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The application of the performance-based budget allocation mechanism to the higher education system in Vietnam

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ABSTRACT: *In Vietnam, the state budget is the main source of funding for the operation of public higher education institutions. With a limited state budget that is divided among many equally important spending purposes, the portion of the state budget devoted to higher education needed to be more modest. This makes it even more important to manage this scarce resource effectively. This paper addresses the performance-based allocation of state budgets for higher education. It employs a non-parametric method of evaluating relative efficiency using the two-stage data envelopment analysis CCR model under constant returns to scale to evaluate universities' performance. The estimation results on a sample of 29 universities under the Ministry of Education and Training management for the academic year 2019-2020 show that the effective universities belonged to all single-disciplinary ones. Management was an important factor leading to the difference in efficiency scores between universities under study.*

KEYWORDS: **Higher education sector, state budget allocation, data envelopment analysis.**
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1. Introduction

Investment in education is a long-term and sustainable investment of individuals and society. Education equips individuals with knowledge and skills, contributing to increased productivity and income. Becker (1993) argues that investment in education increases productive wages or produces effects on earnings. For society, education plays a role in increasing human capital, an important determinant of economic growth (Aghion & Howitt, 1998; Lucas, 1988; Romer, 1990; Mankiw et al.,1992). In the context of globalization and the development of the knowledge-based economy, higher education is the level that plays a key role in providing high-quality human resources to the economy.

In the past, in most countries, higher education was an 'elite' level of training, available only to a small group of a country's population. Today, higher education has become a 'universal' level of training, so its scale is expanding very rapidly, and training types are very diverse, leading to a huge need for financial resources to fund this level of education.

The process of expansion and development has brought this sector many challenges, especially in terms of financial investment. First, the level of investment from the public sector in education in 2020 was only about 5% of the GDP, of which priority was given to general education and only 0.33% for higher education. Vietnam was considered an exception with a very low level of public expenditure per GDP on higher education among the Association of South East Asian Nations countries (compared to 0.57% in Indonesia, 0.64% in Thailand, 1.0% in Singapore, and 1.13% in Malaysia) and the highest degree of tuition dependency in the region (Vinh, 2022; World Bank, 2020). This level of investment needs to catch up with the need to develop high-quality human resources for the knowledge-based economy in the context of globalization and international integration. Second, the allocation of investments from the state budget has followed the same pattern, based on the capacity of the state budget, the average calculation method and traditional input-based norms (the number of students, the number of employees, history of state budget allocation in previous years) but not associated with quality and outcome criteria. Third, implementing state budget allocation to public higher education institutions has involved different governing bodies (ministries, government agencies, and provincial People's Committees). This leads to the absence of a principle of uniform and fair allocation among the beneficiaries of the state budget. Fourth, in addition to the state budget, the government has encouraged higher education institutions to diversify their investment sources through mobilizing sources from the private sector and revenues from production, business and service provision activities of higher education institutions. In fact, non-budget funding sources for this sector were very limited and unsustainable. Out of total non-budget resources, tuition fees from learners played the most important role, while revenues from activities that generate income for higher education institutions were insignificant (World Bank, 2020).

As of 2020, Vietnam had 237 universities and institutes, of which 170 are public, accounting for about 72%. The state budget was the main funding source for public universities' operations. Over the past several decades, the government has allocated funding for recurrent expenditure to universities through block grants based on historical criteria unrelated directly to the actual number of students or performance criteria. With a limited budget, the government has allowed institutions to diversify financial resources for their activities. However, scholarship and need-based loan programs have had low coverage, low loan limits, and unattractive repayment terms for borrowers. To ensure sustainable financing, Vietnam was recommended to increase the state budget level while increasing the mobilization of resources from the private sector. At the same time, Vietnam was recommended to apply the principles of resource allocation according to international practices, such as ensuring efficiency and equity, objectivity and transparency, long-term financial stability and result-based allocation. The budget allocation for recurrent expenditure, research and investment activities should follow a performance-based approach (World Bank, 2020).

To the author's knowledge, up to the time of this study, the literature on the mechanism of state budget allocation for higher education in Vietnam still needed improvement. Most studies described the actual situation using descriptive statistical methods, and only a few used cost-effectiveness analysis methods. This paper addresses the issue of performance-based allocation of state budgets for higher education in Vietnam. In particular, this study applies the data envelopment analysis (hereinafter referred to as DEA), a non-parametric method, to assess the relative efficiency of universities. The results of this analysis are expected to provide useful policy implications for managers and users of the state budget in the higher education sector.

The rest of this paper is organized as follows. Section 2 reviews the existing literature. Section 3 presents the methodology and data sources, followed by section 4, which discusses the results of the empirical analysis. Finally, section 5 concludes and reveals some policy implications.

