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Research paper

A Slack-Based Measures for Improving the Efficiency Performance of Departments in Universitas Malikussaleh

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Abstract

Data Envelopment Analysis (DEA) is a data-oriented performance evaluation method that has a very satisfactory performance when there are multiple inputs and outputs presented in the form of set of peer Decision Making Units (DMU). In the discussion of DEA, basically measures the efficiency of each DMU in specific performance based on DEA Efficiency Scores. In DEA, when there is a value of Non-Zero Input and Output Slacks then this often means inefficiency. This scalar measures directly with the input surplus and the output of the short decision of the decision making unit (DMU). Universitas Malikussaleh as one of the State Universities in Indonesia, it is necessary to follow the regulations of the Ministry of Research, Technology and Higher Education of the Republic of Indonesia (KEMENRISTEKDIKTI), one of which is the measurement of efficiency based on the number of lecturers research, the efficient use of resources included in the number of lecturers and employees, as well as students who can be accommodated based on efficiency measurements using DEA. This paper will measure the efficiency of each department in Malikussaleh University and if there is an inefficient department then it will be measured based on slack-based measures to advise aspects that need attention so that the department can be efficient.

Keywords: *Data Envelopment Analysis, Decision Making Units, Input and Output Slack, Slack-Based Measures*

1. Introduction

Research on benchmarking is now evolving as a follow-up to the process of improvement, quality assurance, evaluation and performance improvement [1]. [2] have used DEA CCR for measuring the relative efficiency of capital and resource placement. DEA has become one of the most appropriate methods for comparing the various Decision Making Units (DMUs) associated with public services such as universities [3].

Measuring the efficiency of college performance is very important to do, but it is difficult to do considering the characteristics of each different college especially if the college is viewed as a non profit organization with multiple outputs generated from multiple inputs. Research conducted by [4] there are 2 (two) main outputs that can be used to measure the performance of universities, namely: the number of graduates and the number of publications. [5] has develops a method to evaluate efficiency for all departments in Universitas Malikussaleh using DEA with bounded output.

A main objective of DEA is to measure the efficiency of a Decision Making Unit (DMU) by a scalar measure, ranging between zero (the worst) and one (the best) [6]. This scalar value is measured through a linear programming model. Specifically, the Charnes-Cooper-Rhodes (CCR) model deals with the ratio of multiple inputs and outputs in an attempt to gauge the relative efficiency of the DMUs. This fractional program is solved by transforming it into an equivalent linear program . The optimal objective value (θ^*) is called the ratio (or *radial*) *efficiency* of the DMU. The optimal solution reveals the existence, if any, of a surplus in inputs and a shortage in outputs (called *slacks*). A DMU with the full ratio efficiency, $\theta^* = 1$, and with no *slacks* in any optimal solution is called *CCR-efficient*. Otherwise, the DMU has a disadvantage against the DMUs in its reference set. Therefore, in discussing total efficiency, it is important to observe both the ratio efficiency and the slacks [6].

Universitas Malikussaleh as one of the State Universities in Indonesia, it is necessary to follow the regulations of the Ministry of Research, Technology and Higher Education (KEMENRISTEKDIKTI), one of which is the measurement of efficiency based on the number of lecturers research, the efficient use of resources included in the number of lecturers and employees, as well as students who can be accommodated based on efficiency measurements using DEA. This paper will measure the efficiency of each department in Universitas Malikussaleh and if there is an inefficient department then it will be measured based on slack-based measures to advise aspects that need attention so that the department can be efficient.

The rest of this paper is organized as follows. In Section 2 we will provide related works in DEA. In Section 3 we describe the methodology used in this research and in Section 4 we provide the experimental process performed in this research. Results and discussion are given in Section 5 and finally, we conclude the research in Section 6.

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2. Related Works

Research conducted by [7] is necessary to measure the relative efficiency of the Decision Making Unit (DMU) in cases involving multiple inputs and outputs. This can be done by analyzing the unctrollable input by using the return to scale variable in the efficiency scale, where it is assumed that the input is not in the convex state. [6] and [8] using Slack-Based Measure in the terms to get full ratio efficiency, $\theta^* = 1$, and with no *slacks* in any optimal solution is called *CCR-efficient.* [9] proposes a slack-based context-dependent DEA which allows a full evaluation of inefficiency in a DMUs performance.

