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Efficiency analysis of select state universities and colleges in Southern Philippines using data envelopment analysis

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Abstract

Objectives: This study aims to evaluate the relative efficiency of select state universities and colleges (SUCs) in Southern Philippines using the input-oriented constant returns to scale (CRS) model and input-oriented variables returns to scale (VRS) model of data envelopment analysis (DEA). **Methods:** The input-oriented CRS and VRS model of the DEA is applied to analyze efficiency of selected state universities and colleges in Southern Philippines using four inputs (namely, Number of faculty members, personnel services and maintenance and other operating expenses (PS+MOOE), estimated cost per student, and tuition fee) and three outputs (namely, number of students enrolled, PRC rating, and number of graduates) as parameters. DEA works by comparing each decision-making unit (DMU) and classifies them as either efficient or less efficient. It also provides information on how these less efficient DMUs can be improved. **Findings:** Results of the study show how each unit perform when compared to other units. It showed that among the 26 SUCs considered in this study, only ten (10) SUCs are identified efficient and the remaining sixteen (16) SUCs are less efficient under the input-oriented CRS model. On the other hand, only thirteen (13) SUCs are identified efficient while the remaining thirteen (13) are less efficient under the input-oriented VRS model. These difference in the results from the two DEA models used may be due to the fact that CRS tends to lower the efficiency score while the VRS tends to raise the efficiency score. **Application:** DEA provides insights on how the less efficient SUCs can be improved by adopting the efficiency reference set (ERS) weights of the identified efficient SUCs against the less efficient SUCs in order to improve efficiency. In this way, results of this study provide insights on how the less efficient SUCs in Southern Mindanao can be helped for them to become efficient units.

Keywords: Efficiency; higher education; data envelopment analysis

1 Introduction

Each country values education because it is the way for upward social and economic mobility. It is also responsible in offering capable and competent human resources who will have the ability to perform day-to-day tasks according to the standards that are set by the society. It additionally breaks the bounds made by the differences in a diverse society and encourages the citizens to come together for progress to be done. Just like any educational institutions elsewhere in the world, the fundamental aspiration of the Philippine education is to enhance the quality of life of every Filipino.

Education in the Philippines is managed and regulated by the Department of Education (DepEd), Commission on Higher Education (CHED) and Technical Education and Skills Development Authority (TESDA). DepEd is responsible for the K–12 basic education; it exercises full and exclusive control over public schools and nominal regulation over private schools, and it also enforces the national curriculum that has been put in place since 2013. CHED and TESDA, on the other hand, are responsible for higher education; CHED regulates the academically-oriented universities and colleges while TESDA oversees the development of technical and vocational education institutions and programs in the country.

The assessment of performance of state universities and colleges (SUCs) in the Philippines is important in view of the long-standing issues and concerns that beset the country's system of higher education. In particular, the higher education subsector is haunted by issues of (i) limited and inequitable access to higher education; (ii) inequitable financing of public higher education; (iii) lack of overall vision, framework, and plan for higher education resulting in the proliferation of low quality higher education institutions (HEIs) and programs, oversubscribed and undersubscribed programs as well as skills and job mismatch; (iv) deteriorating quality of higher education due to inadequate faculty credentials and as indicated by the declining performance of graduates in professional licensure exams; (v) crowding out of private provision; and (vi) underdeveloped innovation system [(1)].

Determining the efficiency of educational institution is of great importance. Efficiency analysis of HEIs will allow decision-making units to define policies and guidelines that will improve quality, redirecting policies and decision-making to improve efficiency according to research findings. It translates into actions based on proven empirical evidence, and not on the beliefs and perceptions of the faculty of the institutions or policy guidelines [(2)].

Several techniques have been developed, and have been applied to estimate the efficiency of educational organizations. These include econometric approaches that utilize ordinary least squares regression and stochastic frontier estimation as well as a group of linear programming approaches falling under the rubric of Data Envelopment Analysis (DEA) [(2–4)].

