaining the coefficient (John et al., 2013).

The explanation of employing a nonparametric methodology in analyzing the efficiency of universities is associated with the possibility of engaging numerous outputs and inputs at the same time, in conjunction with traditionally parametric methodologies engaged in efficiency study (Aristovnik and Obadic, 2014).

An efficient analysis of universities funding can improve the quality of policy and decision making process. Thus, the aim of this paper is to evaluate the efficiency of all state public funded universities from Romania, respectively 48 entities between 2012 and 2018, by using DEA method.

The rest of the paper is organized as follows: next section illustrates the relevant literature review, section 3 describes data and methodology used in this research, section 4 discusses the empirical findings, and the last section concludes the findings and future research directions.

1. Literature review

Many authors have evaluated the efficiency in higher education system with DEA methodology. Some have studied it from the point of view of university as a whole while others evaluated the efficiency at academic departments’ level within university (Abd Aziz et al., 2013).

Abbott and Doucouliagos (2003) analyzed the technical and scale efficiency for 36 universities own by the Australian government using DEA. The authors used as an output factors for measure teaching, the number of students, respectively full time equivalent, the number of students enrolled in under-graduate and in post-graduate programs, and the post-graduate and under-graduate degrees awarded. The inputs considered were the number of academic staff, respectively full time equivalent, the total number of non-academic staff, and the universities expenditure beside labour cost.

Johnes (2006) studied technical efficiency in higher education system. He measured institutions efficiency having as case study universities in England. The author used also DEA techniques in their study. The results revealed a significant difference between the least and most efficient universities in England. Flegg et al. (2004) as well applied DEA and the method Malmquist to measure the efficiency of 45 universities from United...
Kingdom. Their study focus was on measuring efficiency changes over time. In 2010 Katharaki and Katharakis employed DEA in order to analyze the efficiency in 20 public universities in Greece with the focus on resources used in two most important activities, namely research and teaching. Avkiran (2001) adopted DEA in order to measure the relative efficiency of universities from Australia. The author based the research on three models that showed the academic overall performance, educational service performance and fee-paying enrolments performance. Ramírez-Correa et al. (2012) applied DEA to evaluate the efficiency of Chile universities. The authors’ findings exposed no differences, from statistical significance point of view, between public universities and private universities.

Research made by Tyagi et al. (2009) using DEA evaluate pure, technical and scale efficiency for 19 departments within Indian universities. In this sense was conducted sensitivity analysis to test the robustness of results efficiency. Martín (2006) engaged DEA method analysis as well when assessing the departments’ performance of a university in Spain. His study showed that there are differences not only between departments but also in different areas within the same departments. Koksal and Nalcaci (2006) approached the measurement of efficiency in a Turkey engineering college. The authors’ research was at academic departments’ level and they use DEA methodology. In order to improve their research, the authors integrated several criteria that regarded decisions made by university managers and government bodies as well. DEA is considered not only a method to measure the efficiency but a strategic planning tool for academic departments within public universities (Moreno and Tadepalli, 2002). Kao and Hung (2008) studied the academic departments of a university in Taiwan in order to evaluate the efficiency. Academic departments with similar features were categorized into groups by applying cluster analysis.

In this paper, our focus is to evaluation the efficiency of Romanian public universities that received budget allocation from 2012 to 2018 in relation with full time enrolled equivalent students at university level and undergraduate and graduate number of budgeted students.

2. Data and methods
The data comprises 48 annual observations of Romanian public universities over the period 2012-2018. All data come from the National Council for the Financing of Higher Education (CNFIS, 2018). Table no. 1 reveals the selected measures which concerns the funding of higher education institutions and the number of students. The indicators were selected in accordance with previous studies (Visbal-Cadavid et al., 2017; Quiroga-Martinez et al., 2018).

<table>
<thead>
<tr>
<th>Model</th>
<th>Inputs</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>First DEA model</td>
<td>Core funding</td>
<td>The number of students funded from the state budget</td>
</tr>
<tr>
<td></td>
<td>Additional funding</td>
<td>(all the three levels: undergraduate, graduate and doctoral studies)</td>
</tr>
<tr>
<td></td>
<td>The value of doctoral grants</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Institutional development funding</td>
<td></td>
</tr>
<tr>
<td>Second DEA model</td>
<td>Core funding</td>
<td>The number of students funded from the state budget</td>
</tr>
<tr>
<td></td>
<td>Additional funding</td>
<td>(undergraduate and graduate)</td>
</tr>
<tr>
<td></td>
<td>The value of doctoral grants</td>
<td></td>
</tr>
</tbody>
</table>