3. Methodology

The mathematical model of DEA proposed by CCR is a fractional programming aimed to measure the efficiency of any DMU. The objective function of the model is to maximize a ratio of the sum of weighted output and the sum of weighted input with constraints of the similar ratio for every DMU which should be at most one. The fractional programming model can be expressed as follows [10].

$$Maximize \ \propto = \frac{\sum_{r=1}^{k} u_r y_{r0}}{\sum_{s=1}^{l} v_s x_{s0}} \quad (1)$$

Subject to

$$(1) \ \frac{\sum_{r=1}^{k} u_r y_{rj}}{\sum_{s=1}^{l} v_s x_{sj}}; \qquad j = 1,...,n$$

$$u_r, v_s \geq 0; \qquad r = 1,...,k; \quad s = 1,...,l$$

In the model, there are *n* number of DMUs with *k* number of outputs resulting from 1 number of inputs. Y_{rj} (>0) are the number of ouput of the j^{th} DMU and X_{sj} (<0) are the number of input of the j^{th} DMU. u_r and v_s are the variable weights to be determined after solving the model. The model (1) is in the form of fractional programming, it would be computationally intractable particularly when the number of DMUs is large. Therefore it is necessarily to convert the model (1) into a linear programming problem, as proposed by [10], which can be written as follows (output oriented).

$$Maximize \quad \beta = \sum_{r=1}^{k} u_r y_{rj}$$

Subject to

$$\sum_{s=1}^{l} v_s x_{sj} = 1; \quad (2)$$

$$\sum_{r=1}^{k} u_r y_{rj} - \sum_{s=1}^{l} v_s x_{sj} \leq 0; \qquad \forall j$$

$$u_r, v_s \geq 0 \qquad \forall r, \forall s$$

3.1. Definition and Computational Scheme of Slack-Based Measure

We will deal with *n* DMUs (Decision Making Units) with the input and output matrices $X = (\chi_{ij}) \in R^{mxn}$ and $Y = (y_{ij}) \in R^{sxn}$, respectively. We assume that the data set is positive, i.e., $X > 0$ and $Y > 0$. The production possibility set *P* is defined as

$$P = \{(x, y) \mid x \geq X\lambda, y \leq Y\lambda, \lambda \geq 0\} \quad (3)$$

We consider an expression for describing a certain DMU (x_0, y_0) as

$$x_0 = X\lambda + S^-$$
$$y_0 = Y\lambda - S^+ \quad (4)$$

3.2. Slack-Based Measure in Linear Programming

With $\lambda \geq 0, s^- \geq 0$ and $s^+ \geq 0$. The values $s^- \in R^m$ and $s^+ \in R^s$ indicate the input surplus and output shortage of this expression, respectively, and are called slacks. From the conditions $X > 0$ and $\lambda \geq 0$, it holds

$$x_0 \geq s^- \quad (5)$$

using s^- and s^+, we define an index ρ as follows,

$$\rho = \frac{1 - \frac{1}{m}\sum_{i=1}^{m} s_i^- / x_{io}}{1 + \frac{1}{s}\sum_{i=1}^{s} s_i^+ / y_{io}} \quad (6)$$

It can be verified that ρ satisfies the properties P1 (unit invariant) and P2 (monotone). Furthermore from (5), it holds

$$0 < \rho \leq 1 \quad (7)$$

Then, Slack-Based Measure become the following linear program in *t*, S^-, S^+, and Λ :

$$min \ \tau = t - \frac{1}{m}\sum_{i=1}^{m} S_i^- / x_{io}$$
$$subject \ to \ 1 = t + \frac{1}{s}\sum_{i=1}^{s} s_i^+ / y_{io} \quad (8)$$
$$tx_0 = X\Lambda + S^-$$
$$ty_0 = Y\Lambda - S^+$$
$$\Lambda \geq 0, S^- \geq 0, S^+ \geq 0, t > 0$$

4. Experimental Process

4.1. Data Description

Universitas Malikussaleh is a state university located at Lhokseumawe city of Aceh province, Indonesia. The name Malikussaleh comes from the name of the first king of the well known kingdom Samudra Pasai. This university has 30 Departments with around 20000 students.

