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A DEA Approach Towards Exploring the Sustainability of Funding in Higher Education. Empirical Evidence from Romanian Public Universities

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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.

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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 no. 1: Description of the variables

Model	Inputs	Outputs
First DEA model	Core funding	The number of students funded from the state budget (all the three levels: undergraduate, graduate and doctoral studies)
	Additional funding	
	The value of doctoral grants	
	Institutional development funding	
Second DEA model	Core funding	The number of students funded from the state budget (undergraduate and graduate)
	Additional funding	
	The value of doctoral grants	

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-Martinez 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:

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

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

$$w_k, z_l \geq 0; \forall k, l \tag{3}$$

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:

$$\text{Max} E_m \sum_{k=1}^O w_k \text{Output}_{k,m} \tag{4}$$

$$\text{Subjected to } \sum_{l=1}^I z_l \text{Input}_{l,m} = 1 \tag{5}$$

$$\sum_{k=1}^O w_k \text{Output}_{k,n} - \sum_{l=1}^I z_l \text{Input}_{l,n} \leq 0, \forall n \tag{6}$$

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

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-Campillo 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, Charnes 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:

$$\text{Max} E_m \sum_{k=1}^O w_k \text{Output}_{k,m} + z_{Ol} \tag{8}$$

$$\text{Subjected to } \sum_{l=1}^I z_l \text{Input}_{l,m} = 1 \tag{9}$$

$$\sum_{k=1}^O w_k \text{Output}_{k,n} - \sum_{l=1}^I z_l \text{Input}_{l,n} + z_{Ol} \leq 0, \forall n \tag{10}$$

$$w_k, z_l \geq 0; \forall k, l; z_{Ol} \text{ is unrestricted in sign} \tag{11}$$

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 fulfil 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 α the proportional input increase and β 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.

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

DMU	2012	2013	2014	2015	2016	2017	2018
U01	0.566	0.584	0.649	0.657	0.701	0.686	0.662
U02	0.803	1.000	0.646	0.668	0.680	0.704	0.754
U03	0.542	0.527	0.552	0.554	0.562	0.575	0.579
U04	0.718	0.623	0.643	0.657	0.706	0.692	0.680
U05	0.872	0.851	0.864	0.866	0.860	0.896	0.925
U06	0.281	0.279	0.367	0.336	0.383	0.376	0.396
U07	1.000	1.000	1.000	0.999	1.000	1.000	0.967
U08	0.272	0.227	0.253	0.250	0.342	0.268	0.268
U09	0.384	0.366	0.383	0.400	0.399	0.401	0.414
U10	0.256	0.186	0.201	0.205	0.210	0.213	0.211
U11	0.663	0.567	0.596	0.607	0.589	0.597	0.595
U12	0.961	0.949	0.975	0.967	1.000	1.000	1.000
U13	1.000	1.000	1.000	1.000	1.000	1.000	1.000
U14	1.000	0.966	0.981	1.000	0.995	0.864	0.872
U15	0.782	0.794	0.863	1.000	0.813	0.724	0.847
U17	0.798	0.841	0.844	0.765	0.912	0.732	0.775
U18	0.645	0.647	0.840	0.663	0.749	0.716	0.727
U19	0.678	0.647	0.668	0.687	0.684	0.693	0.679
U20	0.768	0.708	0.848	0.709	0.723	0.725	0.736
U21	0.359	0.484	0.569	0.392	0.391	0.395	0.383
U22	0.274	0.247	0.251	0.255	0.270	0.266	0.285
U23	0.406	0.353	0.397	0.402	0.424	0.439	0.569
U24	0.794	0.933	1.000	0.900	0.980	0.684	0.824
U25	0.935	0.680	0.696	0.658	0.834	0.732	1.000
U26	0.909	1.000	1.000	0.863	1.000	0.780	0.822
U27	0.429	0.816	0.559	0.407	0.445	0.398	0.501
U28	0.900	0.931	0.794	0.728	0.882	0.679	0.700
U29	0.666	0.627	0.639	0.651	0.803	0.676	0.704
U30	0.697	0.612	0.650	0.668	0.681	0.698	0.704
U31	0.812	0.818	0.893	0.799	0.843	0.870	0.886
U32	0.370	0.378	0.617	0.405	0.425	0.415	0.409
U33	0.375	0.281	0.306	0.324	0.396	0.333	0.370
U34	0.999	1.000	0.953	0.816	0.934	0.684	0.710
U35	0.894	0.874	0.861	0.840	0.870	0.870	0.932
U36	0.976	0.895	0.934	0.922	1.000	0.867	0.840
U37	1.000	1.000	1.000	1.000	1.000	0.876	1.000
U38	1.000	1.000	1.000	1.000	0.982	0.930	0.920
U39	0.901	0.801	0.834	0.744	0.843	0.751	0.793
U40	0.810	0.735	0.763	0.766	0.811	0.785	0.800
U41	0.915	0.947	0.941	0.941	1.000	0.874	0.871
U42	1.000	1.000	1.000	1.000	1.000	1.000	1.000
U43	0.928	0.988	0.977	0.939	1.000	1.000	0.934
U44	0.372	1.000	0.500	0.375	0.393	0.346	0.364
U45	0.184	0.179	0.186	0.189	0.248	0.179	0.181
U46	0.633	0.618	0.633	0.643	0.799	0.695	0.715
U47	0.680	0.638	0.664	0.667	0.700	0.694	0.698
U48	0.987	0.826	0.895	0.746	0.834	0.789	0.790
U49	0.409	0.900	0.609	0.463	0.455	0.407	0.440
mean	0.700	0.715	0.714	0.677	0.720	0.666	0.692