Efficiency means that a school achieves maximum results possible with the limited resources it has. This corresponds to the definition of a production function which shows maximum possible output at a given level of input. In this sense schools may be viewed as production units that use inputs and produce outputs. And, even though, one cannot say what the maximum level of output possible is, one can estimate it by observing the schools that produce most outputs at the given level of input. Inefficiency is then measured using the distance between a given school and the most efficient schools. This is the basic principle of the Data Envelopment Analysis.

Data Envelopment Analysis is known as the method of evaluating the performances of relative decision-making units (DMUs). It provides a single measure and easily deals with multiple inputs and multiple outputs. In DEA, comparative efficiency indicators of the units to evaluate are provided. These units were called the Decision-making units (DMU's). The efficiency of a DMU is measured relative to all other DMUs with the simple restriction that all DMUs lay on or below the extreme frontier. The efficiency frontier is a set of segments interconnecting all the efficient DMUs and it acts as an envelope for inefficient units. An inefficient unit can be enveloped below called input-oriented model or above which is the output-oriented model. DEA has become an extensively studied, application driven 'multipurpose tool' for analysing Decision Making Units (DMUs) that consume multiple inputs to produce multiple outputs where the meaning of the words "DMU", "input", and "output" can be quite freely interpreted. In brief, the DEA is a useful method since it truly estimates efficiency by comparing a unit to the best performing units not to average as regression does; and it can model multi-input and output nature of educational production [(5,6)].

Evaluation of school performance is the main issue in the educational system. A current approach to school evaluation considers the school as production unit that uses multiple inputs (resources) and produces multiple outputs (outcomes). In such a setting, the definition and measurement of the inputs and outputs that reflects the operation of a school for evaluation is not an easy task [(7)].

Studies on the efficiency of state universities and colleges (SUCs) in the Philippines have been made, and some of these used DEA in their evaluation. The paper by Cuenca [(7)] looked into the efficiency of SUCs in the whole Philippines using DEA by considering expenditure data as input parameter and number of enrolled students, number of graduates and total revenue for 78 SUCs in the country. The study identified that majority of the SUCs included in the study were less efficient based on the parameters considered. Another paper [(5)] looked into the efficiency of 59 SUCs all over the Philippines and found out that 49

SUCs were efficient. This study considered as its input parameters the (1) number of faculty members, (2) property, plant and equipment, and (3) operating expenses, while the (1) number of students enrolled, (2) graduates and (3) total revenue. While these studies looked into a broader scope, it must be emphasized that limiting the scope for DEA studies has its own advantages. Due to the need for homogeneity among DMUs considered in a DEA study, it is believed that by focusing only on a particular locality would bring better assessment of the SUCs belonging to a similar locality.

This study explores the use of DEA methodology to assess the efficiency of the SUCs in Southern Philippines by considering the input-oriented CRS model and input-oriented VRS model. Specifically, this study aims to identify which institutions are efficient and what aspects are needed to be adjusted in less efficient SUCs using data from the period 2012-2016. Efficiency scores of each SUC are generated by DEA which determines whether it is efficient or less efficient. This study focuses only on assessing the efficiency of educational institutions, specifically SUCs in Southern Philippines, a total of twenty-six (26) DMUs. The parameters considered in this study are based on local and foreign papers by various authors[1,2,7–9]. Hence, the number of faculty members, PS+MOOE, estimated cost per student, and tuition fee are considered as the input parameters while the number of students enrolled, PRC rating, and number of graduates were considered as output parameters in this study.

This paper is organized as follows. Section 1 gives a brief introduction of the problem considered in this paper. Parameters used in this study are presented in Section 2. Section 3 describes the methodology used while section 4 presents the results obtained in this study. A brief conclusion is given in section 5.

2 Parameter setting

DEA is a linear programming-based methodology that has proven to be a successful tool in measuring efficiency. In this study, the Decision-Making Units (DMUs) are the State Universities and Colleges in Southern Philippines (SUCs), which are shown in Table 1 (presented in alphabetical order). It should be noted that in the presentation of results later in this paper, identities of these DMUs are concealed, and therefore do not necessarily follow this order, for purposes of confidentiality.

Table 1. List of SUCs considered as DMUs in this study.