Source: Authors’ work
Institutional funding of Romanian public universities is based on three main components, respectively core, additional and institutional development funding. Core funding covers the fundamental expenditures associated to teaching, being assigned in line with the rule “resources follow the student” and succeeding priority fields of study that guarantees sustainable and competitive progress of society. Additional funding is allocated via the apportionment to universities a total amount of at least 30% of the volume allocated to national public universities as core funding, grounded on norms and standards of performance as set by the CNFIS and approved by the Ministry of Education. As well, the institutional development funds are allocated for the expansion of higher education organisations, being considered own revenues and employed under the rules of university autonomy and in compliance with agreements of institutional financing.

The linear programming technique of Data Envelopment Analysis (DEA) was designed by Charnes et al. (1979) and aims to compare production units that manage the similar resources set and yield the identical group of products, creating an efficient frontier and associated efficiency indicators within the population of explored production units (Visbal-Cadavid et al., 2017). Therefore, the Decision-Making Units (DMUs), namely the Romanian public universities, can be viewed as multi-product organizations that convert funds into goods. The purpose of DEA is to discover the DMUs that engender the maximum output levels by employing the minimum input levels. A DMU will be considered efficient when it is not possible to rise the number of outputs without increasing, by at least one unit, the number of inputs (Quiroga-Martínez et al., 2018). According to Sun et al. (2012), DEA shows the following notable features: it does not require to offer an overall association involving output and input, it does not entail parametric assumptions and weight vectors, it assesses the relative efficiency of DMUs by maximizing the share of the weighted sum of outputs to that of inputs.

In DEA, an inefficient unit may be turn into efficient one either by lessening the input levels while maintaining the outputs constant, namely input orientation or symmetrically, by rising the output levels while keeping the inputs constant, specifically output orientation (Raheli et al., 2017). Current study employs the input-oriented approach. Onward, the efficiency of each DMUs is evaluated by technical efficiency, pure technical efficiency and scale efficiency.

In line with Nassiri and Singh (2009), Mobtaker et al. (2012), Raheli et al. (2017), technical efficiency evaluates DMUs for their performance comparative to other DMUs, and is defined by the ratio of sum of the weighted outputs to sum of the weighted inputs. Therefore, consistent with Jauhar et al. (2017), problem design takes the following form:

\[ \text{Max} E_m = \sum_{k=1}^{O} w_k \frac{\text{Output}_{k,m}}{\sum_{l=1}^{I} z_l \text{Input}_{l,m}} \]  

\[ 0 \leq \sum_{k=1}^{O} w_k \frac{\text{Output}_{k,n}}{\sum_{l=1}^{I} z_l \text{Input}_{l,n}} \leq 1; \ n = 1, 2, \ldots, m \ldots N \]  

\[ w_k, z_l \geq 0; \ \forall \ k, l \]  

where \( E_m \) is the efficiency of the \( m \)th DMU, \( k = 1 \) to \( O \), \( l = 1 \) to \( I \), \( n = 1 \) to \( N \), \( \text{Output}_{k,m} \) is the \( k \)th output of the \( m \)th DMU, \( w_k \) is the weight of output \( \text{Output}_{k,m} \), \( \text{Input}_{l,m} \) is the \( l \)th input of \( m \)th DMU, \( z_l \) is the weight of \( \text{Input}_{l,m} \). \( \text{Output}_{k,n} \) and \( \text{Input}_{l,n} \) are the \( k \)th output and \( l \)th input of the \( n \)th DMU.
According to Charnes et al. (1979), Eq. (1) – Eq. (3) may be condensed to a linear programming format which depict the Charnes, Cooper și Rhodes (CCR) model:

\[
\text{Max } E_m \sum_{k=1}^{\theta} w_k \text{Output}_{k,m} \tag{4}
\]

Subjected to \( \sum_{i=1}^{l} z_i \text{Input}_{l,m} = 1 \) \( \tag{5} \)

\[
\sum_{k=1}^{\theta} w_k \text{Output}_{k,n} - \sum_{i=1}^{l} z_i \text{Input}_{l,n} \leq 0, \forall \ n \tag{6}
\]

\( w_k, z_l \geq 0; \forall k, l \) \( \tag{7} \)

The CCR DEA model presumes constant returns to scale (CRS), indicating that an upsurge in inputs would result in a proportional rise in the outputs. Consistent with Martínez-Camplillo and Fernández-Santos (2019), each DMU is allocated an efficiency indicator between 0 and 1, hence if efficiency score is 1, the DMU can be considered fully efficient, whilst relatively inefficient if efficiency score is less than 1. One possible explanation of a DMU’s inefficiency is that part of its inputs are not exploited entirely (Colbert et al., 2000).

