Performance Evaluation of Faculties at a Private University A Data Envelopment Analysis Approach

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Abstract

This research explores the performance efficiency of faculties at a Malaysian university using data envelopment analysis. The method applies a multiple of input and output variables approach in assessing performance efficiency, which is an added advantage to other approaches using simple performance ratios. Inputs like number of students, number of academic staff working and budgetary allocations and outputs like number of graduates and number of research articles published have been applied in data envelopment analysis to get the performance efficiency of a faculty in a university. Data analysis reveals that all faculties except for one, was found to be efficient when compared to the composite faculty. This research contributes significantly in evaluating each faculty?s performance in relation to a hypothetical composite faculty and ultimately contributes to the overall performance of a university in the education sector.

Index terms— Data Envelopment Analysis, Education, Efficiency, Performance Evaluation.

1 Introduction

ssessment of performance is a crucial component of the management process in any type of organization (Flegg, 2004). Performance measurement is becoming an essential tool for addressing questions of productivity measurement in terms of efficiency, effectiveness and accountability. Meanwhile, Holloway and Mallory (1995) observed that performance is seen as the overall status of an organization in relation to its competitors, or against its own or external standards, and should generally be gauged across a host of measures, namely economy, efficiency and effectiveness. The concept of efficiency refers to the measurement of relationship between inputs and outputs. Hatry (1999) defined efficiency in performance as "the ration of the amount of input (dollar expenditure, personnel time or other physical input) to the amount of product or output produced by the input". In other words, efficiency measures how good an organization or decision making unit (DMU) fully utilizes its resources to produce outputs within a given set of limitations. The efficiency of organizations has been studied by many researchers in different industries, including university departments (Köksal & Nal?aci, 2006).

Assessing the performance of an educational system is an important task but difficult to accomplish since it utilizes multiple inputs to produce multiple outputs most of which are challenging to quantify. Despite the difficulties involved, educational system performance assessment could be made and used to set performance targets, to make resource allocation decisions and to improve overall performance **??**Soterious et.al, 1998).

2 II.

3 Literature review

Measuring the efficiency of a DMU is as easy as comparing its outputs to its input. But when multiple inputs and multiple outputs are involved, the measurement of efficiency becomes difficult. The complex nature of the relationships between multiple inputs and multiple outputs involved in the efficiency analysis of DMUs requires sophisticated techniques which can handle large number of variables and constraints. In 1978, Charnes et al. developed data envelopment analysis (DEA) which was first conceived by Farrell in 1957. Data envelopment analysis is a mathematical programming approach that utilizes multiple inputs and multiple outputs to evaluate the relative efficiencies of DMUs within an organisation and to compare each DMU with other DMUs. The relative efficiency is defined as the ratio of multiple weighted outputs to multiple weighted inputs. According to Nunamaker (1985), the principal strength of DEA "lies in its ability to combine multiple inputs and outputs into a single summary measure of efficiency without requiring specification of any priori weights".

DEA is an attractive tool for performance evaluation due to its unique characteristics, such as, among others, being able to handle multiple inputs and multiple outputs simultaneously, does not require weights of each factor to be assigned in advance, inputs and outputs can be compared against each other without the need to standardize the data and weights DEA was originally developed to examine the efficiency of public schools (Charnes et al., 1978) and has since been applied to various sectors. DEA in education studies focused more on university performance in a specific country for the right allocation of resources, to enhance efficiency of resource utilization (Fernando & Cabanda, 2007). In 2010, Agasisti and Perez-Esparrells used DEA model to compare the efficiency of Italian and Spanish state universities. Köksal and Nal?aci studied the relative efficiency of departments in Turkish engineering universities (Köksal and Nal?aci, 2006). Tajniker and Debevec applied DEA to study technical efficiencies of all secondary schools in UK and estimated models to examine the determinants of efficiency in a particular year and the change of efficiency over the period (Bradley et al, 2001). Other examples of using DEA as an evaluation tool for efficiency university departments are **??**omkins and Green (1988), who studied the overall efficiency of British universities; Beasly (1995) compared chemistry and physics departments; Johnes (1995) studied UK economics departments; and Taylor and Harris (2004) compared the relative efficiency of ten South African universities. DEA is most useful in cases where accounting and financial ratios are of little value and when multiple outputs are produced especially when the relationships are not known (Charnes et al, 1978).