Adiong Memorial Polytechnic State College	Agusan del Sur College of Agriculture and Technology	Basilan State College
Bukidnon State University	Caraga State University	Central Mindanao University
Cotabato City State Polytechnic College	Cotabato Foundation College of Science and Technology	Davao del Norte State Colleges
Davao Oriental State Colleges of Science and Technology	J.H. Cerilles State College	Jose Rizal Memorial State University
University of Science and Technology of Southern Philippines	Misamis Oriental State Colleges of Agriculture and Technology	Northwestern Mindanao State College of Science and Technology
Southern Philippines Agribusiness, Marine and Aquatic School of Technology	Sultan Kudarat State University	Surigao del Sur State University
Surigao State College of Technology	Tawi-tawi Regional Agricultural College	University of Southeastern Philippines
University of Southern Mindanao	Western Mindanao State University	Zamboanga City State Polytechnic College
Zamboanga State College of Marine Sciences and Technology		

The parameters used in this study are defined as follows.

Input parameters considered in this study are (1) the number of faculty members, (2) personnel services and maintenance and other operating expenses (PS+MOOE), (3) estimated cost per student, and (4) tuition fee.

- The faculty members refer to the number of full-time and part time faculty members of an institution.
- Personal Services (PS) refers to the provisions for the payment of salaries, wages and other compensation/benefits. They cover permanent, temporary, contractual and casual employees of the government. Maintenance and Other Operating Expenses (MOOE) refers to recurring expenses to cover day-to-day requirements of agencies to carry out their regular operations
- Estimated Cost per Student refer to the ratio of SUC's PS+MOOE and Weighted Enrolment.

Output parameters are (1) students enrolled, (2) PRC rating, and (3) graduates.

- Enrollment refers to the number of students enrolled in a given year.
- Professional Regulation Commission (PRC) rating refers to the ratio of number of licensure exam passers to takers in each SUC.
- Graduates refer to the total graduates per year of each SUC.

Tables 2 and 3 show the average data for input and output parameters used in this study. These data are taken from the Commission on Higher Education (CHED) State Universities and Colleges Statistical Bulletin within the time period of 2012-2016. There are four inputs and three outputs that are considered in the study. The inputs are the number of faculty, the PS+MOOE (000'), the estimated cost per student and the tuition fee. On the other hand, enrolment, graduates and the PRC passing rates serve as the output.

Table 2. The average data for input parameters

DMU	INPUT			
	FACULTY	PS+MOOE (Million	ESTIMATED COST PER STUDENT	TUITION FEE
DMU 1	699	88439	8482.8	224
DMU2	419	213565.6	18604.8	205
DMU3	1057	355943.8	12785.6	200
DMU4	199	87213.6	15023.6	191.67
DMU5	144	103140.2	18107.2	175
DMU6	150	59927.8	11265.6	246.67
DMU7	110	54121.8	17151	137.5
DMU8	1250	137282	5701.8	375
DMU9	98	45903.6	15158.2	187
DMU10	376	345238.4	31978.8	471
DMU11	470	152258.8	14899.6	425
DMU12	64	48479.6	41390.2	333.33
DMU13	59	24455	11895	150
DMU14	83	62207.4	31704.2	242.67
DMU15	253	89920.8	10791.8	196.5
DMU16	144	60857	18467.2	283.33
DMU17	506	301436.6	18500.8	310
DMU18	149	87124.2	14479.2	190
DMU19	108	83791.8	26004.2	286.67
DMU20	349	128391.8	10947	283.33
DMU21	490	343742.2	22300.8	405
DMU22	20	23393.6	14290.2	125
DMU23	75	56937	18718	200
DMU24	274	112618.4	16149	306.67
DMU25	347	160193.6	15326.8	314.17
DMU26	299	145507.4	14768.8	350

