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Development of a Two-dimensional Productivity Measurement Model for Higher Learning Institutions

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ABSTRACT

Measuring the performance of higher learning institutions (HLIs) is a must for these institutions to stay competitive and to move forward. Initiatives towards constructing a more appropriate and accurate measurement is vital. This paper focuses on formation of a productivity model that consists of efficiency and effectiveness dimensions by utilizing a non-parametric method, data envelopment analysis (DEA). The identification of suitable input, output and outcome variables were done prior to the development of the model. The proposed model is validated by measuring the productivity of 16 public universities in Malaysia for year 2008. However, due to unavailability of one variable data, an estimate was used as a proxy to represent the real data. The results show average efficiency and effectiveness scores are 0.817 and 0.900 respectively and 0.754 is the overall productivity score. A total of six universities were both efficient and effective. The formation of this performance model would work as a complement method to the existing performance methods or as an alternative method in monitoring the level of performance of HLIs especially for the Malaysia public HLIs. The proposed model could be adopted in a different field or sector after priori identification of suitable and related variables of the selected context.

Keywords: Productivity, Efficiency and Effectiveness, Data Envelopment Analysis
JEL Classifications: C610, C623, I23

1. INTRODUCTION

Development of educational performance assessment whether at individual students level or at organizational level is always difficult. However, practitioners continue to devise a better performance assessment approaches due to the importance of those instruments in helping the related authority to monitor their performance and provide direction of improvement. As a mature developing country, Malaysia continues to improve the image and quality of higher educational excellence to world-class standards. The formation of performance measurement models for higher learning institutions (HLIs) is needed in providing a comprehensive performance, so that the institutions can take proper improvement actions based on the results. Therefore, a more systematic mathematical performance measurement model should be developed to assist the HLIs specifically, and Malaysia Ministry of Higher Education (MOE) generally, in improving the existing performance appraisal system. The formation of this performance model will react as an alternative or as a complement to the existing methods in monitoring the level of performance of HLIs.

Performance measurement from the perspective of government agencies is a compilation of reports on efficiency, quality and effectiveness of their programs which would help them to improve the services provided to the citizens (Hatry, 1999; Kestenbaum and Straight, 1995; Nyhan and Martin, 1999). Efficiency is about how well is an organization utilizing the inputs to produce outputs which maybe in tangible or intangible forms, whereas effectiveness is about the relationship between input(s) and output(s) to the final objectives that is the outcome. The outcome is always related with the growth objective and also influenced by multiple factors in organization. Goals and objectives can be achieved when institutions use limited resources to meet the stated objectives

(Mancebon and Molinero, 2000). Besides that, in order to survive in a challenging world, it is essential for service organizations to measure their performance whether they are able to meet the needs of their customers or not (Taylor and Godfrey, 2003).

Most of the present measurements are based on single indicators of different dimensions and more focused on the descriptions of the quality. Normally, the overall performance is computed by adding the individual values of the single indicators. On the contrary, efficiency measure is seen to have more features such as technical, scale and allocative efficiencies. However, measuring only the efficiency dimension of the HLIs is not sufficient if the effectiveness dimension is being ignored.

Since the proposed model consists of many variables that are considered simultaneously, a suitable method of analysis should be utilized. Data envelopment analysis (DEA), which is a non-parametric method pioneered by Charnes et al. (Charnes et al., 1978), is used due to its powerful feature that has the ability to deal with the input(s), output(s) and outcome(s) variable in one equation. After its first appearance, the DEA method has been used widely in various sectors, for example Cave et al. (1991) introduced DEA in measuring performance of higher educational institutions, followed by Breu and Raab (1994), and Johnes and Yu (2008). Therefore, the aim of this study is to present extended DEA based models in measuring both efficiency and effectiveness of performance dimensions. A numerical example to illustrate the application of proposed models is also included.

