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Dahlan Abdullah[1], Saib Suwilo[2], Tulus[3], Herman Mawengkang[4], Syahril Efendi[5]

[1]Informatics Department, Malikussaleh University, Lhokseumawe, Aceh, Indonesia

[2,3,4]Mathematics Department, University of Sumatera Utara, Medan, Indonesia [5]Faculty of Computer Science and Information Technology, University Of Sumatera Utara, Medan, Indonesia

E-mail: dahlan@unimal.ac.id, saibwilo@gmail.com, tulus@usu.ac.id, hmawengkang@yahoo.com

Abstract. The higher education system in Indonesia can be considered not only as an important source of developing knowledge in the country, but also could create positive living conditions for the country. Therefore it is not surprising that enrollments in higher education continue to expand. However, the implication of this situation, the Indonesian government is necessarily to support more funds. In the interest of accountability, it is essential to measure the efficiency for this higher institution. Data envelopment analysis (DEA) is a method to evaluate the technical efficiency of production units which have multiple input and output. The higher learning institution considered in this paper is Malikussaleh University located in Lhokseumawe, a city in Aceh province of Indonesia. This paper develops a method to evaluate efficiency for all departments in Malikussaleh University using DEA with bounded output. Accordingly, we present some important differences in efficiency of those departments. Finally we discuss the effort should be done by these departments in order to become efficient.
Keywords: Data Envelopment Analysis, Efficiency, Higher education, Performance measurement, Output upper bound.

1. Introduction

In Indonesia, universities as higher learning institutions (HLIs) carry great responsibilities toward increasing the living quality of people, developing the welfare of the country and enhancing scientific knowledge. Due to these reasons, the Indonesian Government has put more effort to increase fund to support the educational processes of the HLIs.

It is common in the higher education sectors in Indonesia to obtain some of their financial support from public funding, particularly from students' tuition fee. The same situation also happens in the HLI Malaikulsaleh University, located in Lhokseumawe city of Aceh province, Indonesia.

In the interest of accountability, it is necessarily to measure the efficiency of Malikussaleh University, as the main focus for this research. However, it should be noted that the HLIs sector has characteristics which make it difficult to measure efficiency. HLIs can be regarded as non-profit organization, there would be no output and input in terms of prices. These sectors could produce multiple outputs from multiple inputs.

Generally, efficiency can be thought as a ratio between output and input. However, it should be noted that the ratio is only valid for one output and one input, meaning that this thought is inadequate if there are multiple outputs and inputs. [1] addressed a method to measure efficiency with multiple outputs and inputs, called relative efficiency, by calculating the ratio of weighted sum of outputs and weighted sum of inputs. Then, Charnes, Cooper and Rhodes (CCR) [2] extended Farrell's idea to develop a methodology for evaluating the relative efficiencies of a set of decision making units (DMUs). This methodology is called Data Envelopment Analysis (DEA). Therefore in DEA we should have a set of DMUs, multiple outputs and multiple input. In higher education system DMU could be Departments to produce 2 outputs, such as number of graduates (y_1) and number of publications (y_2), from an input, number of teaching staff (x).

DEA seems to be one of the most suitable method for comparison of efficiency of various units in public services, such as universities [3]. Public services are always influenced by a public policy (government) to give impact whether directly or indirectly to the expenditure spending and other regulation mechanisms. University, as a public service, is provided by various entities (eg. Teaching staff and non-teaching staff) have their own motives to provide services, particularly for students, which are influenced by a whole range of different stakeholders.

Applications of DEA to measure efficiency of university have been discussed by various authors. It should be noted that DEA method does not primarily to measure the efficiency for HLIs. However, due to the fact that universities belong to the organizations which have multiple outputs and inputs without any market prices, DEA is suitable. The first study concerning with the use of DEA in HLI can be found in the PhD thesis of Rhodes [4]. As the HLIs sector, in most countries around the world, is under pressure to increase efficiency and to improve the quality of its educational activity, it is not surprising that most authors discuss the application of DEA in HLIs for their countries.