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**

DMU	2012	2013	2014	2015	2016	2017	2018
U01	1.000	0.963	1.000	1.000	1.000	1.000	1.000
U02	0.822	1.000	0.687	0.675	0.697	0.719	0.760
U03	0.632	0.564	0.601	0.605	0.608	0.607	0.611
U04	0.772	0.674	0.677	0.660	0.743	0.751	0.734
U05	1.000	1.000	1.000	1.000	1.000	1.000	1.000
U06	0.292	0.292	0.381	0.337	0.387	0.452	0.422
U07	1.000	1.000	1.000	1.000	1.000	1.000	1.000
U08	0.456	0.364	0.359	0.401	0.425	0.509	0.406
U09	0.574	0.533	0.530	0.530	0.534	0.512	0.524
U10	0.473	0.363	0.320	0.366	0.346	0.329	0.320
U11	1.000	1.000	0.801	0.853	0.826	0.797	0.774
U12	0.967	0.954	0.976	0.967	1.000	1.000	1.000
U13	1.000	1.000	1.000	1.000	1.000	1.000	1.000
U14	1.000	1.000	1.000	1.000	1.000	0.924	0.873
U15	0.831	0.826	0.922	1.000	0.820	0.798	0.874
U17	0.964	0.881	0.881	0.895	0.940	0.958	1.000
U18	0.716	0.782	0.914	0.912	0.915	0.829	0.953
U19	0.701	0.653	0.677	0.687	0.684	0.701	0.682
U20	1.000	1.000	1.000	1.000	1.000	1.000	1.000
U21	0.360	0.641	0.770	0.392	0.393	0.402	0.393
U22	0.431	0.415	0.357	0.401	0.403	0.392	0.399
U23	0.885	0.760	0.802	0.660	0.669	0.901	1.000
U24	0.874	0.934	1.000	1.000	0.986	0.932	1.000
U25	1.000	1.000	1.000	1.000	1.000	1.000	1.000
U26	1.000	1.000	1.000	1.000	1.000	1.000	1.000
U27	0.434	1.000	0.739	0.421	0.466	0.411	0.569
U28	1.000	0.938	0.817	0.866	0.884	0.855	0.818
U29	0.796	0.778	0.768	0.761	0.840	0.758	0.783
U30	0.698	0.615	0.650	0.669	0.681	0.698	0.718
U31	1.000	1.000	1.000	1.000	1.000	1.000	1.000
U32	0.379	0.381	0.742	0.406	0.425	0.419	0.415
U33	0.485	0.364	0.363	0.393	0.437	0.387	0.541
U34	1.000	1.000	1.000	1.000	1.000	1.000	1.000
U35	0.929	0.925	0.892	0.849	0.877	0.898	0.935
U36	1.000	1.000	1.000	1.000	1.000	1.000	0.877
U37	1.000	1.000	1.000	1.000	1.000	1.000	1.000
U38	1.000	1.000	1.000	1.000	1.000	1.000	1.000
U39	1.000	0.909	0.918	0.904	0.939	1.000	0.951
U40	0.875	0.832	0.872	0.866	0.842	0.834	0.843
U41	1.000	1.000	1.000	1.000	1.000	1.000	0.986
U42	1.000	1.000	1.000	1.000	1.000	1.000	1.000
U43	1.000	1.000	0.991	0.942	1.000	1.000	0.938
U44	0.373	1.000	0.974	0.384	0.399	0.347	0.370
U45	0.796	0.829	0.819	1.000	1.000	0.672	0.612
U46	0.720	0.713	0.727	0.746	0.815	0.884	0.810
U47	0.685	0.661	0.664	0.667	0.712	0.696	0.711
U48	1.000	0.836	0.902	0.798	0.844	0.871	0.873
U49	0.430	1.000	1.000	0.481	0.463	0.436	0.443
mean	0.799	0.820	0.823	0.781	0.792	0.785	0.790