Table 3. The average data for output parameter

DMU	OUTPUT		
	ENROLLMENT	PRC PASSING RATE	GRADUATES
DMU1	10344	25.56	1803
DMU2	10249	33.46	1634
DMU3	25818	36.80	3201
DMU4	5647	18.56	881
DMU5	5516	29.10	746
DMU6	4232	15.90	1463
DMU7	3766	4.68	349
DMU8	23449	32.24	3524
DMU9	2932	38.34	719
DMU10	10371	60.21	1519
DMU11	11504	52.05	1606
DMU12	1059	42.39	203
DMU13	2131	41.70	383
DMU14	1393	59.68	589
DMU15	8521	53.98	1373
DMU16	3019	30.03	449
DMU17	15845	56.63	2395
DMU18	6904	14.79	970
DMU19	3198	16.90	573
DMU20	10913	32.62	1896
DMU21	15175	34.25	2655
DMU22	2280	9.65	399
DMU23	2965	26.64	343
DMU24	6655	42.85	811
DMU25	10055	30.69	1834
DMU26	9328	26.79	1263

3 Formulation of DEA model to assess the efficiency of SUCs

In this study, DEA Input-Oriented Constant Returns to Scale (CRS) model and Input-Oriented Variables Returns to Scale (VRS) model are used to achieve the efficiency results of selected SUCs in the Philippines. Both models are used in the study to determine the efficiency of SUCs because it is uncertain that SUCs perform at optimal scale [1].

In the case of a CRS model, it is assumed that an increase in the amount of inputs consumed would lead to a proportional increase in the amount of outputs produced. CRS reflects the fact that output will change by the same proportion as inputs are changed. In the VRS model, the amount of outputs produced is deemed to increase more or less than the increase in the inputs. VRS reflects the fact that outputs generated may exhibit increasing, constant and decreasing returns to scale. The two input-oriented DEA models are utilized to compare all of the resources used (input parameters) and services provided (output parameters) of each selected SUCs. CRS model tends to lower the efficiency score while VRS model tends to raise efficiency score.

Inputs should be carefully controlled to ensure the quality of state universities and colleges. This is because the quality of inputs determines the quality of outputs. The production process must be properly monitored in the state universities and colleges system in order to determine the quality of outputs.

Let

θ be the efficiency score for DMU k

Y_{kj} be the average value of output k for DMU j

X_{ij} be the average value of input i for DMU j

V_i be the weighted input assigned by DEA

U_k be the weighted output assigned by DEA
λ_j be the weights of the DMUs
j be the DMUs being compared by DEA
i be the input parameters used by DMU j
k be the output parameters used by DMU j
n be the number of DMUs being considered in k
p be the number of outputs being considered in k
q be the number of inputs being considered in i

The equation below shows the Input-oriented CRS model.

$$Min\ \theta = \left[\frac{\left(\sum_{j=1}^{n} U_j Y_{kj}\right)}{\left(\sum_{j=1}^{n} V_i X_{ij}\right)} \right] \tag{1}$$

subject to

$$\left[\frac{\left(\sum_{i=1}^{n} U_j Y_{kj}\right)}{\left(\sum_{i=1}^{n} V_i X_{ij}\right)} \right] \leq 1 \tag{a}$$

$$\sum_{j=1}^{n} \lambda_i X_{ij} \leq \theta\ X_{i0} \quad i = 1, 2, ...q \tag{b}$$

$$\sum_{j=1}^{n} \lambda_J Y_{kj} \geq \theta \mathrm{Y}_{\mathrm{k}0}, \quad \mathrm{k} = 1, 2, \ldots, \mathrm{p}$$
$$\lambda_{\mathrm{j}} \geq 0 \quad \mathrm{j} = 1, 2....., \mathrm{n} \tag{c}$$

For the VRS model, another constraint is added

$$\sum_{j=1}^{n} \lambda_j = 1 \quad \mathrm{j} = 1, 2, \ldots, \mathrm{n} \tag{d}$$

The equivalent form of linear programming model of the above equation is shown below:

$$\begin{aligned} &\text{Min}\ \theta \\ &\text{s.t.} \\ &\sum_{j=1}^{n} \lambda_j x_{ij} - \theta_{io} \leq 0 \\ &\sum_{j=1}^{n} \lambda_j x_{kj} - \theta_{ko} \geq 0 \\ &\sum_{j=1}^{n} \lambda_j = 1 \qquad \text{Add (VRS)} \\ &\lambda_j \geq 0 \end{aligned}$$

In other words, this study tries to minimize Θ, the efficiency score in equation (1), subject to the constraints (a) that will provide an efficiency rating between zero and one which is generally practice. Constraint (b) corresponds to the sum product of inputs and weights of the services unit less than or equal to the inputs of the services unit being evaluated. Lastly, (c) is the sum product of outputs and weights of the service units greater than or equal to the service being assessed. Weights of each departments are given by DEA, and the other service units with non-zero lambda values are the units in the efficiency reference set (ERS). Relative weights are the weights assigned to inputs and outputs have systematic values. The other DMUs with non-zero lambda (λ) values are the units in the Efficiency Reference Set (ERS).