4 III.

5 Methodology

Data envelopment analysis (DEA), a linear programming model, is used as a non-parametric technique for efficiency measurement. Any decision making unit or a division in an organisation whether it is manufacturing or service provider should perform well not only in finance but also in non financial measures. The basic concept of DEA is to form a line of optimal production by efficient DMUs and to spread all inefficient DMUs below that line, referred to as the 'envelop' (Tajnikar & Debevec, 2008). The performance at par or below average is the real measurement especially in service organisation because the service levels are difficult to quantify and fix a numerical target. Therefore if a DMU in an organisation is to be efficient it should provide service at par of the weighted average of the entire organisation as whole. This weighted average is crucial and it is the composite weighted average of all inputs and outputs of an organisation and named as hypothetical organisation.

The aim of this study is to develop a system to measure the efficiency of these faculties and guide the inefficient ones by showing how faculties should improve their teaching and research to be at least the same level as the efficient faculties. There are two different categories of DEA model, input oriented and output oriented. In input oriented models minimizes the usage of input while maintaining the same level of output while in output oriented models, DMUs maximizes the level of output at the same level of input given. It is obvious that the difference between the two models consists of the ability of each faculty to control the quantity of input or output. In this study, output oriented DEA model is found to be more appropriate as the number of faculties is very small, it requires less computational process and it is easier to control inputs than outputs (Thuy Linh Pham, 2011). The efficiency measure of the output oriented model reflects the ability of a faculty to obtain maximum output from a given set of inputs.

6 a) Hypothetical Composite Faculty

To illustrate the DEA modelling process, a linear program is formulated to determine the relative efficiency of various faculties operate in a private university in Malaysia. Using the linear programming model, a hypothetical composite faculty will be constructed, based on the inputs and outputs for all faculties with the same goals. Three input measures and two output measures of each DMU are considered to generate a hypothetical composite faculty. This composite faculty's parameters are computed by using weights to compute a weighted average of the corresponding inputs of all DMUs of an organisation.

7 b) Objective function and Efficiency Index

In any optimisation model there will be an objective function which may be maximised or minimised depending upon the nature of variable being studied. If it is about costing, downtime or waiting time, it is to be minimised. If it is profit, quality or output, it is to be maximised. Similarly in DEA model also the objective function is there, normally E will be used to denote the objective function. The E is the efficiency index of the composite faculty. The efficiency index of the composite faculty is be minimised which means to minimize the input resources available to the composite faculty. Naturally the faculties which are efficient will have a score of 1 and the inefficient faculties will have a score of less than 1. E = the fraction of Faculty of Business Administration's input available to the composite faculty.

8 The decision rule is as follows:

The composite faculty requires as much input as the faculty does. There is no evidence that the faculty is inefficient.

The composite faculty requires less input to obtain the output achieved by the faculty. The c) Equality Constraint DEA model requires that the sum of all weights equal 1, thus the first constraint is (1) wba -weight applied to inputs and outputs for FBA wit -weight applied to inputs and outputs for FIT wss -weight applied to inputs and outputs for FESS wtm -weight applied to inputs and outputs for FHTM d) Input Constraints

The relationship between the inputs of specific and the composite faculty are to be given in the form of constraints for the DEA model to solve. The resources available for the composite faculty should be less than the inputs available for specific faculties. The analogy is to compare each specific faculty to the composite faculty for measuring composite faculty's efficiency by giving the same input given to the specific faculty being tested. If composite faculty's efficiency index is less than 1, it can be concluded that the specific faculty is weak and vice versa. Each input constraint requires an equation to accommodate all faculties' inputs. The general form for the input constraints is as follows:

Weighted input of all faculties (Composite Faculty) ? Input of specific faculty being tested For each output measures, the output for the composite faculty is determined by computing a weighted average of the corresponding outputs for all four faculties. Constraints in the linear programming model require all outputs for the composite faculty to be greater than or equal to the outputs of individual faculties involved in this research. If the inputs for the composite unit shown to be less than the inputs of a particular faculty, the composite faculty is said to have the same or more output for less input. In other words, the faculty being evaluated is less efficient than the composite faculty. Since the composite faculty is based on all four faculties, the faculty being evaluated can be judged as relatively inefficient when compared to composite faculty. It is the weighted average faculty of all faculties operating in a university. CF is taken as the bench mark for comparison of each DMU or faculty in an organisation. CF takes the same inputs and outputs of different faculties in a weighted way. This is like testing whether a DMU or a faculty is at par or below the CF. If it is equal to average, the faculty is treated as efficient and vice versa. To complete the formulation, right-hand-side values for each constraint must be given. In DEA approach, these right-hand-side values are of the input and output values of CF will be the same that of the faculty being tested or compared. Therefore the CF will have the same constraints of a faculty which is being tested. For instance, if FBA is to be tested against the CF, FBA constraints will be the constraints of CF. The models are given in the next section.

IV.

9 Results and discussion

As per previous studies, the above inputs and outputs of the faculties were chosen. The choice of adequate variables for inputs and outputs is still debated, and no unique solutions were definitively suggested **??**Johnes, 2004). For inputs, number of students, number of academic staff and budgetary allocation are being considered. As outputs, this research considers number of graduates as a proxy for for research performances. The most recent data is from the year 2009, therefore, data used to apply DEA model for evaluation is from 2009 of each faculty. The following DEA model is designed for the composite and FBA to evaluate the FBA against the CF. The above DEA model comprises four sections. First section gives the efficient index portrayed in the form of E, the objective function, which is to be minimised. Section two gives the total weight constraint. This is an equality constraint which should be always one. Section three gives the output constraints in the form of equal to or greater than. The CF draws the values from the faculty to be tested. There are two outputs namely graduates and number of research articles published. Section four gives the input constraints. The inputs are the number of students studying presently in each faculty, number of academic staff working and budgetary allocation for each faculty. The CF draws the figures from FBA as right hand side values. But since they are placed in the left hand side they appear with minus sign which is appropriate in algebra. The final section is the non-negative constraint. If these constraints are not given while minimising they may appear with negative values which are to be prevented as there is no negative values for these parameter.

The result after running the solution for the above model as follows: The efficiency index shows 1 for CF and FBA. This result reveals that both CF and FBA are working on the same level of efficiency. The surplus and slacks are zero. The surplus are the right hand side values when the faculty produces more output than CF and similarly slack variable will show the unutilised resources not used by the particular faculty when compared to CF. Since all slack values are zero it is concluded that FBA uses the same inputs and produces the same outputs as CF. Reduced cost is related to objective function while shadow prices are related to constraints. Reduced costs have no role here as this paper evaluates efficiency only. In case of linear programming the values are useful. The shadow prices give the indication that if the right hand side increases by this quantity the efficiency index will change suitably. For output variable graduates if right hand side increases by 0.001 the efficiency index also will increase. For the input variables if the students studying and academic staff decreases by 0.001 and 0.005 will improve the efficiency index. This shows that the department is over staffed and have more students for every academic staff. This requires some realignment in student and staff strength.

10 b) Faculty of Information Technology (FIT)

The following DEA model is framed to evaluate efficiency of Faculty of Information Technology's performance. A closer observation will reveal that there is no change in objective and equality weight constraint. But the right hand side values of output constraints have been replaced with that of FIT output values. Similarly the input constraints values are replaced by input values of FIT which are placed below the CF with minus sign. The results for the FIT DEA model are as follows. FIT is also efficient as the composite faculty and FIT having the efficiency index of one. This implies that the CF uses the same inputs from all faculties and produces the same efficiency index as FIT. The slack, reduced costs and the shadow prices all have the same interpretation as in FBA. This paper's concern is whether the FIT is efficient or not, which is very clear that it s performance is as equal to CF.

11 c) Faculty of Education and Social Sciences (FESS)

The FESS DEA model is as follows. As usual the output constraints right hand side and input values of FESS are substituted in the place of FIT values. The DEA model analysis produces the following results for FESS. FESS also produces an efficiency index of one which indicates that this faculty also as efficient as the other two faculties. The surplus and slack values are nil. The reduced costs and shadow prices have no interpretation in DEA model for this paper. Once CF produces the results it is interpreted as how much output the CF produces with the same inputs given to FESS. Here CF produces the same output as FESS by taking all faculties composite input.