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

DMU	2012		2013		2014		2015		2016		2017		2018	
U01	0.566	drs	0.606	drs	0.649	drs	0.657	drs	0.701	drs	0.686	drs	0.662	drs
U02	0.977	drs	1.000	-	0.941	drs	0.989	drs	0.976	irs	0.980	drs	0.993	drs
U03	0.857	irs	0.934	irs	0.918	irs	0.915	irs	0.924	irs	0.948	irs	0.948	irs
U04	0.930	drs	0.924	drs	0.950	drs	0.995	drs	0.950	drs	0.922	drs	0.926	drs
U05	0.872	drs	0.851	drs	0.864	drs	0.866	drs	0.860	drs	0.896	drs	0.925	drs
U06	0.965	drs	0.955	drs	0.963	irs	0.999	-	0.988	drs	0.832	drs	0.940	drs
U07	1.000	-	1.000	-	1.000	-	0.999	drs	1.000	-	1.000	-	0.967	drs
U08	0.597	irs	0.625	irs	0.706	irs	0.624	irs	0.803	irs	0.528	irs	0.662	irs
U09	0.669	irs	0.687	irs	0.724	irs	0.755	irs	0.747	irs	0.783	irs	0.789	irs
U10	0.540	irs	0.512	irs	0.627	irs	0.559	irs	0.606	irs	0.648	irs	0.659	irs
U11	0.663	irs	0.567	irs	0.744	irs	0.711	irs	0.713	irs	0.750	irs	0.769	irs
U12	0.994	irs	0.995	drs	0.999	irs	0.999	drs	1.000	-	1.000	-	1.000	-
U13	1.000	-	1.000	-	1.000	-	1.000	-	1.000	-	1.000	-	1.000	-
U14	1.000	-	0.966	irs	0.981	irs	1.000	-	0.995	irs	0.935	drs	0.999	-
U15	0.941	drs	0.962	drs	0.936	irs	1.000	-	0.992	irs	0.906	drs	0.969	drs
U17	0.827	drs	0.954	drs	0.958	drs	0.855	drs	0.970	drs	0.764	drs	0.775	drs
U18	0.900	drs	0.827	drs	0.919	drs	0.727	drs	0.818	drs	0.863	drs	0.763	drs
U19	0.968	irs	0.991	drs	0.987	irs	0.999	-	0.999	-	0.989	irs	0.995	drs
U20	0.768	drs	0.708	drs	0.848	drs	0.709	drs	0.723	drs	0.725	drs	0.736	drs
U21	0.996	drs	0.755	irs	0.739	irs	1.000	-	0.996	irs	0.981	irs	0.976	irs
U22	0.636	irs	0.595	irs	0.703	irs	0.635	irs	0.670	irs	0.678	irs	0.714	irs
U23	0.458	irs	0.465	irs	0.495	irs	0.609	irs	0.634	irs	0.487	irs	0.569	irs
U24	0.908	drs	0.999	drs	1.000	-	0.900	drs	0.995	irs	0.733	drs	0.824	drs
U25	0.935	irs	0.680	irs	0.696	irs	0.658	irs	0.834	irs	0.732	irs	1.000	-
U26	0.909	drs	1.000	-	1.000	-	0.863	drs	1.000	-	0.780	drs	0.822	drs
U27	0.990	irs	0.816	irs	0.757	irs	0.966	irs	0.956	irs	0.966	drs	0.880	irs
U28	0.900	drs	0.993	drs	0.972	drs	0.841	drs	0.998	irs	0.793	drs	0.856	drs
U29	0.837	drs	0.806	drs	0.832	drs	0.854	drs	0.956	drs	0.891	drs	0.900	drs
U30	0.998	drs	0.996	drs	1.000	-	1.000	-	0.999	-	1.000	-	0.981	drs
U31	0.812	drs	0.818	drs	0.893	drs	0.799	drs	0.843	drs	0.870	drs	0.886	drs
U32	0.977	irs	0.993	drs	0.832	irs	0.999	-	1.000	-	0.991	drs	0.986	drs
U33	0.772	irs	0.771	irs	0.841	irs	0.824	irs	0.906	irs	0.862	irs	0.684	irs
U34	0.999	drs	1.000	-	0.953	drs	0.816	drs	0.934	drs	0.684	drs	0.710	drs
U35	0.963	drs	0.944	drs	0.966	drs	0.988	drs	0.991	irs	0.970	drs	0.997	irs
U36	0.976	drs	0.895	drs	0.934	drs	0.922	drs	1.000	-	0.867	drs	0.958	drs
U37	1.000	-	1.000	-	1.000	-	1.000	-	1.000	-	0.876	drs	1.000	-
U38	1.000	-	1.000	-	1.000	-	1.000	-	0.982	irs	0.930	irs	0.920	irs
U39	0.901	drs	0.881	drs	0.909	drs	0.824	drs	0.898	drs	0.751	drs	0.834	drs
U40	0.926	drs	0.883	drs	0.875	drs	0.884	drs	0.963	drs	0.941	drs	0.949	drs
U41	0.915	drs	0.947	drs	0.941	drs	0.941	drs	1.000	-	0.874	drs	0.883	drs
U42	1.000	-	1.000	-	1.000	-	1.000	-	1.000	-	1.000	-	1.000	-
U43	0.928	drs	0.988	drs	0.987	drs	0.996	irs	1.000	-	1.000	-	0.996	irs
U44	0.997	irs	1.000	-	0.513	irs	0.977	drs	0.986	irs	0.995	drs	0.985	drs
U45	0.232	irs	0.216	irs	0.228	irs	0.189	irs	0.248	irs	0.266	irs	0.296	irs
U46	0.878	drs	0.867	drs	0.871	drs	0.862	drs	0.980	drs	0.786	drs	0.882	drs
U47	0.992	drs	0.965	drs	1.000	-	1.000	-	0.982	irs	0.998	irs	0.981	drs
U48	0.987	drs	0.988	drs	0.992	irs	0.934	drs	0.988	drs	0.906	drs	0.905	drs
U49	0.951	drs	0.900	irs	0.609	irs	0.963	drs	0.984	irs	0.934	drs	0.992	irs
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). irs 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**