2. EFFICIENCY AND EFFECTIVENESS

Both efficiency and effectiveness are generally known as quality metrics or key performance indicators, and are often regarded as having the same meaning. However, in a more serious discussion on performance management, both terms have different meanings. Management Encyclopedia defines efficiency as "doing things right," while effectiveness is about "doing the right thing." Mandl et al. (2008) have discussed these measures in the context of public spending. In addition, they concluded that the analysis of the efficiency and effectiveness is the relationship between inputs, outputs and achievements. Output means organization products, whether in the form of goods or services. Input refers to raw materials or materials needed to produce the output. Inputs include human resources, financial resources, resource materials or other incurred costs.

Generally, efficiency depicts the ability to produce output(s) with minimum resources, whereas the effectiveness of an organization refers to the level of achievement relative to the goals or objectives set by the management. In simpler words, efficiency refers to the ratio of outputs to input, and effectiveness is the ratio of the achieved outcomes, compared to available output(s) or input(s). For public organizations, the concept of effectiveness has always been associated with the effect or impact or outcome of services or goods provided to the users. Thus this concept must be extended to include the outcome or impact of the output to the output user. Effectiveness is fundamental to the success of an organization, and efficiency is the minimum requirements for the organization after success is achieved. The conceptual relation between the two concepts is illustrated as shown in Figure 1.

3. DEA

DEA was first used for evaluation of relative efficiency based on its definition as ratio of obtained outputs and inputs (Charnes et al., 1978). Since then, DEA has been widely applied to measure the relative efficiency of a set of DMUs which uses the same inputs to produce the same outputs (AlWadood et al., 2011; Kao, 2014; 2015). Much effort has been devoted to breaking down the overall performance into components namely, efficiency and effectiveness, so that the sources of inefficiency can be identified. Therefore, this study proposes two-dimensional model from a two-stage evaluation process where the outputs of the first stage are the inputs of the second stage as illustrated in Figure 1.

3.1. The Proposed Conceptual Model

First, the basic or conceptual model to measure efficiency and effectiveness are as follows. Efficiency model is defined as the ratio of weighted sum of outputs to weighted sum of inputs, while effectiveness is defined as weighted sum of outcomes to weighted sum of outputs. In short, the models can be represented as

Then, the two individual models are combined as the product of the two measures and defined as the two-dimensional productivity model, which can be written as:

$$\text{Efficiency } (\text{EFFY}) = \frac{\text{Weighted sum of outputs}}{\text{Weighted sum of inputs}}$$

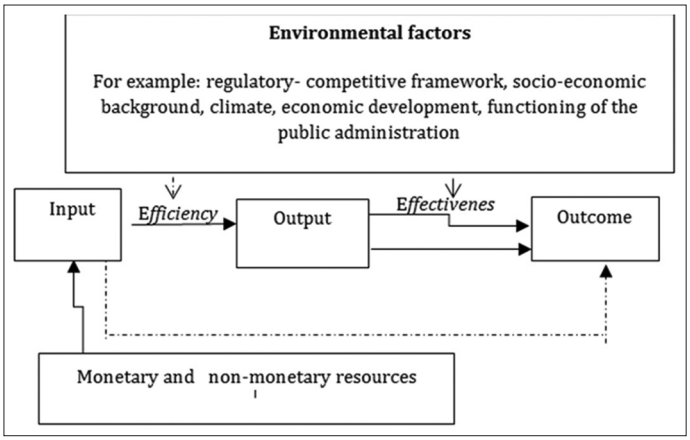
$$\text{Effectiveness } (\text{EFFS}) = \frac{\text{Weighted sum of outcomes}}{\text{Weighted sum of outputs}}$$

The two-dimensional productivity model = EFFY × EFFS

3.2. The Two-dimensional Productivity Model

Now, suppose a production process is composed of a series of two-dimensional processes (namely efficiency and effectiveness) as depicted in Figure 1. The whole process uses m inputs X_{ik},

