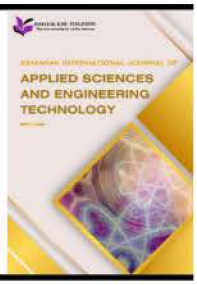
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Efficiency Measurement of a Public University: A Slack-Based Data Envelopment Analysis Approach

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ABSTRACT

Education stands as a pivotal force in today's globalized world, particularly for developing nations that rely on a well-educated populace to foster future economic. In recent year, there has been increasing pressure in measuring the efficiency of public especially considering their vital role in providing accessible and high-quality education with limited resources. Data Envelopment Analysis (DEA) emerges as a powerful mathematical tool for identifying inefficiencies based on the scope of educational services provided. DEA offers insights into resource allocation and utilization within public universities, providing valuable information to university management for alternative efficiency assessment methods. Therefore, this research employs slack-based measure (SBM) DEA approach to evaluate the efficiency of a public university in Malaysia for the year 2020. The finding shows that 11 faculties out of 26 faculties are operating at perfect efficiency with efficiency values of one (1). Additionally, suggestions are proposed for targeted improvement.

1. Introduction

Education stands as a pivotal force in today's globalized world, particularly for developing nations that rely on a well-educated populace to foster future economic [1]. In alignment with the necessity to cultivate a competitive and capable educational system, Malaysian higher education institutions have embarked on significant improvements. These modifications span across policies, goals, and motivations, with a clear aim: to transform Malaysia into a prominent regional education hub. This ambition aligns with the country's broader vision of increased global participation and economic fortitude. To realize this vision, considerable efforts have been directed towards embracing the internationalization and globalization of Malaysian higher education. Such initiatives are not only geared towards attracting international talent but also towards enhancing the quality and visibility of the nation's educational offerings on the world stage. This refinement draws attention to Malaysia's proactive measures in adapting its higher education system to global standards, thereby asserting its commitment to educational excellence and international recognition [2].

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The Malaysian Government displays a resolute commitment to higher education. This commitment is underscored by the substantial annual budget allocation to this sector, which stands among most of the government's total annual budget. Compared to the UNESCO benchmarks, this allocation is among the highest when viewed in the context of prominent Asian nations such as Hong Kong, Singapore, South Korea, and Japan, as well as neighbouring ASEAN countries like Indonesia and Thailand. This strategic financial dedication signifies the government's recognition of the pivotal role of higher education in national development and its determination to foster an environment conducive to academic excellence and international recognition. It also underscores the strategic importance the government places on higher education as a key driver for national progress and competitiveness. The implication is clear: despite remarkable progress, Malaysian public universities continue to face challenges in aligning with rapidly evolving global educational environments. This underscores a pressing need to intensify efforts in efficiency improvement across the public university sector in Malaysia.

The initial step towards enhancing the performance of public universities is a rigorous performance evaluation of their efficiency activities. In prevailing literature, the production of public universities is conceptualized as an intricate process that transforms various inputs into valuable outputs. This transformation process and its performance can be evaluated by an efficiency measurement indicator. The definition of efficiency is maximizing output from minimal inputs [3]. Hence, efficiency becomes a crucial metric to quantify a university's overall performance, facilitating governmental bodies in the judicious allocation of resources and the crafting of policies that bolster desired outputs.

Predominantly, Data Envelopment Analysis (DEA) is employed to assess the efficiency of public universities due to its flexibility in handling multiple and varied input-output datasets [4]. DEA, thus, serves as a comprehensive tool, capable of capturing the multifaceted efficiency dimensions of public universities' operations. The application of DEA transcends conventional fiscal indicators, enabling enhanced managerial decision-making and providing empirical support for informed policy-making in the higher education sector. The majority of efficiency studies in public universities utilizing Data Envelopment Analysis have applied the radial model approach, which assumes proportional changes in inputs and outputs. To address this limitation and provide a more nuanced assessment, a non-radial slack-based measure (SBM) DEA approach is proposed for application within a Malaysian public university context. The non-radial approach of the SBM DEA approach allows for a more detailed analysis as it accommodates non-proportional adjustments in inputs and outputs, thus providing a comprehensive measure of efficiency and potentially revealing additional insights into the areas necessitating improvement.