DMU	2012	2013	2014	2015	2016	2017	2018
U01	0.541	0.561	0.622	0.634	0.649	0.652	0.631
U02	0.773	0.862	0.641	0.654	0.672	0.686	0.730
U03	0.479	0.505	0.542	0.549	0.556	0.555	0.561
U04	0.687	0.614	0.634	0.650	0.668	0.680	0.675
U05	0.832	0.816	0.835	0.839	0.846	0.867	0.896
U06	0.268	0.261	0.342	0.316	0.339	0.346	0.371
U07	1.000	1.000	1.000	0.994	1.000	1.000	0.943
U08	0.235	0.215	0.236	0.234	0.293	0.252	0.255
U09	0.366	0.352	0.368	0.382	0.387	0.387	0.386
U10	0.211	0.176	0.187	0.189	0.192	0.193	0.191
U11	0.586	0.547	0.568	0.580	0.565	0.566	0.556
U12	0.926	0.905	0.932	0.941	1.000	1.000	1.000
U13	1.000	1.000	1.000	1.000	1.000	1.000	1.000
U14	1.000	0.851	0.852	0.843	0.982	0.862	0.871
U15	0.746	0.730	0.863	0.748	0.800	0.719	0.740
U17	0.744	0.688	0.753	0.686	0.780	0.728	0.753
U18	0.631	0.631	0.810	0.649	0.687	0.686	0.710
U19	0.667	0.631	0.649	0.665	0.671	0.675	0.667
U20	0.755	0.695	0.826	0.692	0.690	0.707	0.728
U21	0.345	0.464	0.529	0.366	0.373	0.371	0.366
U22	0.244	0.240	0.243	0.245	0.248	0.254	0.271
U23	0.380	0.330	0.372	0.375	0.385	0.403	0.521
U24	0.784	0.866	1.000	0.657	0.889	0.674	0.827
U25	0.925	0.672	0.689	0.649	0.799	0.714	1.000
U26	0.829	0.774	1.000	0.754	0.897	0.777	0.799
U27	0.422	0.785	0.546	0.399	0.394	0.382	0.486
U28	0.745	0.759	0.653	0.649	0.759	0.676	0.679
U29	0.640	0.625	0.632	0.635	0.695	0.660	0.649
U30	0.654	0.597	0.629	0.656	0.673	0.688	0.694
U31	0.797	0.804	0.875	0.782	0.807	0.842	0.828
U32	0.361	0.366	0.586	0.390	0.384	0.396	0.396
U33	0.330	0.267	0.287	0.301	0.325	0.311	0.349
U34	0.978	1.000	0.654	0.629	0.883	0.681	0.707
U35	0.867	0.854	0.845	0.835	0.837	0.864	0.928
U36	0.957	0.878	0.914	0.901	1.000	0.858	0.838
U37	0.936	0.834	0.833	0.843	0.980	0.871	1.000
U38	1.000	1.000	1.000	1.000	0.974	0.927	0.917
U39	0.858	0.683	0.706	0.717	0.828	0.746	0.780
U40	0.745	0.735	0.760	0.763	0.775	0.777	0.772
U41	0.895	0.927	0.939	0.941	0.971	0.868	0.863
U42	1.000	1.000	0.994	0.984	1.000	1.000	1.000
U43	0.900	0.982	0.976	0.938	1.000	1.000	0.927
U44	0.362	1.000	0.486	0.337	0.355	0.337	0.330
U45	0.171	0.172	0.154	0.150	0.199	0.157	0.176
U46	0.629	0.613	0.620	0.630	0.687	0.683	0.655
U47	0.664	0.629	0.657	0.659	0.668	0.685	0.681
U48	0.867	0.742	0.889	0.743	0.771	0.784	0.768
U49	0.379	0.530	0.590	0.378	0.385	0.393	0.418
mean	0.669	0.670	0.682	0.636	0.682	0.653	0.673