Data envelopment analysis (DEA) is a powerful mathematical method that utilizes linear programming (LP) to determine the relative efficiencies of a set of functionally similar decision-making units[8]. In this study, each SUC are compared with regards on the inputs and outputs. It also determines the most efficient and the least efficient departments of the said institution.

To solve for the relative efficiency of each DMU in DEA, formulation of DEA model in spread sheet is required and Excel Solver is used to calculate the efficiency of units. If the efficiency score of the unit is one (θ =1), that unit is classified to be 100% relatively efficient (best practices). On the other hand, if the efficiency score of the unit is less than one (θ<1), it implies that the relative efficiency score of that unit being evaluated is less than 100%, hence, that unit is less efficient.

DMU	OUTPUT			INPUT					WEIGHTS	EFFICIENCY
	ENROLLMENT	PRC PASSING RATE	GRADUATES	FACULTY	PS+MOOE	ESTIMATED COST PER STUDENT	TUITION FEE			
DMU1	10344	25.56	1803	699	88439	8482.8	224			
DMU2	10249	33.46	1634	419	213565.6	18604.8	205			
DMU3	25818	36.80	3201	1057	355943.8	12785.6	200			
DMU4	5647	18.56	881	199	87213.6	15023.6	191.67			
DMU5	5516	29.10	746	144	103140.2	18107.2	175			
DMU6	4232	15.90	1463	150	59927.8	11265.6	246.67			
DMU7	3766	4.68	349	110	54121.8	17151	137.5			
DMU8	23449	32.24	3524	1250	137282	5701.8	375			
DMU9	2932	38.34	719	98	45903.6	15158.2	187			
DMU10	10371	60.21	1519	376	345238.4	31978.8	471			
DMU11	11584	52.05	1606	470	152258.8	14899.6	425			
DMU12	1059	42.39	203	64	40479.6	41390.2	333.33			
DMU13	2131	41.70	283	59	24455	11895	150			
DMU14	1393	59.68	509	83	62207.4	31704.2	242.67			
DMU15	8521	53.98	1373	253	89920.8	10791.8	196.5			
DMU16	3019	30.03	449	144	60857	18467.2	283.33			
DMU17	15845	56.63	2395	506	301436.6	18500.8	310			
DMU18	6904	14.79	970	149	87124.2	14479.2	190			
DMU19	3198	16.90	573	108	83791.8	26004.2	286.67			
DMU20	10913	32.62	1896	349	128391.8	10947	283.33			
DMU21	15175	34.25	2655	490	343742.2	22300.8	405			
DMU22	2280	9.65	399	20	23343.6	14290.2	125			
DMU23	2965	26.64	343	75	56937	18718	200			
DMU24	6655	42.85	811	274	112618.4	16149	306.67			
DMU25	10055	30.69	1834	347	160193.6	15326.8	314.17			
DMU26	9328	26.79	1263	299	145507.4	14768.8	350			
								EFFICIENCY		
								VUE		

A		RHS		LHS
OUTPUT	ENROLLMENT	0	>=	0
	PRC PASSINGRATE	0	>=	0
	GRADUATES	0	>=	0
B	FACULTY	0	<=	0
	PS+MOOE	0	<=	0
INPUT	ESTIMATEDCOST PERSTUDENT	0	<=	0
	TUITIONFEE	0	<=	0

Fig 1. Excel solver setup for the CRS and VRS DEA models.