2. Literature review

The outcome-based university funding has been widely adopted in many countries in recent decades. Most studies asserted that this allocation mechanism enhanced productivity and quality of higher education by tying institutions' performance with managers' accountability. Reddy et al. (2016) investigated the impact and implications of performance-based funding models in the United States that seek greater accountability in higher education and tie state financial support directly to institutional performance. The authors concluded that the performance-based funding model grabbed institutions' attention and led them to change their policies and practices. At the same time, for this funding model to work properly and effectively, performance evaluation must be based on a set of appropriate performance indicators and measured better tailored to institutional missions. There have been numerous studies on outcome-based budgeting for higher education, such as Albright (1998), Anderes (1995), Crowder & Janosik (2001), Layzell (1999), Pratolo et al. (2020), and others.

The performance of higher education institutions is generally measured by teaching outputs (graduates) and research and development outputs (publications). Studies on this topic often used the relative efficiency assessment method, DEA. Taylor and Harris (2004) examined the relative efficiency of South African universities using DEA. A series of seven models were run. A combination of the annual output of graduates and research as the output variable was tested against various input variables, including financial and non-financial inputs. Sexton et al. (2012) proposed an efficiency-based mechanism for state funding of public colleges and universities using DEA. They concluded that this funding mechanism was viable and provided incentives to institution administrators to eliminate wasteful spending and increase positive outcomes while maintaining educational quality and research productivity. Kauffmann et al. (2000) proposed a model for allocating resources to research programs that considered research quality and productivity criteria. The model developed a two-axis evaluation space for research alternatives by integrating quality function deployment and DEA. Using these two decision-making tools simultaneously allowed a program manager to compare and prioritize alternative research investments.

Up to the time of this study, there has been no research on the issue of outcome-based funding for higher education institutions in Vietnam using DEA. As recommended by the World Bank, Vietnam should apply a combination of the funding formula and performance contracts for recurrent activities and competitive funds for investment activities (World Bank, 2020).

3. Methodology

3.1. DEA framework

DEA was developed based on the seminar paper by Farrell (1957) and first introduced by Charnes et al. (1978) as a method to measure relative efficiency between like organizations. They measured efficiency in the form of a ratio called the CCR ratio, which generalizes the classical engineering science ratio definition of single output and single input to multiple outputs and inputs without requiring pre-assigned weights. The efficiency of a decision-making unit (hereinafter referred to as *DMU*) is measured in relation to the other observed *DMU*s. All observed *DMU*s make up a region called a production possibility set which is enveloped by the line connecting efficient *DMU*s. It means that all efficient *DMU*s' positions represent the efficient frontier, below which lie inefficient *DMU*s.

This definition is expressed in the following fractional model:

$$\max f_o = \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}} \qquad (3.1)$$

subject to

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1, \quad i = 1,\dots,m;\ j = 1,\dots,n;\ r = 1,\dots,s.$$

$$u_r, v_i > 0.$$

where y_{rj}, x_{ij} (> 0) represent output and input data for DMU_j with the ranges for i and r. The objective is to obtain weights v_i and u_r that maximize the ratio of the evaluated DMU_o (θ^*). We can rewrite the model in the linear programming form as follows:

$$\max_{v,u} \qquad \theta = \sum_{r=1}^{s} u_r y_{r0} \qquad (3.2)$$

subject to

$$\sum_{i=1}^{m} v_i x_{i0} = 1$$

$$-\sum_{i=1}^{m} v_i x_{ij} + \sum_{r=1}^{s} u_r y_{rj} \le 0$$

$$v_i \ge 0,\ u_r \ge 0.$$

The CCR-type models, under "weak efficiency" (or Farrell efficiency), evaluate the radial (proportional) efficiency θ^* but do not take account of the input excesses and output shortfalls. Under the CCR-efficiency, which adds the Pareto-Koopmans efficiency conditions, a *DMU* is called CCR-efficient if it satisfies both conditions: $\theta^*= 1$ and all slacks are zero. It should be noted that "weak efficiency" satisfies the condition $\theta^* = 1$; "strong efficiency" satisfies two conditions: $\theta^* = 1$ and all slacks are zero (Cooper et al., 2007).

In reality, efficiency in relation to productivity can be interpreted differently. Efficiency can be considered as an attempt to minimize inputs while producing at least the given output levels, or in another way; efficiency involves maximizing outputs while using no more than the given inputs (Cooper et al., 2007). The former is an input-oriented approach, and the latter is an output-oriented one. In this study, the state budget input is a fixed amount because this is actually a limited source, and it is not easy to flexibly adjust the budget allocation structure of a sector. So, given the allocated state budget, each *DMU* will maximize its outputs to achieve efficiency. In such a setting, the study employs the output-oriented CCR model to measure the relative efficiency of all observed *DMU*s. The model is written in the dual linear programming form as follows:

$$\max_{\delta,\mu} \quad \delta \qquad (3.3)$$

subject to

$$x_{i0} - \sum_{j=1}^{n} x_{ij}\mu_j \geq 0$$

$$\delta y_{r0} - \sum_{j=1}^{n} y_{rj}\mu_j \leq 0$$

$$\mu_j \geq 0.$$

where δ is a scalar (satisfying $\delta \geq 1$) that measures the observed *DMU*'s technical efficiency or the geometrical distance of its position to the efficiency frontier. If $\delta > 1$, the *DMU* is inside the frontier or inefficient. If $\delta = 1$, the *DMU* lies on the frontier or is efficient. μ, a vector of constants, measures the weights to project inefficient *DMU*s on the frontier.