The data of 19 Departments (DMU) with two outputs and two inputs is shown in Table1. There are 11 departments are still new, therefore they do not have graduates yet. As a consequence, these 11 departments are not included in Table 1.

Table 1: List of DMU with input and output data

DMU	INPUT		OUTPUT	
	Number of Lecturers	Number of Students	Number of Research	Number of Graduates
Information Technology	17	588	5	610
Civil Engineering	26	747	5	533
Architectural Engineering	15	396	5	195
Industrial Engineering	17	467	5	300
Chemical Engineering	25	348	5	252
Mechanical Engineering	23	499	5	224
Electrical Engineering	19	420	5	326
Agribusiness	17	689	5	273
Agro-Technology	34	822	5	284
Aquaculture	10	501	5	204
Communication Science	11	719	5	273
Political Science	11	262	5	183
Sociology	13	487	5	204
Anthropology	9	173	5	116

Jurisprudence	50	1096	5	467
Medicine	30	278	4	257
Management	48	1265	5	1302
Economic Development	11	853	5	290
Accounting	23	1127	5	417

4.2. Testing

Using (2) we can find the score of efficiency. For example for DMU1 (Department of Information Technology), the linear programming model can be written as follows.

Maximize 610 U1 + 5 U2
Subject to
17 V1 + 588 V2 = 1
610 U1 + 5 U2 - 17 V1 - 588 V2 <= 0
533 U1 + 5 U2 - 26 V1 - 747 V2 <= 0
195 U1 + 5 U2 - 15 v1 - 396 V2 <= 0
300 U1 + 5 U2 - 17 V1 - 467 V2 <= 0
252 U1 + 5 U2 - 25 V1 - 348 V2 <= 0
224 U1 + 5 u2 - 23 V1 - 499 V2 <= 0
326 U1 + 5 U2 - 19 V1 - 420 V2 <= 0
273 U1 + 5 U2 - 17 V1 - 689 V2 <= 0
284 U1 + 5 U2 - 34 V1 - 822 V2 <= 0
204 U1 + 5 U2 - 10 V1 - 501 V2 <= 0
273 U1 + 5 U2 - 11 V1 - 719 V2 <= 0
183 U1 + 5 U2 - 11 V1 - 262 V2 <= 0
204 U1 + 5 U2 - 13 V1 - 487 V2 <= 0
116 U1 + 5 U2 - 9 V1 - 173 V2 <= 0
467 U1 + 5 U2 - 50 V1 - 1096 V2 <= 0
257 U1 + 5 U2 - 30 V1 - 278 V2 <= 0
1302 U1 + 5 U2 - 48 V1 - 1265 V2 <= 0
290 U1 + 5 U2 - 11 V1 - 852 V2 <= 0
417 U1 + 5 U2 - 23 V1 - 1127 V2 <= 0
U1, U2, V1, V2 >= 0
END

We use software LINDO Release 6.1 Demo Version. The expression (3) is in LINDO format.
The result is as follows.

OBJECTIVE FUNCTION VALUE
1) 1.000000

VARIABLE	VALUE	REDUCED COST
U1	0.001639	0.000000
U2	0.000000	0.000000
V1	0.058824	0.000000
V2	0.000000	0.000000

It can be seen that DMU1 is efficient, as the value of β is 1.0.The score of efficiency for all DMUs can be found in Table 2.