Based on the above, this paper aims to measure public university efficiency using the Slack-Based Measure (SBM) of Data Envelopment Analysis model. First, the study scrutinizes universities using an efficiency measure derived from SBM to identify areas of input excess and output shortfall within the universities' operational framework. This paper contributes to the related literature by applying a SBM methodological approach to estimate the efficiency of a Malaysian public university and support a better understanding of the factors driving university efficiency. Second, the efficiency of resource utilization and quality of output in producing educational services are analysed through this non-radial approach, allowing for a more nuanced efficiency assessment. Specifically, on a sample of 26 Malaysian faculties is used in this study.

The remainder of this paper is structured as follows. The second section presents a literature review in measuring the efficiency of Public University. The third section describes the data envelopment analysis. The fourth section describes the methodological approach and application. Fifth section describes results and discussions, and the final section provides a concluding remark.

2. Literature Review in Measuring The Efficiency Of Public University

Efficiency measurement in Public Universities have conventionally employed a range of methodologies, often emphasizing parametric and non-parametric techniques to measure efficiency [5]. However, the complexity of PUs [6] —marked by multifaceted operational dynamics and service delivery mechanisms—necessitates a more robust analytical approach. Consequently, Data Envelopment Analysis is identified as a particularly suitable method for this context. Within the domain of university efficiency measurement, existing literature presents varied findings across different studies. In study by Kao and Hung [7], they used DEA to evaluate the relative efficiency of 41 departments of the National Cheng Kung University in Taiwan. The results of the study found that top university administrators can detect departments that are inefficient in using their resources as well as identify weak departments that need effort and focus so that the department's level of efficiency can be improved. Whereas, Pietrzak *et al.,* [8] discussed the issue of the extent to which higher education institutions (HEI) carry out their tasks and what are the appropriate methods of measuring HEIs' performance. To discuss the issue, they have presented the results of empirical research on 33 faculties in Polish universities using DEA. The findings of their study successfully determine the appropriate benchmark for inefficient HEIs and measure the gaps that these HEIs must fill in order to become efficient in the future.

Additionally, Alwadood *et al*., [9] have used DEA to measure the relative efficiency of six academic departments in selected faculties in a Malaysian public university. The results of this study found that all academic departments in the faculty recorded a satisfactory efficiency which is at a high level. According to them, less efficient departments have the potential to improve their performance by referring to efficient departments. However, their study only focused on measuring the efficiency of the department alone, ignoring the measurement of the effectiveness of the department itself. Naderi [10] reported that a considerable portion of academic departments are operating at a high level of efficiency, with about half achieving efficient status. Similarly, Bouzouita [11], noted high average technical and scale efficiency among Higher Education Institutions in Tunisia. Salas-Velasco [12] observed an encouraging average efficiency rate of 92% among Spanish universities. Despite these positive results, it is essential to recognize that the aforementioned studies employed radial measurement models, which may oversimplify the efficiency evaluation by assuming proportional reductions in inputs or outputs.

Therefore, the non-radial model, such as the Slacks-Based Measure (SBM) Model, which can offer a different perspective on efficiency. The SBM Model addresses the issue of input excesses and output shortfalls separately, which means it can provide a more nuanced analysis by looking at each input and output dimension individually. This distinction is particularly relevant for public universities as the non-radial model allows for a more detailed assessment of where universities may be underperforming. It acknowledges that not all inputs and outputs can be adjusted at the same rate and highlights specific areas where improvements can be made, potentially leading to greater and more targeted results. By incorporating SBM into the assessment of public universities, stakeholders can gain a more comprehensive understanding of efficiency of the public university. This could facilitate more informed decision-making and better allocation of resources, ultimately enabling these institutions to achieve heightened levels of academic productivity and quality.