As mentioned above, the CCR models do not take into account non-radial non-zero slacks, while the slack-based models (SBM) proposed by Tone (2001) do. According to him, a *DMU* is CCR-efficient if and only if it is SBM-efficient. Based on this relationship between CCR-efficiency and SBM-efficiency, the study will also use the output-oriented SBM model to have a deeper look into the status of *DMU*s when identifying their non-radial non-zero slacks. The output-oriented SBM model is written as follows:

$$\rho_0^* = \min_{\lambda, s^+} \frac{1}{1 + \frac{1}{s}\sum_{r=1}^{s} s_r^+ / y_{r0}} \qquad (3.4)$$

subject to

$$x_0 \geq X\lambda$$

$$y_0 = Y\lambda - s^+$$

$$\lambda \geq 0, \ s^+ \geq 0.$$

In the formula (3.4), ρ^* is the efficiency score of the observed *DMU*. s_r^+ is the output shortfall. It should be noted that ρ^* in (3.4) is never greater than δ^* in (3.3) because (3.4) includes output slacks.

3.2. The method of compensating for non-homogeneity

DEA is used to measure the relative efficiency among homogeneous *DMU*s in terms of the nature of the operations they perform, the measures of their efficiency, and the conditions under which they operate (Haas & Murphy, 2003). In this study, all *DMU*s are engaged in the same process of operations: teaching and research. The same measures of efficiency (defined by the selected inputs and outputs in the DEA models) are applied equally to all *DMU*s. However, the *DMU*s under study are not homogeneous in terms of operating conditions. Specifically, they are of different scales (sizes) and their operating fields are diversified. To compensate for such different operating conditions, one possibility is to group *DMU*s by homogeneous characteristics, or another possibility is to use regression models to adjust for non-homogeneity. For this study, the former is not feasible because of some reasons. First, the number of selected universities is small. Second, the number of multi-disciplinary (or comprehensive) universities is not small among the selected universities. Hence, the classification by fields of specialization is very difficult. This study, therefore, uses the two-stage method introduced by Sexton et al. (1994) to adjust for non-homogeneity. The results of the output-oriented CCR model are used as a baseline in the comparison. The process is performed in the following steps:

First, it runs the output-oriented CCR model using raw data to identify a set of efficiency scores for all *DMU*s in the evaluation field.

Second, it runs a regression analysis on the set of efficiency scores obtained in the previous step using a set of the so-called ‘site characteristics’, which are assumed to account for differences in efficiency not attributable to management and can be considered as environmental variables (Haas & Murphy, 2003). The following regression is performed using Eviews software:

Expected efficiency score = *Intercept* + *Field* + *Field*Size* (3.5)

In this case, the scale and field of operation of the *DMU*s are seen as site characteristics. Since training is a fundamental and mainstream activity of all universities regardless of size, the scale is calculated based on the real numeric value of the collected data on the number of graduates, which are weighted by training levels. It can be understood that the higher the graduate level, the more training resources are required. Thereby, doctoral graduates are assigned with 1, master graduates with 0.666, and bachelor graduates with 0.333 (George et al., 2012; Oanh & Ngoc, 2016). The field of operation is categorized by “specialized university”, to which is assigned value ‘0’, and “comprehensive university”, to which is assigned value ‘1’.

Third, it adjusts all outputs to consider the ‘site characteristics’. Then, it runs the output-oriented CCR model for the second time using the original input and the adjusted outputs. This step produces a new set of efficiency scores based on the adjusted output data, which are derived by multiplying the level of each output by the ratio of the unadjusted efficiency score to its expected efficiency score (Haas & Murphy, 2003).

“*If the regression is a perfect fit, that is, all differences in efficiency are attributable to differences in the identified operating conditions, then a second DEA iteration places all DMUs on the efficiency frontier. This property shows that the regressions do not distort the results in a limiting case. If the regressions are not a perfect fit, any differences among DMU efficiency scores produced by a second DEA iteration are attributed to management ...*

Theorem (SST). *If the regression model relating site characteristics to the unadjusted efficiency score is a perfect fit, then every DMU will have an adjusted efficiency score equal to one*” (Haas & Murphy, 2003).

Fourth, it indicates possibilities for inefficient *DMU*s to improve to efficient positions by adjusting their output levels. To do this using DEAP2.1 software, it needs to run the output-oriented slack-based model (O_SBM) under CRS. However, using the Vietnamese DEA version 3.0, it was still able to do this without having to run the O_SBM model.