Further, Banker et al. (1984) proposed the Banker, Chames și Cooper (BCC) model which admits variable returns to scale (VRS), inferring that a variation in inputs would result in an unequal modification in outputs. The general form of the BCC model may be represented as follows:

\[
\text{Max } E_m \sum_{k=1}^{\theta} w_k \text{Output}_{k,m} + z_{0l} \tag{8}
\]

Subjected to \( \sum_{i=1}^{l} z_i \text{Input}_{l,m} = 1 \) \( \tag{9} \)

\[
\sum_{k=1}^{\theta} w_k \text{Output}_{k,n} - \sum_{i=1}^{l} z_i \text{Input}_{l,n} + z_{0l} \leq 0, \forall \ n \tag{10}
\]

\( w_k, z_l \geq 0; \forall k, l; z_{0l} \) is unrestricted in sign \( \tag{11} \)

Scale efficiency shows that some part of inefficiency refers to unsuitable size of DMU and if DMU moved toward the best size, the overall efficiency (technical) can be enhanced at the same level of technologies (inputs). Scale efficiency can be calculated as below:

\[
\text{Scale efficiency} = \frac{\text{Technical efficiency}}{\text{Pure technical efficiency}} \tag{12}
\]

With the purpose of DEA practice, the homogeneity of DMUs must be certified, whereas all DMUs must fulfill three rules: the employed activities must be analogous and the aims should be identical, it should use similar inputs to yield the equivalent outputs, it should...
function within comparable settings (Abd Aziz et al., 2013). In this framework, the selected universities may be considered homogeneous as long as it employs comparable resources and produce similar outputs, also sharing matching purposes. At the same time, homogeneity is highlighted by the fact that all DMUs are public Romanian universities. By considering $\alpha$ the proportional input increase and $\beta$ the ensuing proportional growth of the single output (Banker and Thrall, 1992), increasing returns to scale (IRS) prevail if $\beta > \alpha$, whereas decreasing returns to scale (DRS) succeed if $\beta < \alpha$ (Banker et al., 2011).

3. Empirical findings

First, we explore the efficiency of funding for the entire three-cycle system. In this regard, Appendix no. 1 and Appendix no. 2 report the values of technical efficiency from CRS and VRS. Therefore, the outcomes provide support for a higher efficiency ensuing from VRS than CRS, even in both approaches the efficiency is decreasing over the selected period. As well, the number of fully efficient universities is superior in the VRS method (20 in 2012 and 2013, 17 in 2014 and 2017, 18 in 2015 and 2016, 16 in 2018) as compared to the CRS technique (6 in 2012 and 2015, 9 in 2013 and 2016, 7 in 2014, 5 in 2017 and 2018). Besides, the results of VRS expose that 11 universities are fully efficient for the whole period, whilst the CRS approach point out only two fully efficient DMUs. Beyond the fact that some universities reveal a unitary efficiency score, proving a maximization of the funding in relation to the number of students that can be financed from the state budget, according to the regulations in force, we emphasize that a distinction is needed according to the institution's objectives regarding the quality of the educational process.

The values associated to scale efficiency for the first DEA model are shown in Appendix no. 3. Thus, the results indicate that merely two universities are fully efficient over the time span 2012-2018. According to Visbal-Cadavid et al. (2017), the DEA method indicates the extent to which input and output variables can be improved so that a higher education institution becomes effective.

Onward, the efficiency of funding for the undergraduate and graduate levels is investigated. The figures regarding technical efficiency from CRS and VRS are exhibited in Appendix no. 4 and Appendix no. 5. Similar to the outcomes from the first DEA model, technical efficiency resulting from the VRS approach is larger than that from CRS. However, the number of fully efficient DMUs is lower in the second DEA model, even if the VRS method still displays more universities with efficiency score equal to one (16 in 2012, 2013 and 2017, 14 in 2014, 13 in 2015, 15 in 2016, 12 in 2018) than the CRS approach (5 in 2012, 2014, 2017 and 2018, 6 in 2013 and 2016, 2 in 2015). Therewith, merely a single university appears fully efficient over the entire period when considering the CRS method as compared to 7 universities in case of the VRS. The variation of the efficiency scores from one academic year to another may be due to demographic changes, educational offer, as well as the degree of achievement of quality institutional objectives.