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. 5: The outcomes of the second DEA model – technical efficiency from variable return to scale

DMU	2012	2013	2014	2015	2016	2017	2018
U01	0.743	0.796	1.000	1.000	1.000	1.000	1.000
U02	0.796	0.943	0.647	0.656	0.676	0.701	0.746
U03	0.590	0.544	0.587	0.594	0.597	0.602	0.608
U04	0.726	0.663	0.667	0.654	0.737	0.737	0.721
U05	1.000	1.000	1.000	1.000	1.000	1.000	1.000
U06	0.269	0.265	0.358	0.318	0.366	0.422	0.395
U07	1.000	1.000	1.000	1.000	1.000	1.000	1.000
U08	0.430	0.332	0.352	0.379	0.425	0.509	0.406
U09	0.572	0.514	0.517	0.516	0.527	0.504	0.508
U10	0.448	0.293	0.320	0.346	0.342	0.325	0.320
U11	1.000	1.000	0.780	0.837	0.807	0.784	0.771
U12	0.939	0.911	0.934	0.944	1.000	1.000	1.000
U13	1.000	1.000	1.000	1.000	1.000	1.000	1.000
U14	1.000	0.852	0.858	0.860	1.000	0.916	0.873
U15	0.770	0.742	0.914	0.825	0.805	0.743	0.776
U17	0.849	0.823	0.820	0.819	0.908	0.901	0.882
U18	0.695	0.774	0.885	0.910	0.900	0.817	0.921
U19	0.692	0.638	0.658	0.667	0.673	0.679	0.669
U20	1.000	1.000	1.000	1.000	1.000	1.000	1.000
U21	0.346	0.628	0.767	0.367	0.378	0.376	0.377
U22	0.382	0.359	0.353	0.390	0.403	0.392	0.399
U23	0.885	0.760	0.802	0.660	0.669	0.901	1.000
U24	0.870	0.874	1.000	1.000	0.946	0.930	1.000
U25	1.000	1.000	1.000	1.000	1.000	1.000	1.000
U26	1.000	1.000	1.000	1.000	1.000	1.000	0.916
U27	0.426	1.000	0.738	0.415	0.413	0.394	0.563
U28	0.838	0.809	0.783	0.851	0.861	0.853	0.744
U29	0.717	0.679	0.668	0.657	0.824	0.688	0.725
U30	0.662	0.598	0.631	0.657	0.675	0.688	0.699
U31	1.000	1.000	1.000	1.000	1.000	1.000	0.944
U32	0.373	0.369	0.739	0.391	0.388	0.398	0.399
U33	0.476	0.336	0.348	0.376	0.394	0.387	0.511
U34	1.000	1.000	0.947	0.933	0.957	0.961	0.815
U35	0.905	0.856	0.850	0.836	0.845	0.897	0.931
U36	1.000	1.000	1.000	1.000	1.000	1.000	0.848
U37	1.000	0.876	0.867	0.890	0.981	1.000	1.000
U38	1.000	1.000	1.000	1.000	1.000	1.000	1.000
U39	1.000	0.888	0.902	0.887	0.930	1.000	0.890
U40	0.823	0.830	0.867	0.864	0.839	0.826	0.790
U41	1.000	1.000	1.000	1.000	1.000	1.000	0.882
U42	1.000	1.000	1.000	1.000	1.000	1.000	1.000
U43	0.960	1.000	0.981	0.941	1.000	1.000	0.928
U44	0.364	1.000	0.974	0.369	0.359	0.338	0.336
U45	0.791	0.631	0.524	0.562	0.662	0.537	0.582
U46	0.716	0.687	0.696	0.702	0.805	0.792	0.732
U47	0.667	0.634	0.659	0.660	0.670	0.685	0.683
U48	0.868	0.791	0.900	0.771	0.833	0.864	0.839
U49	0.396	0.728	1.000	0.449	0.389	0.426	0.432
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