3. Data Envelopment Analysis

Data Envelopment Analysis is a non-parametric method measuring relative of a peer set of units called decision making units (DMUs) [13]. The history of DEA dates back to 1978 when it was first introduced by Charnes, Cooper, and Rhodes [14]. The seminal paper by Charnes, Cooper, and Rhodes introduced the CCR model, named after the initials of the authors, which addressed the measurement of efficiency for DMUs utilizing multiple inputs to produce multiple outputs. The CCR model was based on the concept of Pareto efficiency and was an extension of earlier work by Farrell [15]. Farrell's work had focused on single-input, single-output cases, and the CCR model generalized this to multiple-input, multiple-output scenario. In DEA, there are typically two types for measuring efficiency of DMUs; radial and non-radial [13]. Radial models assume proportional change of inputs/outputs and usually remaining slacks are not directly accounted for inefficiency [16]. On the other hand, non-radial models deal with slacks of each input/output individually and independently, and integrate them into an efficiency measure, called SBM [17].

4. Methodology

In the approach of Data Envelopment Analysis (DEA), many models have been introduced, and one of the most fundamental is the CCR model. Based on this model, the efficiency of a Decision Making Unit (DMU), denoted as E_o, is measured through the ratio of weighted sum of outputs, $w_j y_j$, to the weighted sum of inputs, $v_i x_i$, and this problem is solved through a fractional programming model such as equation (1). The CCR model is subject to Constant Returns to Scale (CRS).

$$\text{Maximize } E_o = \frac{\sum_{j=1}^{s} w_j \, y_{jo}}{\sum_{i=1}^{r} v_i \, x_{io}}$$

Subject to,

$$\frac{\sum_{j=1}^{s} w_j y_{jm}}{\sum_{i=1}^{r} v_i \, x_{im}} \leq 1; \;\; m = 1, 2 \ldots, n$$

$$w_j \geq 0; \;\; j = 1, 2 \ldots, s$$
$$v_i \geq 0; \;\; i = 1, 2 \ldots, r \qquad (1)$$

where:

y_{jo} = the amount of output j produced by DMU under evaluation
y_{jm} = the amount of output j produced by DMU *m*
x_{io} = the amount of input i used by DMU under evaluation
x_{im}= the amount of input i used by DMU *m*
w_j = weight of output j considered non-negative
v_i= weight of input i considered non-negative
n = number of DMUs
s = number of outputs
r = number of inputs
E_o = objective function for the efficiency of DMU under evaluation

Additionally,

In measuring the efficiency of DMUs, DEA literature distinguishes between radial and non-radial measures. The Slack-Based Measure, a prominent non-radial approach defined by Tone in 2001, affords a more discerning evaluation of efficiency due in large part to its capability to rectify both slack in inputs and deficiency in outputs simultaneously. For instance, within a university context, faculties could be considered as individual DMUs, each utilizing various resources (inputs) to produce educational and research outcomes (outputs). If we denote the i^{th} input and the r^{th} output of the *j*th DMU (faculty) as x_{ij} (i = 1, 2,..., m) and y_{rj} (r = 1, 2,..., s), respectively (where *j* ranges from 1 to n), then the SBM model as per Tone's formulation can be presented as follows, as Model (2):

$$p_o = min. \frac{1 + \frac{1}{m}\sum_{i=1}^{m} \frac{t_{i_o}^-}{x_{io}}}{1 - \frac{1}{s}\sum_{r=1}^{s} \frac{t_{r_o}^+}{y_{ro}}},$$

Subject to

$$\begin{aligned}
&\sum_{j=1}^{J} \lambda_j X_{ij} + t_{i_o}^- = x_{io}, && ,i = 1,\dots,m, \\
&\sum_{j=1}^{J} \lambda_j Y_{rj} - t_{r_o}^+ = y_{ro}\,, && ,r = 1,\dots,s, \\
&\lambda_j,\ t_{i_o}^-, t_{r_o}^+ \geq 0, && j = 1,\dots,J
\end{aligned} \tag{2}$$

Using the SBM model, each faculty's performance is evaluated by seeking the maximal reduction of input excess and maximization of outputs. Consequently, this model not only identifies inefficiencies but highlights potential areas for improvement by pushing each faculty towards the 'furthest' point of efficiency, effectively pinpointing the sources of ineffectiveness within the university's operational systems.