The scores of scale efficiency corresponding to the second DEA model are exposed in Appendix no. 6. We notice that merely a single university is fully efficient over the entire period.
Conclusions
In this study we analyzed 48 Romanian public universities over the period of 2012-2018. Our focus was on the efficiency of funding of higher education institutions in relation with the number of students. All data was collected from the National Council for the Financing of Higher Education. We investigated the efficiency of funding by employing DEA for the entire three-cycle system. As funding system in Romanian public universities is based on three main components, correspondingly core, additional and institutional development funding, we considered them as inputs. The outcomes of the first DEA model – technical efficiency from constant return to scale and technical efficiency from variable return to scale, revealed that 11 out of 49 public universities are fully efficient for the whole period when VRS was applied, whilst the CRS approach showed only two fully efficient DMUs. When was considered scale efficiency, the results merely showed two universities to be fully efficient over the period analyzed.

In order to evaluate better the efficiency of funding, we also investigated the undergraduate and graduate levels as well. Technical efficiency outcome from CRS and VRS showed similar results as in the first DEA model, respectively VRS approach was larger than CRS. Though, the number of fully efficient DMUs is lower in the second DEA model than the CRS approach. In this last DEA model only one university appeared to be fully efficient over the entire period when was considered the CRS method as compared to 7 universities in case of the VRS.

In terms of research limitations, the present article aimed at the study based on the number of students. Thus, the analysis should also be based on quality elements, namely the quality of the teaching process and the quality of the graduates.

The results of the DEA model consider maximizing effects. Future directions of study can be oriented towards the quality of the results, respectively of the graduates through corrections with ex-ante indicators, such as the report of the universities regarding the proportion of students who meet / have fully achieved the learning objectives (“assessment of learning”) and ex-post which aims at the quality of graduates quantified from specific indicators: rapid advancement / career promotion, employability. Therefore, the level of funding should be corrected with elements based on quality indicators of the result.

References


Martín, E., 2006. Efficiency and quality in the current higher education context in Europe: an application of the data envelopment analysis methodology to performance assessment of departments within the University of Zaragoza. *Quality in Higher Education*, 12(1), pp.57-79.


Appendix no. 1: The outcomes of the first DEA model – technical efficiency from constant return to scale