12 d) Faculty of Hospitality and Tourism Management

The following DEA model is applied for FHTM to assess the efficiency. As usual the input and outputs are adjusted suitability with the values of FHTM. The results are as follows. CF shows that the efficiency index as 0.958, which means the composite faculty is able to obtain only an output of 0.958 with the resources available to all faculties. In other words to produce the outputs of FHTM the CF requires only 98.5% of inputs. The FHTM either wastes the resources or it is unable to produce as much output as required for this given level of resources. The composite faculty is more efficient than FHTM and the data envelopment analysis has identified FHTM as relatively inefficient. The academic staff and resources available to it are in surplus by 3.151 and 29,564 respectively. These figures suggest either the FHTM should reduce these figures or it should improve the output for these given level of inputs.

13 V. Conclusion

Universities are an important component of human capital formation in a country. The DEA model takes all DMUs resources and outputs produced as the basis and evaluate the DMUs on individual basis. This DEA model does not take outside variables into account while evaluating the DMUs. It compares within the organisation. This controls the exogenous variables in assessing the efficiencies of DMUs. This DEA model was applied on the data collected from a Malaysian private university on four faculties (DMUs) to assess their efficiency. It is found that out of four faculties, one faculty is not functioning as other faculties. This may be an indication to the top management to realign the faculty or to control the expenditure or to improve the efficiency. The inefficient faculty could learn from the efficient faculties and conduct a self audit and identify the causes of its own inefficiency. More administrative attention may be needed to the unit since it performs poorly. economic: a frontier analysis, European Economics Review, 301-314 11. Johnes, J., ??2004) [1] [2] [3]

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Figure 1:

$$E_q := \begin{cases} 1, & \textit{Faculty is efficient} \\ < 1, & \textit{Faculty is not efficient} \end{cases}$$

Figure 2:

1

	FBA	FIT	FESS	FHTM
Input Measures				
Number of students studying	621	134	421	428
Number of academic staff working	38	16	21	33
Budgetary allocation (in RM)	28,221	14,870	7700	54,260
Output Measures				
Number of graduates	879	135	559	557
Number of research activities	18	9	2	4
a) Faculty of Business Administration (FBA)				

Figure 3: Table 1 :

2

	CFE	FBA	FIT	FESS	FHTM	
Minimise	E					
Subject to						
Total weights		wba	+ wit	+ wss	+ wtm	= 1
Number of graduates		879wba	+ 135wit	+ 559wss	+ 557wtm	? 879
Number of research activities		18wba	+ 9wit	+ 2wss	+ 4wtm	? 18
Number of students	-621E	+ 621wba	+ 134wit	+ 421wss	+ 428wtm	? 0
Number of academic staff	-38E	+ 38wba	+ 16wit	+ 21wss	+ 33wtm	? 0
Budgetary allocation	-28,221E					

[Note: + 28,221wba + 14,870wit + 7700wss + 54,260wtm ? 0]

Figure 4: Table 2 :

3

	Efficiency Index	Surplus or Slack	Reduced Cost Shadow prices	Allowable Increase	Allowable Decrease
Composite faculty	1	1	0	0	1
FBA	1	1	0	0.035	0
FIT	0.000	0	0	0.046	0
FESS	0.000	0	0	0	0.029
FHTM	0	0	0	0	0.060
Weights	1	0	0.101	0	0
Graduates	879	0	0.001	0	0
Research activities	18	0	0	0	1E+30
Students studying	0.000	0	-0.001	0	0
Academic staff	0.000	0	-0.005	0	0
Budgetary allocation	0.000	0	0	0	0

Figure 5: Table 3 :

4

	CFE	FBA	FIT	FESS	FHTM	
Minimise	CFE					
Subject to						
Total weights		wba	+ wit	+ wss	+ wtm	= 1
Number of graduates		879wba	+ 135wit	+ 559wss	+ 557wtm	? 135
Number of research activities		18wba	+ 9wit	+ 2wss	+ 4wtm	? 9
Number of students	- 134E	+ 621wba	+ 134wit	+ 421wss	+ 428wtm	? 0
Number of academic staff	- 16E	+ 38wba	+ 16wit	+ 21wss	+ 33wtm	? 0
Budgetary allocation	- 14,870E	+ 28,221wba	+ 14,870wit	+ 7700wss	+ 54,260wtm	? 0