3.3. Data

To illustrate an outcome-based approach to allocating financial resources to higher education institutions, the study conducts a simulation of the cost-effectiveness assessment based on the dataset of a group of 29 universities in Vietnam. Up to the time of the study, although Vietnam’s higher education system consisted of 237 universities, including 172 public universities and 65 private universities, the management was fragmented by various ministries or People’s Committees of provinces/cities. To collect appropriate and consistent data for the study, only universities under the Ministry of Education and Training management, according to decision No. 960/QĐ-TTg dated August 6, 2018 were selected. The data was collected from the “three publicly reported issues” column on the universities’ websites for the 2019-2020 academic year. Among 35 universities under the Ministry of Education and Training, 6 universities/institutions were excluded from the sample due to insufficient or inconsistent information. Each is treated as a *DMU* (see Table 1). This dataset consists of one input and ten output variables. The single input variable is the budget allocated to each university. Output variables are classified by teaching and research activities. Teaching outputs consist of the number of graduates from undergraduate, master and doctoral training programs. Research outputs generated from the state budget are measured

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Table 1: Input and output data of the selected universities

University	DMU	(I)State budget (billion VND)	(O)Bachelor	(O)Master	(O)Doctor	(O)Sponsored projects of university level	(O)Sponsored projects of ministerial level	(O)Sponsored projects of national level	(O)Paper in domestic and international journals	(O)Journal paper in WoS/ Scopus	(O)Journal paper in ISI, SCI, SCIE	(O)Grants for journal papers in ISI, SCI, SCIE (million VND)
Da Nang University	*DMU*1	36.340	5772	1345	11	156	17	2	934	154	310	960
Hue University	*DMU*2	162.684	7501	337	103	345	49	6	0	833	321	976
Thai Nguyen University	*DMU*3	199.844	3515	766	92	253	62	8	0	136	236	722
Hanoi University of Science and Technology	*DMU*4	29.830	3862	1038	68	136	40	41	581	461	491	1476
Can Tho University	*DMU*5	421.601	6954	667	31	110	12	5	465	216	213	680
Da Lat University	*DMU*6	59.512	1186	170	29	45	2	0	250	40	39	121
Dong Thap University	*DMU*7	71.620	2159	199	0	40	13	3	332	104	85	257
University of Transport and Communication	*DMU*8	55.880	1729	230	4	0	10	0	102	55	80	247
Hanoi University	*DMU*9	93.050	1659	3	47	42	2	1	4	0	0	0
Kien Giang University	*DMU*10	21.546	740	0	0	30	1	0	0	0	6	15
National Economics University	*DMU*11	16.00	3840	962	106	80	12	20	113	268	101	250
University of Economics Ho Chi Minh City	*DMU*12	4.000	3121	1067	20	12	5	2	0	160	224	667
University of Law Ho Chi Minh City	*DMU*13	1.900	1431	265	6	12	4	2	75	0	3	10
Hanoi University of Mining and Geology	*DMU*14	42.473	1500	514	8	38	13	11	295	63	152	438
Hanoi Open University	*DMU*15	3.018	1513	404	1	23	3	1	0	0	5	13
Ho Chi Minh City Open University	DMU16	3.600	1480	194	3	90	17	10	72	31	220	550
Foreign Trade University	*DMU*17	9.332	1793	303	8	42	38	14	0	20	1	28
Nha Trang University	*DMU*18	23.826	1876	49	0	0	5	1	16	0	47	137
Quy Nhon University	*DMU*19	65.420	2027	115	4	0	10	15	0	75	47	148
Hanoi National University of Education	*DMU*20	170.000	1380	491	3	19	12	27	233	143	103	315
Hanoi Pedagogical University 2	*DMU*21	100.176	1768	170	15	22	3	1	321	0	155	461
Hung Yen University of Technology and Education	*DMU*22	31.000	1528	48	0	17	2	2	0	30	38	117
Ho Chi Minh City University of Technology and Education	*DMU*23	37.815	1782	73	16	66	5	0	0	112	41	123
Ho Chi Minh City University of Education	*DMU*24	58.777	3037	312	12	0	5	0	177	0	141	420
Tay Bac University	*DMU*25	53.345	987	97	0	0	11	0	205	10	129	380
Tay Nguyen University	*DMU*26	69.119	1427	116	5	40	23	0	50	0	18	51
Thuongmai University	*DMU*27	3.630	5750	634	5	42	10	0	0	51	39	123
Vinh University	*DMU*28	110.000	2507	676	21	0	5	0	161	59	14	45
Hanoi University of Civil Engineering and Construction	*DMU*29	68.000	1905	187	13	37	64	16	80	0	113	306

Source: Compiled by the author from the report "The three publicly reported issues for the academic year 2019-2020" on universities' websites.