DMU	2012		2013		2014		2015		2016		2017		2018	
U01	0.728	drs	0.705	drs	0.622	drs	0.634	drs	0.649	drs	0.652	drs	0.631	drs
U02	0.972	drs	0.914	irs	0.991	drs	0.997	drs	0.994	irs	0.979	drs	0.979	drs
U03	0.813	irs	0.929	irs	0.923	irs	0.924	irs	0.932	irs	0.922	irs	0.923	irs
U04	0.947	drs	0.926	drs	0.950	drs	0.993	drs	0.906	drs	0.923	drs	0.936	drs
U05	0.832	drs	0.816	drs	0.835	drs	0.839	drs	0.846	drs	0.867	drs	0.896	drs
U06	0.997	drs	0.987	drs	0.954	irs	0.996	drs	0.928	drs	0.820	drs	0.940	drs
U07	1.000	-	1.000	-	1.000	-	0.994	drs	1.000	-	1.000	-	0.943	drs
U08	0.546	irs	0.649	irs	0.670	irs	0.617	irs	0.689	irs	0.495	irs	0.629	irs
U09	0.640	irs	0.685	irs	0.711	irs	0.740	irs	0.735	irs	0.768	irs	0.760	irs
U10	0.471	irs	0.600	irs	0.585	irs	0.545	irs	0.561	irs	0.595	irs	0.595	irs
U11	0.586	irs	0.547	irs	0.728	irs	0.693	irs	0.700	irs	0.722	irs	0.722	irs
U12	0.986	irs	0.994	drs	0.997	drs	0.998	drs	1.000	-	1.000	-	1.000	-
U13	1.000	-	1.000	-	1.000	-	1.000	-	1.000	-	1.000	-	1.000	-
U14	1.000	-	0.999	drs	0.993	irs	0.980	irs	0.982	irs	0.941	drs	0.998	drs
U15	0.968	drs	0.984	drs	0.944	irs	0.907	drs	0.993	irs	0.968	drs	0.954	irs
U17	0.876	drs	0.836	drs	0.919	drs	0.838	drs	0.858	drs	0.808	drs	0.854	drs
U18	0.907	drs	0.815	drs	0.915	drs	0.713	drs	0.764	drs	0.839	drs	0.770	drs
U19	0.963	irs	0.988	drs	0.986	irs	0.997	drs	0.997	irs	0.993	irs	0.998	drs
U20	0.755	drs	0.695	drs	0.826	drs	0.692	drs	0.690	drs	0.707	drs	0.728	drs
U21	0.997	drs	0.739	irs	0.690	irs	0.998	drs	0.986	irs	0.987	irs	0.970	irs
U22	0.638	irs	0.670	irs	0.688	irs	0.626	irs	0.614	irs	0.648	irs	0.678	irs
U23	0.429	irs	0.434	irs	0.464	irs	0.567	irs	0.576	irs	0.447	irs	0.521	irs
U24	0.901	drs	0.990	drs	1.000	-	0.657	drs	0.940	drs	0.726	drs	0.827	drs
U25	0.925	irs	0.672	irs	0.689	irs	0.649	irs	0.799	irs	0.714	irs	1.000	-
U26	0.829	drs	0.774	drs	1.000	-	0.754	drs	0.897	drs	0.777	drs	0.872	drs