<table>
<thead>
<tr>
<th>DMU</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>U01</td>
<td>0.366</td>
<td>0.584</td>
<td>0.649</td>
<td>0.657</td>
<td>0.701</td>
<td>0.686</td>
<td>0.662</td>
</tr>
<tr>
<td>U02</td>
<td>0.803</td>
<td>1.000</td>
<td>0.646</td>
<td>0.668</td>
<td>0.680</td>
<td>0.704</td>
<td>0.754</td>
</tr>
<tr>
<td>U03</td>
<td>0.542</td>
<td>0.527</td>
<td>0.552</td>
<td>0.554</td>
<td>0.562</td>
<td>0.575</td>
<td>0.579</td>
</tr>
<tr>
<td>U04</td>
<td>0.718</td>
<td>0.623</td>
<td>0.643</td>
<td>0.657</td>
<td>0.706</td>
<td>0.692</td>
<td>0.680</td>
</tr>
<tr>
<td>U05</td>
<td>0.872</td>
<td>0.851</td>
<td>0.864</td>
<td>0.866</td>
<td>0.860</td>
<td>0.896</td>
<td>0.925</td>
</tr>
<tr>
<td>U06</td>
<td>0.281</td>
<td>0.279</td>
<td>0.367</td>
<td>0.336</td>
<td>0.383</td>
<td>0.376</td>
<td>0.396</td>
</tr>
<tr>
<td>U07</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>0.999</td>
<td>1.000</td>
<td>1.000</td>
<td>0.967</td>
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<tr>
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<td>0.722</td>
<td>0.753</td>
<td>0.750</td>
<td>0.742</td>
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<td>0.268</td>
</tr>
<tr>
<td>U09</td>
<td>0.384</td>
<td>0.366</td>
<td>0.383</td>
<td>0.400</td>
<td>0.399</td>
<td>0.401</td>
<td>0.414</td>
</tr>
<tr>
<td>U10</td>
<td>0.256</td>
<td>0.186</td>
<td>0.201</td>
<td>0.205</td>
<td>0.210</td>
<td>0.213</td>
<td>0.211</td>
</tr>
<tr>
<td>U11</td>
<td>0.663</td>
<td>0.567</td>
<td>0.596</td>
<td>0.607</td>
<td>0.589</td>
<td>0.597</td>
<td>0.595</td>
</tr>
<tr>
<td>U12</td>
<td>0.961</td>
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<td>0.975</td>
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<td>1.000</td>
<td>1.000</td>
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<tr>
<td>U13</td>
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<td>1.000</td>
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<td>1.000</td>
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</tr>
<tr>
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<td>0.847</td>
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<td>0.841</td>
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<td>0.912</td>
<td>0.732</td>
<td>0.775</td>
</tr>
<tr>
<td>U18</td>
<td>0.645</td>
<td>0.647</td>
<td>0.840</td>
<td>0.663</td>
<td>0.749</td>
<td>0.716</td>
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<td>U19</td>
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<td>0.693</td>
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<tr>
<td>U20</td>
<td>0.768</td>
<td>0.708</td>
<td>0.848</td>
<td>0.709</td>
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<tr>
<td>U21</td>
<td>0.159</td>
<td>0.484</td>
<td>0.569</td>
<td>0.392</td>
<td>0.391</td>
<td>0.395</td>
<td>0.393</td>
</tr>
<tr>
<td>U22</td>
<td>0.274</td>
<td>0.247</td>
<td>0.251</td>
<td>0.255</td>
<td>0.270</td>
<td>0.266</td>
<td>0.285</td>
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<tr>
<td>U23</td>
<td>0.406</td>
<td>0.353</td>
<td>0.397</td>
<td>0.402</td>
<td>0.424</td>
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<td>0.569</td>
</tr>
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<td>0.933</td>
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<td>0.980</td>
<td>0.664</td>
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<td>0.935</td>
<td>0.690</td>
<td>0.696</td>
<td>0.658</td>
<td>0.834</td>
<td>0.732</td>
<td>1.000</td>
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<tr>
<td>U26</td>
<td>0.909</td>
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<td>0.816</td>
<td>0.559</td>
<td>0.407</td>
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<td>0.698</td>
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<tr>
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<td>0.710</td>
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<td>0.894</td>
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<td>0.840</td>
<td>0.870</td>
<td>0.870</td>
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<td>0.922</td>
<td>1.000</td>
<td>0.887</td>
<td>0.840</td>
</tr>
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*Source: Authors’ estimations*

Note: The abbreviation of each DMU is in line with National Council for the Financing of Higher Education- CNFIS (2012-2018).
Appendix no. 2: The outcomes of the first DEA model – technical efficiency from variable return to scale

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Source: Authors’ estimations

Note: The abbreviation of each DMU is in line with National Council for the Financing of Higher Education- CNFIS (2012-2018).
## Appendix no. 3: The outcomes of the first DEA model – scale efficiency

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| Mean | 0.871 | 0.859 | 0.859 | 0.867 | 0.906 | 0.848 | 0.872 |

**Source:** Authors’ estimations

**Notes:** The abbreviation of each DMU is in line with National Council for the Financing of Higher Education- CNFIS (2012-2018). drs denotes increasing returns to scale and drs depicts decreasing returns to scale.
Appendix no. 4: The outcomes of the second DEA model – technical efficiency from constant return to scale

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Source: Authors’ estimations

Appendix no. 5: The outcomes of the second DEA model – technical efficiency from variable return to scale

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**mean** 0.771 0.780 0.798 0.749 0.771 0.770 0.762

*Source: Authors' estimations*

**Note**: The abbreviation of each DMU is in line with National Council for the Financing of Higher Education -CNFIS (2012-2018).
### Appendix no. 6: The outcomes of the second DEA model – scale efficiency

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<td>0.728</td>
<td>0.590</td>
<td>0.842</td>
<td>0.989</td>
<td>0.923</td>
<td>0.966</td>
</tr>
<tr>
<td>mean</td>
<td>0.862</td>
<td>0.850</td>
<td>0.844</td>
<td>0.847</td>
<td>0.876</td>
<td>0.844</td>
<td>0.875</td>
</tr>
</tbody>
</table>

**Notes:** The abbreviation of each DMU is in line with National Council for the Financing of Higher Education – CNFIS (2012-2018). irs denotes increasing returns to scale and drs depicts decreasing returns to scale.

**Source:** Authors’ estimations