Table 2. Correlations among outputs

	Bachelor	Master	Doctor	Sponsored projects of university level	Sponsored Projects of Ministerial level	Sponsored projects of national level	Paper in other international and domestic journals	Paper in WoS/ Scopus	Paper in ISI, SCI, SCIE	Grants for papers in ISI, SCI, SCIE (million VND)
Bachelor	1	0.53531	0.601189	0.599587	0.350028	0.577107	0.704036	0.321464	0.089657	0.686112
Master	0.53531	1	0.489486	0.414769	0.011457	0.490774	0.725831	0.489558	0.358574	0.750193
Doctor	0.601189	0.489486	1	0.6257	0.595484	0.997154	0.690527	0.47879	0.483995	0.657131
Sponsored projects of university level	0.599587	0.414769	0.6257	1	0.556133	0.615588	0.398136	0.214031	0.363255	0.364506
Sponsored projects of ministerial level	0.350028	0.011457	0.595484	0.556133	1	0.577965	0.184223	0.011615	0.245015	0.175334
Sponsored projects of national level	0.577107	0.490774	0.997154	0.615588	0.577965	1	0.680674	0.479339	0.497273	0.648814
Paper in other international and domestic journals	0.704036	0.725831	0.690527	0.398136	0.184223	0.680674	1	0.438325	0.404517	0.792697
Paper in WoS/ Scopus	0.321464	0.489558	0.47879	0.214031	0.011615	0.479339	0.438325	1	0.464873	0.64828
Paper in ISI, SCI, SCIE	0.089657	0.358574	0.483995	0.363255	0.245015	0.497273	0.404517	0.464873	1	0.206781
Grants for papers in ISI, SCI, SCIE	0.686112	0.750193	0.657131	0.364506	0.175334	0.648814	0.792697	0.64828	0.206781	1

Table 3. Descriptive statistics: Input and Outputs

	State budget (billion VND)	Bachelor	Master	Doctor	Sponsored project of university level	Sponsored project of ministerial level	Sponsored project of national level	Paper in other international and domestic journals	Paper in WoS/Scopus	Paper in ISI, SCI, SCIE	Grants for papers in ISI, SCI, SCIE (million VND)
Mean	66.9	58.517	6.483	15.690	104.172	116.276	154.069	394.207	346.069	21.759	2,611
Median	42.5	38	2	10	51	85	75	265	250	8	1,793
Maximum	422	345	41	64	833	491	934	1345	1476	106	7,501
Minimum	1.9	0	0	1	0	0	0	0	0	0	740
Std. Dev.	85.6	78.763	9.716	17.644	173.665	117.991	215.345	360.797	354.735	31.188	1,790
Obs	29	29	29	29	29	29	29	29	29	29	29

by the number of research projects of the state (and the National Foundation for Science and Technology), ministerial, and university levels, the number of papers published in domestic and international journals (in the list of WoS/Scopus, ISI, SCI, SCIE), and grants for journal papers in ISI, SCI, SCIE.

As can be seen from Table 2, there is a relatively high correlation among the ten outputs. Table 3 illustrates the descriptive statistics for the input and outputs employed in the study. Notably, the standard deviations are significantly high for all variables, implying considerable differences among the *DMU*s.

4. Results

The study used the output-oriented CCR model to measure the cost-efficiency of 29 *DMU*s in the academic year 2019-2020. It should be noted that in DEA, ‘efficiency’ is understood in relative terms, i.e., a *DMU*, which is the best practice unit among evaluated units, is considered an efficient one. This best practice unit may not be the best practice in absolute terms.

The estimation results on the collected data shown in Table 4 indicate that there were 5 efficient *DMU*s. These *DMU*s had efficiency scores of 1 and made up the efficiency frontier. Among the 5 efficient *DMU*s, there were 4 single-disciplinary *DMU*s, and the remaining was a small multi-disciplinary one. With the collected data, the biggest multi-disciplinary *DMU*s belonged to the group with low efficiency. The average efficiency score of all evaluated *DMU*s was rather low (0.384). It is noted that the gaps in efficiency scores of *DMU*s were very large because there were 19 *DMU*s with efficiency scores below the average performers.

Table 4. Results of the output-oriented CCR model under constant returns to scale using the collected data

DMU	Score	Rank	1/Score	Reference set (DMU)
*DMU*1	0.770	9	1.299	12, 13, 16
*DMU*2	0.185	13	5.405	11, 12, 16
*DMU*3	0.118	18	8.457	11, 16
*DMU*4	0.966	6	1.035	12, 13, 16
*DMU*5	0.041	29	24.181	12, 13, 16
*DMU*6	0.130	15	7.690	11, 12, 13
*DMU*7	0.154	14	6.505	12, 13
*DMU*8	0.075	22	13.329	12, 13, 16
*DMU*9	0.788	8	1.270	11, 16
*DMU*10	0.060	26	16.637	16, 27
*DMU*11	1.000	1	1.000	11
*DMU*12	1.000	1	1.000	12
*DMU*13	1.000	1	1.000	13
*DMU*14	0.222	11	4.504	12, 13, 16
*DMU*15	0.703	10	1.422	12, 16, 27
*DMU*16	1.000	1	1.000	16
*DMU*17	0.880	7	1.136	11, 16
*DMU*18	0.072	23	13.864	13, 16, 27
*DMU*19	0.092	21	10.889	12, 16
*DMU*20	0.070	25	14.226	12, 13, 16
*DMU*21	0.095	20	10.538	13. 16
*DMU*22	0.053	27	18.817	12, 16, 27
*DMU*23	0.130	15	7.693	13, 16
*DMU*24	0.098	19	10.157	13, 16
*DMU*25	0.119	17	8.398	13, 16
*DMU*26	0.072	23	13.844	11, 16
*DMU*27	1.000	1	1.000	27
*DMU*28	0.051	28	19.541	11, 12, 13
*DMU*29	0.203	12	4.937	11, 16