Figure 1: The concept of efficiency and effectiveness



Source: Mandl et al., 2008

i = 1,..., m to produce s outcomes Y_{rk}, r = 1,..., s. Different from the conventional one-dimensional production process, here the production process is composed of two-dimensional process with q intermediate products $Z_{pk,}$ P = 1,…q, where the intermediate products Z_{pk} are the outputs of model 1 (EFFY model) as well as the inputs of model 2 (EFFS model).

$$\text{Max } E_k^1 = \frac{\sum_{p=1}^{q} w_p Y_{pk}}{\sum_{i=1}^{m} v_i x_{ik}} \quad (1)$$

$$\text{Subject to } \frac{\sum_{p=1}^{q} w_p Y_{pj}}{\sum_{p=1}^{q} w_p X_{pk}} \leq 1; j = 1,2 \ \ldots, \ n$$

$$\text{Max } E_k^2 = \frac{\sum_{r=1}^{s} u_r Z_{rk}}{\sum_{p=1}^{q} w_p X_{pj}} \quad (2)$$

$$\text{Subject to } \frac{\sum_{r=1}^{s} u_r Z_{rj}}{\sum_{p=1}^{q} w_p X_{pj}} \leq 1; j=1,2\ldots, n, \ u_r, w_p \geq \epsilon;$$

r=1,2 …, s; p=1,……., q

The overall two-dimensional performance model is the product of the EFFY and EFFS measures as

$$E_k = E_k^1 \times E_k^2 \quad (3)$$

Where, $0 \leq E_k, E_k^1, E_k^2 \leq 1$. A unit of analysis is said to be fully efficient or effective or both if E_k^1 or E_k^2 or E_k are equal to one respectively.

Since this is a basic model, the next step is to define the input(s), output(s) and outcome(s) in the context of HLIs.

3.3. The Inputs, Outputs and the Outcomes in the Context of HLIs

All the variables were identified through literatures and Malaysia Ministry of Education's documents. This study selects "lecturers of different categories" as the inputs in order to produce "graduate students" of different levels of degree programs. Besides that, lecturers have to generate research grants and doing research. Therefore, the amount of research grant, in Ringgit Malaysia (RM) is also chosen as another output. Table 1 shows the identified variables to measure efficiency of universities.

Effectiveness relates input or output to their good impact, or the outcome. In the context of HLIs, the graduate students who are being employed would be considered the positive impact of being graduated since their services are needed by the industries or government agencies. Therefore, this study selects "the employed graduates" as the outcomes of universities for the teaching component. This argument is parallel with Israeli (2007), who indicates that effectiveness should focus on the final result which is the achievement of the organizational goal where these graduates can contribute to the progress of the nation. The inputs or outputs and outcomes for measuring effectiveness are shown in Table 2. Due to unavailability or confidentiality of the data, the number of employed students is estimated based on Malaysia Graduate Tracer Study (2011) that stated that around 49.9%, 86%, and 94% of degree, masters, and PhD graduates had jobs after 6 month of graduation respectively. In term of research, the monetary value (RM) of the grant is used as input and the university is considered effective if it has the ability to produce publication since publication is the good impact from the research grant awarded to the lecturers that act as the researchers. In relation to that, the number of publication is treated as the outcome of research.

3.4. Decision Making Units (DMUs) or Units to be Analyzed

In the context of Malaysia HLIs, obviously, the units to be analysed are universities in Malaysia. For this research, 16 public universities were selected due to availability of data.

4. RESULTS AND FINDINGS

The descriptive summary of the raw data is presented in Tables 3 and 4 shows the performance of 16 Malaysia public universities for year 2008.