From literature it can be found that the assessment of efficiency for HLI in UK has gained a lot of attention. [5] have stated that UK can be regarded as the leader in evaluation of university effectiveness. [6] apply DEA to HLIs in England in the period 2000/01 – 2002/03 to assess the cost structure and the performance of various HLI groups. [7] puts forward another example of DEA application for HLIs in England. He examined more than 100 HLIs using data for the year 2000/01, and found out that technical and scale efficiency for English higher education sector appear to be high on average.

[8] consider that higher education sectors which gain much fund from government is necessarily to be assessed their efficiency performance. In order to be able to get the efficiency result they use DEA, using a sample of 33 Poland faculties specialized in social sciences. They use output oriented model of Charnes-Cooper-Rhodes (CCR) with two inputs and three outputs. In order to analyze the level of competitiveness of HEIs in some countries in Europe, [9] use the score of efficiency for each HEI resulting from DEA method. Their main research is to determine the level of competitiveness of higher education of the Republic of Serbia and Autonomous Province of Vojvodina compared to other HEIs in Europe. [10] also use DEA to evaluate efficiency of HLI in Hungary in order to establish competitiveness with HLI in the European countries.

[11] feature DEA to examine the relative efficiency in conducting research of 109 Chinese regular universities for the year 2003 and 2004. The Impact and productivity of research are treated as output variables, and then for the input variables they use number of staff, students, capital and resources. The same kind of research was also conducted by [12]. However they use DEA and stochastic frontier analysis, and the HLI sectors they consider are universities of science and technology in China. The application of DEA to investigate the efficiency assessment of Iranian public universities was proposed by [13].

The aim of this paper is to evaluate efficiency of all department of Malikussaleh University using DEA. The output variables are number of research produced and number of graduates from input variables number of staff and number of students. We use DEA with CCR model with output oriented. In this case the output variables are bounded. For output oriented, the inputs are assumed to be fixed, while the outputs proportionally expanded would be explored. This type of orientation is deemed to

be more appropriate for university education [10]. For further explanation on DEA with output-bounded data can be found in [14].

2. Linear programming model of DEA

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.

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

Subject to

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

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

In the model, there are n number of DMUs with k number of outputs resulting from l number of inputs. y_{rj} (>0) are the number of output of the jth DMU and x_{sj} (>0) are the number of input of the jth 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 [2], which can be written as follows (output oriented).

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

Subject to

$$\sum_{s=1}^{l} v_s x_{sj} = 1;$$

$$\sum_{r=1}^{k} u_r y_{rj} - \sum_{s=1}^{l} v_s x_{sj} \leq 0; \qquad \forall j \tag{2}$$

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

3. Evaluating the efficiency of each department (DMU) of Malikussaleh University

Malikussaleh University is a state university located at Lhokseumawe city of Aceh province, Indonesia. The name Malaikulsaleh 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. The data shown in Table 1 is for the academic year 2016/2017.

Table 1. List of DMU with input and output data.

NO	DMU	INPUT		OUTPUT	
		NUMBER OF TEACHING STAFF	**NUMBER OF STUDENT**	**NUMBER OF RESEARCH**	**NUMBER OF GRADUANT**
1	INFORMATION TECHNOLOGY	17	588	5	610
2	CIVIL ENGINEERING	26	747	5	533
3	ARCHITECTURAL ENGINEERING	15	396	5	195
4	INDUSTRIAL ENGINEERING	17	467	5	300
5	CHEMICAL ENGINEERING	25	348	5	252
6	MECHANICAL ENGINEERING	23	499	5	224
7	ELECTRICAL ENGINEERING	19	420	5	326
8	AGRIBUSINESS	17	689	5	273
9	AGROTECHNOLOGY	34	822	5	284
10	AQUACULTURE	10	501	5	204
11	COMMUNICATION SCIENCE	11	719	5	273
12	POLITICAL SCIENCE	11	262	5	183
13	SOCIOLOGY	13	487	5	204
14	ANTHROPOLOGY	9	173	5	116
15	JURISPRUDENCE	50	1096	10	467
16	MEDICINE	30	278	4	257
17	MANAGEMENT	48	1265	5	1302
18	ECONOMIC DEVELOPMENT	11	853	5	290
19	ACCOUNTING	23	1127	5	417