As mentioned above, all *DMU*s are engaged in the same process of operations (teaching and research), but they are not homogeneous in terms of operating conditions. Thus, in order to evaluate the influence of non-homogeneity factors on the efficiency scores of the *DMU*s, the study carried out a regression analysis on the DEA efficiency scores obtained from the previous step. The regression results show that at the significance level of 0.05, the R^2 value was quite small (0.0634). That means the regression results did not prove goodness of fit. In this case, we can conclude that the differences in efficiency scores among the *DMU*s, produced by the second DEA iteration, were not attributable to the site characteristics but to management (Sexton et al., 2012). In this study, the hypothetical site characteristics include the size and field of operation of the *DMU*s. In reality, the *DMU*s in the sample differ in geographical location, mission, vision, operating principles, budget management and expenditures. This reveals an important implication that if a competent administrator can identify substantial heterogeneities as site characteristics to include in the model, the more accurate the obtained performance scores will be. It should be noted that this will only be possible if the required data are available and/or transparent enough.

In the next step, all ten outputs were adjusted by multiplying each output level of each *DMU* by the ratio of the *DMU*'s unadjusted efficiency score to its expected efficiency score. The new data sets with the original input and the adjusted outputs are presented in Table 5.

The results of estimation on the adjusted data using the output-oriented CCR model under constant returns to scale are shown in Table 6. The results show that 14 *DMU*s were CCR-efficient. Interestingly, all the efficient *DMU*s were single-disciplinary, except for one small-scale multi-disciplinary. Positioned nearest the efficiency frontier were large-scale multi-disciplinary *DMU*s. The least efficient group belonged to the small-scale multi-disciplinary *DMU*s. It should be noted that all differences in efficiency scores of the *DMU*s here were attributable to management factors. We can see the differences in the efficiency scores as well as the ranks of the *DMU*s between the first round DEA and the

Table 5. New data set with original input and adjusted output data

DMU	(I)State budget (billion VND)	(O)Bachelor	(O)Master	(O)Doctor	(O)Sponsored projects of university level	(O)Sponsored projects of ministerial level	(O)Sponsored projects of national level	(O)Paper in domestic and international journals	(O)Journal paper in WoS/Scopus	(O)Journal paper in ISI, SCI, SCIE	Grants for journal papers in ISI, SCI, SCIE (million VND)
*DMU*1	36.340	5772	1345	11	156	17	2	934	154	310	960
*DMU*2	162.684	7501	337	103	345	49	6	0	833	321	976
*DMU*3	199.844	3515	766	92	253	62	8	0	136	236	722
*DMU*4	29.830	3862	1038	68	136	40	41	581	461	491	1476
*DMU*5	421.601	6954	667	31	110	12	5	465	216	213	680
*DMU*6	59.512	1186	170	29	45	2	0	250	40	39	121
*DMU*7	71.620	2159	199	0	40	13	3	332	104	85	257
*DMU*8	55.880	1729	230	4	0	10	0	102	55	80	247
*DMU*9	93.050	1659	3	47	42	2	1	4	0	0	0
*DMU*10	21.546	740	0	0	30	1	0	0	0	6	15
*DMU*11	16.00	3840	962	106	80	12	20	113	268	101	250
*DMU*12	4.000	3121	1067	20	12	5	2	0	160	224	667
*DMU*13	1.900	1431	265	6	12	4	2	75	0	3	10
*DMU*14	42.473	1500	514	8	38	13	11	295	63	152	438
*DMU*15	3.018	1513	404	1	23	3	1	0	0	5	13
*DMU*16	3.600	1480	194	3	90	17	10	72	31	220	550
*DMU*17	9.332	1793	303	8	42	38	14	0	20	1	28
*DMU*18	23.826	1876	49	0	0	5	1	16	0	47	137
*DMU*19	65.420	2027	115	4	0	10	15	0	75	47	148
*DMU*20	170.000	1380	491	3	19	12	27	233	143	103	315
*DMU*21	100.176	1768	170	15	22	3	1	321	0	155	461
*DMU*22	31.000	1528	48	0	17	2	2	0	30	38	117
*DMU*23	37.815	1782	73	16	66	5	0	0	112	41	123
*DMU*24	58.777	3037	312	12	0	5	0	177	0	141	420
*DMU*25	53.345	987	97	0	0	11	0	205	10	129	380
*DMU*26	69.119	1427	116	5	40	23	0	50	0	18	51
*DMU*27	3.630	5750	634	5	42	10	0	0	51	39	123
*DMU*28	110.000	2507	676	21	0	5	0	161	59	14	45
*DMU*29	68.000	1905	187	13	37	64	16	80	0	113	306

second one. The second DEA iteration indicates that the average efficiency score of all evaluated *DMU*s was improved significantly (0.853). It is worth noting that the gaps in efficiency scores of *DMU*s were narrowed greatly, and the number of *DMU*s with efficiency scores lower than the average *DMU* also decreased to only 12 *DMU*s.