U27	0.991	irs	0.785	irs	0.740	irs	0.961	irs	0.952	irs	0.970	drs	0.863	irs
U28	0.889	drs	0.939	drs	0.834	drs	0.763	drs	0.882	drs	0.793	drs	0.913	drs
U29	0.893	drs	0.921	drs	0.946	drs	0.967	drs	0.843	drs	0.960	drs	0.896	drs
U30	0.988	irs	0.997	drs	0.998	drs	0.999	drs	0.998	irs	1.000	-	0.993	drs
U31	0.797	drs	0.804	drs	0.875	drs	0.782	drs	0.807	drs	0.842	drs	0.877	drs
U32	0.968	irs	0.991	drs	0.793	irs	0.997	drs	0.988	drs	0.995	drs	0.992	drs
U33	0.694	irs	0.795	irs	0.825	irs	0.800	irs	0.824	irs	0.805	irs	0.682	irs
U34	0.978	drs	1.000	-	0.691	drs	0.674	drs	0.922	drs	0.708	drs	0.867	drs
U35	0.958	drs	0.997	drs	0.994	drs	0.998	irs	0.990	irs	0.963	drs	0.997	drs
U36	0.957	drs	0.878	drs	0.914	drs	0.901	drs	1.000	-	0.858	drs	0.989	drs
U37	0.936	drs	0.952	drs	0.961	drs	0.948	drs	0.999	drs	0.871	drs	1.000	-
U38	1.000	-	1.000	-	1.000	-	1.000	-	0.974	irs	0.927	irs	0.917	irs
U39	0.858	drs	0.769	drs	0.783	drs	0.809	drs	0.890	drs	0.746	drs	0.876	drs
U40	0.906	drs	0.886	drs	0.876	drs	0.884	drs	0.924	drs	0.940	drs	0.978	drs
U41	0.895	drs	0.927	drs	0.939	drs	0.941	drs	0.971	drs	0.868	drs	0.978	drs
U42	1.000	-	1.000	-	0.994	irs	0.984	irs	1.000	-	1.000	-	1.000	-
U43	0.937	drs	0.982	drs	0.995	drs	0.998	irs	1.000	-	1.000	-	0.998	drs
U44	0.994	irs	1.000	-	0.499	irs	0.913	drs	0.989	irs	0.999	-	0.984	irs
U45	0.216	irs	0.272	irs	0.294	irs	0.267	irs	0.301	irs	0.291	irs	0.302	irs
U46	0.878	drs	0.892	drs	0.891	drs	0.898	drs	0.853	drs	0.862	drs	0.894	drs
U47	0.994	drs	0.993	drs	0.998	drs	0.998	drs	0.996	irs	0.999	irs	0.997	drs
U48	0.999	irs	0.938	drs	0.987	irs	0.963	drs	0.926	drs	0.907	drs	0.915	drs
U49	0.957	drs	0.728	irs	0.590	irs	0.842	drs	0.989	irs	0.923	drs	0.966	irs
mean	0.862		0.850		0.844		0.847		0.876		0.844		0.875	

Source: Authors' estimations

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.