Application:

University Teknologi MARA (UiTM) is a public university based in Shah Alam, the capital city of Selangor, Malaysia. UiTM has grown into one of the nation's largest institutions of higher learning in terms of size and population. The university offers a wide array of programs and has a diverse student body. For the purposes of measurement, data from 26 faculties will be considered for the year 2020, with attention given to two specified outputs and two inputs. In general, the agreed inputs for universities can be classified as human resources and physical capital as suggested by Johnes [18], Johnes *et al*., [19] as well as Katharaki and Katharakis [20]. Therefore, this study takes into account faculty input as human resources and physical capital, where student enrolment [21,22] represent physical capital and number of academic staff [23,24] represent human resources. Additionally, the outputs are number of graduate students [25,26] and number of indexed publications [27,28,29]. The inputs and outputs used in this study are illustrated in Figure 1.



Fig. 1. Inputs and Outputs

5. Results and Discussion

Table 1 displays the results from the SBM model. According to this model, efficient faculty is characterized by an efficiency score of one, alongside input savings and output surpluses that are zero, indicating no room for additional input or reduction in output without affecting efficiency. Conversely, faculty are identified as inefficient by efficiency scores less than one, along with value of input excesses and output shortfalls. Overall, the efficiency values provide a measure of how effectively each faculty is utilizing its resources, with values closer to 1 indicating higher efficiency. Faculty 3, Faculty 4, Faculty 6, Faculty 10, Faculty 16, Faculty 17, Faculty 19, Faculty 21, Faculty 22, Faculty 24 and Faculty 26 are operating at perfect efficiency with efficiency values of 1. Contrary Faculty 1, Faculty 12, and Faculty 23 are operating at relatively low efficiency levels with efficiency values below 0.400.

Table 1
Efficiency score for 26 faculties

No.	Faculties	Efficiency Score
1	Faculty 1	0.305
2	Faculty 2	0.620
3	Faculty 3	1
4	Faculty 4	1
5	Faculty 5	0.493
6	Faculty 6	1
7	Faculty 7	0.692
8	Faculty 8	0.794
9	Faculty 9	0.500
10	Faculty 10	1
11	Faculty 11	0.578
12	Faculty 12	0.323
13	Faculty 13	0.406
14	Faculty 14	0.471
15	Faculty 15	0.430
16	Faculty 16	1
17	Faculty 17	1
18	Faculty 18	0.672
19	Faculty 19	1
20	Faculty 20	0.435
21	Faculty 21	1
22	Faculty 22	1
23	Faculty 23	0.315
24	Faculty 24	1
25	Faculty 25	0.471
26	Faculty 26	1

Table 2 provides the slacks of inputs and outputs can be reduce or increase of each faculty in terms of student enrolment, academic staff, number of graduate students, and number of indexed publications to achieve efficiency status. For example, for **faculty 1, this faculty** has the potential to decrease of 34 in student enrolment and 49 in academic staff to achieve efficiency status. Furthermore, this faculty 1 could also afford to increase 242 in the number of graduate students, and 81 in the number of indexed publications to achieve efficiency status.

Table 2
Slack value for inefficient faculties

Faculties	Input excess		Output shortfall	
	Student Enrolment	Academic Staff	No. of Graduate Students	No. of Indexed Publications
Faculty 1	34	49	242	81
Faculty 2	506			27
Faculty 5	3402		130	
Faculty 7	1155	20		1
Faculty 8	1888		23	
Faculty 9	1801			14
Faculty 11	1523			18
Faculty 12	23420			234
Faculty 13	5896			19
Faculty 14	3478			24
Faculty 15	8938			91
Faculty 18	6071	16	95	12
Faculty 20	11611	8	2	180
Faculty 23	2519			97
Faculty 25	1347			26

6. Conclusion

The study's results demonstrate the practicality and effectiveness of the Slack-Based Measure of Data Envelopment Analysis approach as an analytical tool for pinpointing inefficiencies within the operational structure of public university faculties. By highlighting specific areas where input resources exceed necessity, or where output results fall short, the SBM approach facilitates the formulation of precise and actionable recommendations to foster efficiency. A key contribution of this study is the novel application of the SBM method to a Malaysian public university context, marking a departure from prior research. The implementation of SBM in this unique setting not only enriches the academic discourse on educational efficiency but also provides insights that could guide policy and decision-making to enhance the performance of Malaysian public universities.

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