Using model (2) we can find the score of efficiency. For example for DMU_1 (Department of Information Technology), the linear programming model can be written as follows.

$$Maximize\ 610U_1 + 5U_2$$
Subject to
$$17V_1 + 588V_2 = 1$$
$$610U_1 + 5U_2 - 17V_1 - 588V_2 \leq 0$$
$$533U_1 + 5U_2 - 26V_1 - 747V_2 \leq 0$$
$$195U_1 + 5U_2 - 15V_1 - 396V_2 \leq 0$$
$$300U_1 + 5U_2 - 17V_1 - 467V_2 \leq 0$$
$$252U_1 + 5U_2 - 25V_1 - 348V_2 \leq 0$$
$$224U_1 + 5U_2 - 23V_1 - 499V_2 \leq 0$$
$$326U_1 + 5U_2 - 19V_1 - 420V_2 \leq 0$$
$$273U_1 + 5U_2 - 17V_1 - 689V_2 \leq 0$$
$$284U_1 + 5U_2 - 34V_1 - 822V_2 \leq 0$$
$$204U_1 + 5U_2 - 10V_1 - 501V_2 \leq 0$$
$$273U_1 + 5U_2 - 11V_1 - 501V_2 \leq 0$$
$$183U_1 + 5U_2 - 11V_1 - 262V_2 \leq 0$$

(3)

$$204U_1 + 5U_2 - 13V_1 - 487V_2 \leq 0$$
$$116U_1 + 5U_2 - 9V_1 - 173V_2 \leq 0$$
$$467U_1 + 5U_2 - 50V_1 - 1096V_2 \leq 0$$
$$257U_1 + 5U_2 - 30V_1 - 278V_2 \leq 0$$
$$1302U_1 + 5U_2 - 48V_1 - 1265V_2 \leq 0$$
$$290U_1 + 5U_2 - 11V_1 - 852V_2 \leq 0$$
$$417U_1 + 5U_2 - 23V_1 - 1127V_2 \leq 0$$
$$U_1, U_2, V_1, V_2 \geq 0$$

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
U_1,	0.001639	0.000000
U_2,	0.000000	0.000000
V_1,	0.058824	0.000000
V_2,	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 DMU_S 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	MEDICINE	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 $DMU_1, DMU_{10}, DMU_{14}, DMU_{16}$, and DMU_{18} are efficient. However if the output variable the number of research (y_2) is increased significantly then the corresponding DMU would be efficient. For example, DMU_2 is inefficient. If y_2 is increased from 5 to 15 then it would be efficient. DMU_3 is inefficient formerly, if we increase y_2 from 5 to 10, it would be efficient. It should be noted that the number of staff for DMU_2 and DMU_3, respectively, are 26 and 15. In order to control the flexibility of output variables, it is necessarily to add the constraints in model (2) with bounded output.

$$LB_{rj} \leq u_r y_{rj} \leq UB_{rj}$$

Where LB is lower bound and UB is upper bound for DMU j.

4. Conclusions

The efficiency assessment of all Department in Malikussaleh University is carried out using CCR output oriented model. The analysis of efficiency can be done by varying the output variables, while the input variables are kept fixed. Nevertheless the output variables should be upper bounded. It is found out that the main important in order to be efficient is to have more number of research. As a matter of fact this finding is synchronized with the urge from Indonesia Government about to have more research scheme.

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