The results in the output-oriented CCR model also suggest that the less efficient *DMU*s could technically (proportionally) adjust their outputs to reach the efficiency frontier at their respective output enlargement rates. These rates reflected the radial distances from them to the efficiency frontier. In other words, they were calculated based on relative comparison of the efficiency scores between them and the *DMU*s on the efficiency frontier and closest to them. The column "1/Score" presents the technical output enlargement rates of less efficient *DMU*s, and the column "Reference set" indicates the efficient *DMU*s which are the best references for the less efficient *DMU*s evaluated. Therefore, 15 less efficient *DMU*s could project themselves to the frontier by proportionally adjusting their outputs at the indicated enlargement rates. For example, if *DMU*1 wanted to be fully efficient, it would have to proportionally increase its outputs at the rate of 1.111 regarding *DMU*12, *DMU*13, *DMU*16 and *DMU*21, the four efficient *DMU*s and nearest to it. This approach demonstrates the importance of selecting *DMU*s with as similar characteristics as possible for altering the shape of the efficient frontier and thus determining a suitable reference set. In other words, the efficiency scores in DEA are sensitive to sample size and data errors (Salerno, 2003).

The Vietnamese DEA add-in for Excel version 3.0 allows us to see slacks of input(s) and/or output(s) of less efficient *DMU*s. The output-oriented CCR model under constant returns to scale suggests that for less efficient *DMU*s to become efficient, they have to maximize the outputs while keeping the input unchanged. In table 4, the input slack is denoted by $s^-(1)$ and always has zero value as the input is kept unchanged in the output-oriented models. The output slacks are denoted by $s^+(1)$ to $s^+(10)$, respectively. Thus, given the allocated state budget, *DMU*1, for example, in order to be fully efficient, would produce 35,127 bachelors, 7,070 masters, and 185 doctors more, need 18 ministerial-level projects, 12 university-level projects, and 6 journal articles in ISI, SCI, and SCIE. As we can see, all 15 *DMU*s evaluated

Table 6. Results of the output-oriented CCR model (under CRS) using the adjusted data

DMU	Score	Rank	1/Score	Reference set (DMU)	$s^-(1)$	$s^+(1)$	$s^+(2)$	$s^+(3)$	$s^+(4)$	$s^+(5)$	$s^+(6)$	$s^+(7)$	$s^+(8)$	$s^+(9)$	$s^+(10)$
*DMU*1	0.900	17	1.111	12, 13, 16, 21	0.000	35,127	7,071	185	0	18	12	0	0	6	0
*DMU*2	0.983	15	1.017	12, 16, 23, 27	0.000	180,284	36,169	514	0	0	0	27	0	940	2,749
*DMU*3	0.652	22	1.533	16, 17, 27	0.000	234,319	28,869	353	0	0	51	421	0	753	1,626
*DMU*4	0.832	18	1.202	11, 12, 13, 16	0.000	13,354	3,021	0	0	1	0	0	3	5	0
*DMU*5	0.905	16	1.106	12, 13, 23	0.225	556,918	127,712	2,685	0	202	97	0	0	695	1,678
*DMU*6	0.502	29	1.992	12, 13, 23	0.000	46,129	9,510	194	0	24	14	0	0	44	128
*DMU*7	0.574	26	1.741	12, 13	0.002	64,897	14,645	313	37	14	13	0	0	130	390
*DMU*8	1.000	1	1	8	0.000	0	0	0	0	0	0	0	0	0	0
*DMU*9	0.771	21	1.298	11, 16	0.000	3,165	1,082	0	0	3	4	25	45	47	118
*DMU*10	0.823	19	1.214	16	0.005	28,474	3,758	58	0	18	13	90	39	253	633
*DMU*11	1.000	1	1	11	0.000	0	0	0	0	0	0	0	0	0	0
*DMU*12	1.000	1	1	12	0.000	0	0	0	0	0	0	0	0	0	0
*DMU*13	1.000	1	1	13	0.000	0	0	0	0	0	0	0	0	0	0
*DMU*14	1.000	1	1	14	0.000	0	0	0	0	0	0	0	0	0	0
*DMU*15	0.789	20	1.267	12, 16, 27	0.000	1,808	0	13	0	1	0	1	29	36	106
*DMU*16	1.000	1	1	16	0.000	0	0	0	0	0	0	0	0	0	0
*DMU*17	1.000	1	1	17	0.000	0	0	0	0	0	0	0	0	0	0
*DMU*18	0.547	27	1.828	8, 12, 16, 29	0.005	7,755	2,396	45	19	0	1	0	95	0	0
*DMU*19	0.640	23	1.564	12, 17, 20	0.000	1,516	399	9	40	0	0	336	0	19	52
*DMU*20	1.000	1	1	20	0.000	0	0	0	0	0	0	0	0	0	0
*DMU*21	1.000	1	1	21	0.000	0	0	0	0	0	0	0	0	0	0
*DMU*22	1.000	1	1	22	0.000	0	0	0	0	0	0	0	0	0	0
*DMU*23	1.000	1	1	23	0.000	0	0	0	0	0	0	0	0	0	0
*DMU*24	1.000	1	1	24	0.000	0	0	0	0	0	0	0	0	0	0
*DMU*25	0.543	28	1.843	8, 13, 24	0.000	7,259	1,372	32	14	0	2	0	43	0	20
*DMU*26	0.630	25	1.587	13, 16, 17	0.000	33,323	5,409	117	0	0	32	0	49	58	172
*DMU*27	1.000	1	1	27	0.000	0	0	0	0	0	0	0	0	0	0
*DMU*28	0.638	24	1.569	12, 13	0.000	112,445	25,608	538	180	32	30	0	0	448	1,327
*DMU*29	1.000	1	1	29	0.000	0	0	0	0	0	0	0	0	0	0