The set of units to be evaluated and the data (inputs and outputs) needed to apply in DEA have to be identified. The data are the actual inputs i used and outputs k generated. This means that the amount of i^{th} input used by the j^{th} unit and the amount of k^{th} output generated by the j^{th} unit are required in order to evaluate the relative efficiency of units.

All DMUs are being evaluated to identify if they are efficient or less efficient. The results of the efficiency rating lie within the interval of zero (0) and one (1). The best practices units are relatively efficient and are identified by an efficiency score of one (θ =1). This defines that the relatively efficient unit where there is no chance to improve efficiency compared with the performance of other unit in the data. The less efficient units are identified by an efficiency score of less than one (θ<1). Efficiency is achieving the goal with lesser resources. Therefore, in this study, efficient SUCs are those who have high output parameters but lesser input parameters (resources) while the less efficient SUCs are those who have high input measures but lesser outputs.

DEA is a very powerful technique in benchmarking [3,5]. There is a need to evaluate less efficient DMUs so that efficiency can be improved. Improvement can be acquired by making each less efficient unit as efficient as to the identified efficient "best practices" units. Specific changes can be classified for the less efficient units through solving the composite values. In order to compute the composite values, it requires the Efficiency Reference Set (ERS) weights. ERS, which is represented by λ, indicates the relatively efficient units against the less efficient units. This shows the set of ERS units that produce as much or more outputs and use less inputs, providing information as to how to improve efficiency of the less efficient units.

Composite values are obtained from the sum of the assigned ERS weights of the efficient unit against the less efficient units and then multiplied to the actual outputs and inputs of the efficient units. It indicates the combination of the operating techniques utilized by the efficient units. The results computed can create a composite hypothetical branch that processes the same number or amount of outputs generated but requires lesser inputs used than the less efficient unit.

4 Results and Discussions

Efficiency ratings both for the CRS and VRS models are shown in Table 4. DMUs with an efficiency score of 1 or 100% is considered to be best practice set or efficient school while DMUs that has an efficiency score of less than 1 or 100% is considered to be less efficient.

Table 4. The Input-Oriented CRS and VRS efficiency ratings

	DMU	efficiency			
		CRS	In percent	VRS	In percent
1	DMU1	0.90130826	90.13	1	100
2	DMU2	0.90019243	90.01	0.925536206	92.55
3	DMU3	1	100	1	100
4	DMU4	0.751573718	75.16	0.830240381	83.02
5	DMU5	0.937437102	93.74	0.938409262	93.84
6	DMU6	1	100	1	100
7	DMU7	0.797978346	79.80	0.943526522	94.35
8	DMU8	1	100	1	100
9	DMU9	0.976732861	97.67	0.980774197	98.08
10	DMU10	0.703248523	70.32	1	100
11	DMU11	0.810018533	81	0.876927105	87.69
12	DMU12	0.922099323	92.21	0.93626599	93.63
13	DMU13	1	100	1	100
14	DMU14	1	100	1	100
15	DMU15	1	100	1	100
16	DMU16	0.542094955	54.21	0.633053963	63.31
17	DMU17	1	100	1	100
18	DMU18	1	100	1	100
19	DMU19	0.530383375	53.04	0.535680704	53.57
20	DMU20	1	100	1	100
21	DMU21	0.949561582	94.96	1	100
22	DMU22	1	100	1	100
23	DMU23	0.761282964	76.13	0.811336366	81.13
24	DMU24	0.685650174	68.57	0.701995852	70.20
25	DMU25	0.887557858	88.76	0.913876734	91.39
26	DMU26	0.881607927	88.16	0.885217272	88.52

It can be seen that in CRS model, out of the 26 SUCs there are 16 schools whose efficiency scores are less than 100% which is considered to be less efficient. The less efficient schools are the following: DMU1, DMU2, DMU4, DMU5, DMU7, DMU9, DMU10, DMU11, DMU12, DMU16, DMU19, DMU21, DMU23, DMU24, DMU25, and DMU26. In order for these less efficient SUCs to benefit from this study, they should minimize their inputs in accordance to the amounts calculated by the CRS DEA model to become efficient.