Table 2: Result of efficiencies for each DMU using output-oriented DEA

NO	DMU	DEA SCORE
1	Information Technology	1.0
2	Civil Engineering	0.6982436
3	Architectural Engineering	0.6818709
4	Industrial Engineering	0.7045490
5	Chemical Engineering	0.8069085
6	Mechanical Engineering	0.5265533
7	Electrical Engineering	0.8263003
8	Agribusiness	0.6639550
9	Agrotechnology	0.3810771
10	Aquaculture	1.0
11	Communication Science	0.9912544
12	Political Science	0.9152225
13	Sociology	0.7845375
14	Anthropology	1.0
15	Jurisprudence	0.4226586
16	Medical	1.0
17	Management	0.9921286
18	Economic Development	1.0
19	Accounting	0.5871874

From Table 2 we would be able to observe that DMU1, DMU10, DMU14, DMU16, and DMU18 are efficient. For DMU 2, DMU 3, DMU 4, DMU5, DMU6, DMU7, DMU8, DMU11, DMU12, DMU13, DMU15, DMU17, and DMU19 we can use Slack-Based Measure in determining the input surplus dan the output shortage. The slack value of each DMU can be seen in Table 3.

Table 3: Slack Value for The Inefficient DMU

NO	DMU	SLACK VALUE
1	Civil Engineering	0.301756
2	Architectural Engineering	0.318129
3	Industrial Engineering	0.295451
4	Chemical Engineering	0.228036
5	Mechanical Engineering	0.473447
6	Electrical Engineering	0.173700
7	Agribusiness	0.336045
8	Agrotechnology	0.618923
9	Communication Science	0.008746
10	Political Science	0.084778
11	Sociology	0.215462
12	Jurisprudence	0.577341
13	Management	0.007871
14	Accounting	0.412813

According to the Slack value we can determine the input surplus and the output shortage. For example we can see the DMU Civil Engineering with the slack value 0.301756.
We can increase the output of U_2 (Number of Research) according to the slack value using (4)
$U_2 = 5 + 5*0.301756 = 7$

We can decrease the input of V_2 (Number of Students) according to the slack value using (4)
$V_2 = 747 - 747*0.301756 = 522$

Using Slack-Based Measure We can provide recommendations for improving the efficiency of each department at the Universitas Malikussaleh that can be seen in Table 4.

Table 4: Recomendation of Input and Output for Every DMU to Become Efficient

DMU	INPUT		OUTPUT	
	Number of Lecturers	Number of Students	Number of Research	Number of Graduates
Civil Engineering	26	522	7	533
Architectural Engineering	15	270	8	195
Industrial Engineering	17	329	7	300
Chemical Engineering	25	268	6	252
Mechanical Engineering	23	262	8	224
Electrical Engineering	19	347	6	326
Agribusiness	17	407	9	273
Agro-Technology	34	313	8	284
Communication Science	11	712	6	273
Political Science	11	239	6	183
Sociology	13	382	7	204
Jurisprudence	50	463	8	467
Management	48	1255	6	1302
Accounting	23	561	10	417

Using Slack-Based Measures, Inefficient DMU can become efficient according to the input and output for every DMU. The result of using Slack-Based Measures, all of inefficient DMU become efficient that can be seen in Table 5.

Table 5: The Result of Slack-Based Measures for Inefficient DMU

NO	DMU	DEA Score
1	Civil Engineering	1.0
2	Architectural Engineering	1.0
3	Industrial Engineering	1.0
4	Chemical Engineering	1.0
5	Mechanical Engineering	1.0
6	Electrical Engineering	1.0
7	Agribusiness	1.0
8	Agrotechnology	1.0
9	Communication Science	1,0
10	Political Science	1,0
11	Sociology	1.0
12	Jurisprudence	1.0
13	Management	1.0
14	Accounting	1.0

5. Result and Discussion

The results show that we can use Slack-Based Measure in determining the input surplus and the output shortage. This method can give advise aspects that need attention so that the department can be efficient. The results of this study indicate that the suggestion for improvement of efficiency in general is in line with the provisions of the Ministry of Research, Technology and Higher Education of the Republic of Indonesia (KEMENRISTEKDIKTI), that the number of lecturers research should be improved and also need to consider the ratio between the ratio of the number of lecturers and students. Where most of the results of Slack-Based Measure is largely the increase in output in the form of the number of research faculty and reduce the input of the number of students received to improve the quality of education.

6. Conclusion

First, when there is a value of Non-Zero Input and Output Slacks then this often means inefficiency. Second, we can use Slack-Based Measure in determining the input surplus and the output shortage. This method can give advise aspects that need attention so that the department can be efficient. In the future, we should find different benchmarks for inefficient DMUs.

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