as less efficient are multi-disciplinary *DMU*s. The main reasons derived from the results would probably be that the multi-disciplinary *DMU*s include units of basic sciences (such as mathematics, physics, etc.) that normally have lower enrolment levels. Moreover, it is, in reality, more difficult to produce as many research products in the fields of basic sciences as in the applied sciences. The results obtained from the model provide a more comprehensive and objective view of the performance of each *DMU* as well as all assessed *DMU*s. The model is therefore useful in assisting institution administrators in reducing wasteful expenditures and improving operational outcomes.

5. Conclusions

In today's modern, knowledge-based economy, there is a growing demand for high-quality human resources. Higher education is the level of education that produces such resources, and universities are responsible for this crucial task. Therefore, investing in higher education is both necessary and essential. From an economic perspective, education is partly a private good, but it is also a social commodity that benefits not only individuals but also society as a whole. Higher education is therefore viewed as a partnership between individuals seeking personal advancement and the government working for the greater good of society. In most countries, governments play a dominant role in investing in higher education due to its positive externalities on society and economic development. However, for developing countries like Vietnam, which have limited budgets and many equally important spending priorities, the allocation of resources for general and higher education is insufficient. This fact necessitates the efficient management of these scarce resources, following the principles of economics.

In order to meet the actual need of the economy and society, the output-oriented budget allocation model is currently adequate for Vietnam. That means the allocation of the state budget will be based on universities' performance, representing socio-economic development priorities. These priorities will be indicated by the planned outputs of each university which correspond to the need of the market and overall objectives of the development of society. The outputs will be specified by the number of graduates of all training levels and the number of research products (such as publications, patents, grants, and revenues from businesses and services). In addition, the output indicators also need to reflect the output quality. For teaching output, it is necessary to distinguish graduates between training levels, the percentage of graduates who find jobs suitable to their majors right after graduation, and career advancement. For research output, the distinction should be made in terms of the quality and/or applicability of different research products. The unit costs for training will be calculated based on the output indicator, which is the number of graduates, rather than the input indicator, which is the number of 'quota' students like now. This means universities will decide on enrolment size for themselves. This allocation mechanism helps improve the efficiency of training and research as well as the efficiency of resources in the higher education system.

DEA technique is a good practice that provides a scientific basis for the decision to allocate financial resources to the higher education sector. Applying the two-stage DEA output-based CCR model under constant returns to scale for the sample of 29 universities for the academic year 2019-2020, it found that all the efficient *DMU*s were single-disciplinary and the least efficient group belonged to the multi-disciplinary DMUs. Interestingly, all differences in efficiency scores of the *DMU*s under study were not attributable to the initially hypothesized site characteristics (size and field of operation) but to management factors. This technique allows for an assessment of the effectiveness of the funds allocated to universities and shows how universities can improve their performance scores and thus become cost-effective units. It is obvious that the output-based allocation mechanism has created a competitive ground for universities that makes them to be more aware of the efficiency of financial resources, the quality of training and research, and the need of society. Although it is a good and scientific practice to allocate financial resources to higher education, it has not been widely applied in practice. A fairly similar model has been applied to some school-related activities in several states in the United States. For example, North Carolina successfully applied this model to pupil transportation, and Washing State followed. It should be noted that DEA still has some limitations. First, DEA identifies best practice units among the ones being evaluated. In reality, even the best-performing units may not operate efficiently in absolute terms. Moreover, it is impossible to undertake tests of statistical significance with DEA scores as possible with regression analyses (Abbott & Doucouliagos, 2003). Second, DEA is sensitive to sample size and data errors as outliers in the data may alter the shape of the efficient frontier and distort efficiency scores of units using similar input/output proportions. In addition, as a non-parametric and deterministic approach, it is not possible to deal with random errors in the data (Salerno, 2003). This implies that it would require caution and flexibility when applying this model. Kuah and Wong (2011) and Sexton et al. (2012) agree that there is no single set of defined inputs and outputs in assessing higher education performance. Therefore, it can be a challenge for administrators because the model needs to be built to capture the appropriate inputs, outputs, and site characteristics that best reflect the higher education system and its organizational goals. Last but not least, DEA as well as other quantitative performance evaluation methods, requires a complete and consistent statistical database on the assessed units. To realize this model, our statistical work needs significant improvement.

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