Based on Table 4, the results show that seven universities: UM, UPM, UTM, UUM, UMS, UPSI and UTHM with score 1 are efficient which positioned them at first rank with respect to efficiency measure. In terms of effectiveness, a total of 8

Table 1: Variables to measure efficiency

Activities in university	Inputs	Outputs
Teaching	1. Number of professors (A) 2. Number of assoc. professors (AP) 3. Number of lecturers (L)	1. Number of graduated degree students (UG) 2. Number of graduated master students (M) 3. Number of graduated PhD students (PhD)
Research		Total amount of Research Grants in Ringgit Malaysia. (RG)

Table 2: Variables to measure effectiveness

Activities in university	Intermediate input/output	Outcomes
Teaching	1. Number of graduated degree students. (UG) 2. Number of graduated masters students.(M) 3. Number of graduated PhD students. (PhD)	1. Number of graduated degree students who are employed* (UGW) 2. Number of graduated masters students who are employed*(MW) 3. Number of graduated PhD students who are employed*. (PhDW)
Research	Amount of research grant in RM (RG)	Number of publications (P)

*Estimated values based on Graduate Tracer Study Report 2010. *Estimated values based on Malaysia Graduate Tracer Study Report 2010

Table 3: Summary of inputs, outputs and outcomes

Value	P	AP	L	RG	UG
Maximum	319	971	5180	543224	12124
Minimum	15	15	269	3.74296	645
Average	90.5	209	980.4	34160.2	3725.2
SD	90.2	241.9	1134.1	131440.1	2898.2
Value	**MS**	**PHD**	**MSW**	**PhDW**	**PUB**
Maximum	1366	183	1174.8	172.0	1626
Minimum	5	1	4.3	0.94	0
Average	540.9	49.1	465.2	46.2	263.9
SD	490.9	61.3	422.2	57.6	422.7

SD: Standard deviation

Table 4: Comparative analysis of efficiency and effectiveness model and overall two measure performance of selected Malaysia PHLIs for year 2008

Malaysia PHLIs	Efficiency		Effectiveness		2- Dim.	Overall
	Score	Rank	Score	Rank	Performance score	Rank
UM	1.000	1	1.000	1	1	1
USM	0.8424	10	0.8424	13	0.7096	11
UKM	0.8882	9	0.8878	11	0.7885	9
UPM	1.000	1	1.000	1	1	1
UTM	1.000	1	0.8591	12	0.8591	8
UUM	1.000	1	1.000	1	1	1
UIAM	0.6540	12	0.9028	10	0.5904	12
UNIMAS	0.4813	15	1.000	1	0.4813	13
UMS	1.000	1	1.000	1	1	1
UPSI	1.000	1	1.000	1	1	1
UiTM	0.9004	8	0.9890	9	0.8905	7
UMT	0.7773	11	1.000	1	0.7773	10
UTHM	1.000	1	1.000	1	1	1
UTeM	0.6076	13	0.6071	16	0.3689	15
UMP	0.5905	14	0.6458	15	0.3814	14
UniMAP	0.3253	16	0.6718	14	0.2185	16
Average	0.8167		0.9004		0.7540	

universities were ranked at first position since their effectiveness scores were equal to one. Six universities were both efficient and effective for year 2008. The efficiency and effectiveness average scores are 0.8167 and 0.900 respectively which reflect that the institutions are generally more effective but a little less efficient, whereas the overall two-dimensional productivity score for the 16 universities is at 0.7540. UniMAP and UTeM seem to be the least efficient and least effective respectively, while UniMAP once again become the least productive in both dimensions.

5. CONCLUSION

This paper illustrates the development of a two-dimensional productivity measurement model based on DEA method in measuring HLIs. The two-dimensions include efficiency and effectiveness that relate input, output and outcome variables which composed the basic conceptual productivity model. The proposed model is validated by applying it in measuring the two-dimensional productivity of 16 public universities in Malaysia for year 2008. The results show that only seven and eight universities were efficient and effective respectively, while only six universities were both efficient and effective for that particular year. The results are beneficial to the universities specifically and to the related ministry generally in planning and taking suitable actions for advancement of the institutions. The proposed model can be enhanced by inclusion of more relevant variables and can be adapted to measure performance of different entities in different context.

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