Figure 6: Table 4 :

5

	Efficiency Index	Surplus or Slack	Reduced Cost Shadow prices	Allowable Increase	Allowable Decrease
Composite faculty	1	1	0	1E+30	1
FBA		0.000 0	0	1E+30	3.634
FIT	1	1	0	2.708	1E+30
FESS	0	0	4.968	1E+30	4.968
FHTM	0	0	4.213	1E+30	4.213
Weights	1	0	-2.634	0	0.500
Graduates	135	0	0	0	1E+30
Research activities	9	0	0.404	9	0
Students studying	0.000	0	-0.007	0	1E+30
Academic staff	0.000	0	0	1E+30	0
Resources available	0.000	0	0	1E+30	0

Figure 7: Table 5 :

6

	CF	FBA	FIT	FESS	FHTM	
Minimise	E					
Subject to						
Total weights		wba	+ wit	+ wss	+ wtm	= 1
Number of graduates		879wba	+ 135wit	+ 559wss	+ 557wtm	? 559
Number of research activities		18wba	+ 9wit	+ 2wss	+ 4wtm	? 2
Number of students	-421E	+ 621wba	+ 134wit	+ 421wss	+ 428wtm	? 0
Number of academic staff	-21E	+ 38wba	+ 16wit	+ 21wss	+ 33wtm	? 0
Budgetary allocation	-7,700E	+ 28,221wba	+ 14,870wit	+ 7700wss	+ 54,260wtm	? 0

Figure 8: Table 6 :

7

	Efficiency Index	Surplus or Slack	Reduced Cost Shadow prices	Allowable Increase	Allowable Decrease
Composite faculty	1	1	0	1E+30	1
FBA	0	0	0.537	1E+30	0.537
FIT		0.000 0	0	0.235	0.931
FESS	1	1	0	0.931	0.417
FHTM	0	0	5.781	1E+30	5.781
Weights	1	0	0.734	0	0
Graduates	559	0	0	0	1E+30
Research activities	2	0	0.133	0	0
Students studying	0.000	0	0	1E+30	0
Academic staff	0.000	0	0	1E+30	0
Resources available 0.000		0	0.000	0	1E+30

Figure 9: Table 7 :

8

	CF	FBA	FIT	FESS	FHTM	
Minimise	E					
Subject to						
Total weights		wba	+ wit	+ wss	+ wtm	= 1
Number of graduates		879wba	+ 135wit	+ 559wss	+ 557wtm	? 557
Number of research activities		18wba	+ 9wit	+ 2wss	+ 4wtm	? 4
Number of students	-428E	+ 621wba	+ 134wit	+ 421wss	+ 428wtm	? 0
Number of academic staff	-33E	+ 38wba	+ 16wit	+ 21wss	+ 33wtm	? 0
Budgetary allocation	-54,260E + 28,221wba + 14,870wit + 7700wss + 54,260wtm ? 0					

Figure 10: Table 8 :

9

	Efficiency Index	Surplus or Slack	Reduced Cost Shadow prices	Allowable Increase	Allowable Decrease
Composite faculty	0.958	0.958	0	1E+30	1
FBA	0.567	0.567	0	0.039	1.138
FIT	0.433	0.433	0	0.051	1E+30
FESS	0	0	0.022	1E+30	0.022
FHTM	0	0	0.042	1E+30	0.042
Weights	1	0	0.107	0.371	0.366
Graduates	557	0	0.002	322	150.784
Research activities	14.105	10.105	0	10.105	1E+30
Students studying	0.000	0	-0.002	40.871	1E+30
Academic staff	-3.151	3.151	0	1E+30	3.151
Resources available	-29564	29564	0	1E+30	29564

Figure 11: Table 9 :

Figure 12:

The University under consideration has four faculties, Faculty of Business Administration (FBA), Faculty of Information Technology (FIT), Faculty of Education and Social Science (FESS) and Faculty of Hospitality and Tourism Management (FHTM).

teaching performance (production of human capital) and the number of research articles published as proxy

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