In VRS model, out of the 26 SUCs there are 13 schools whose efficiency scores are less than 100% which is considered to be less efficient. The less efficient schools are the following: DMU2, DMU4, DMU5, DMU7, DMU9, DMU11, DMU12, DMU16, DMU19, DMU23, DMU24, DMU25, and DMU26. In order for the inefficient or less efficient schools to benefit from this study, DMUs should minimize their inputs in accordance to the amounts calculated by the VRS DEA model to become efficient.

Based on the results, it can be observed that CRS model produces a fewer number of efficient units and has lower efficiency scores among all the DMUs compared to VRS model.

Figure 2 presents the efficiency reference set (ERS) or the benchmarks of less efficient schools assessed in CCR input-oriented model. These ERS includes the group of schools against which each inefficient school was found to be most directly inefficient.

EFFICIENCY REFERENCE SETS (ERS)																
	DMU1	DMU 2	DMU 4	DMU5	DMU7	DMU 9	DMU 10	DMU 11	DMU 12	DMU 16	DMU 19	DMU 21	DMU 23	DMU 24	DMU 25	DMU 26
DMU 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DMU2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DMU 3	0.006671794	0.22756062	0	0	0	0	0	0.023125804	0	0	0	0.025532285	0	0	0	0
DMU 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DMU 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DMU 6	0	0.252709984	0.023850924	0	0	0.235303011	0	0	0	0	0.039512078	0.299990048	0	0	0.230658398	
DMU 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DMU 8	0.420775162	0	0	0	0	0	0	0.042557101	0	0	0	0	0	0	0	0
DMU 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DMU 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DMU 11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DMU 12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DMU 13	0	0	0	0	0	0.745628021	0.559170029	0	0.060093374	0.442933137	0.033347956	0	0.41026439	0.188110981	0	0
DMU 14	0	0	0	0	0	0	0	0	0.668299368	0	0	0	0	0	0	0
DMU 15	0.217648884	0.390286781	0.380480414	0.423079225	0.182423494	0.64949864	0.482229881	0.708803618	0	0.176165222	0.131411093	1.554541672	0.065048628	0.604823748	0.589669282	0.057629929
DMU 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DMU 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DMU 18	0	0	0.33371803	0.12651999	0.251301392	0	0.734404382	0	0	0.02674503	0	0	0.033421078	0.159390548	0.0760437	0.467836658
DMU 19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DMU 20	0	0	0	0	0	0	0	0.354558865	0	0	0	0	0	0	0.323401082	0.513790075
DMU 21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DMU 22	0	0	0	0.455021017	0.209028333	0	0	0	0	0.172195816	0.807002835	0	0.572678993	0	0	0
DMU 23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DMU 24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DMU 25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DMU 26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fig 2. The efficiency reference sets of input-oriented CRS DEA Model for less efficient SUCs

In the CRS DEA model, these ERS weights are generally referred to as Lambda (λ) values in the DEA models. These values are used in computing the composite value of less efficient DMUs in order to determine the potential improvement of the identified less efficient DMUs to become efficient.

After solving the ERS, results are used to come up with composite hypothetical values which are then used to make the less efficient DMUs produce more desirable results. These values are obtained by multiplying the ERS of less efficient DMUs to the respective actual values of inputs and outputs of each SUC declared as relatively efficient DMU by CRS model. The composite values are then subtracted to the actual outputs and inputs of the less efficient DMU. The difference of the composite value and the actual value, either negative or positive result, provide the potential improvement for the less efficient DMU to become efficient. Negative result means that the current input or output of the less efficient DMU must be increased to the obtained value to attain efficiency. A positive result, on the other hand, means that the current input or output used by the less efficient DMU must be reduced to the obtained value for the DMU to become efficient. A sample computation is shown in Figures 3 and 4.

	DMU 3			DMU 8			DMU 15		COMPOSITE
	25818			23449			8521		11894
	36.8			32.24			53.98		25.5592
	3201			3524			1373		1803
0.0067	1057	+	0.4208	1250	+	0.2176	253	=	588
	355943.8			137282			89920.8		79719.85514
	12785.6			5701.8			10791.8		4833.27664
	200			375			196.5		201.8984

Fig 3. The calculation of composite in DMU 1 assigned using input-oriented CRS DEA model

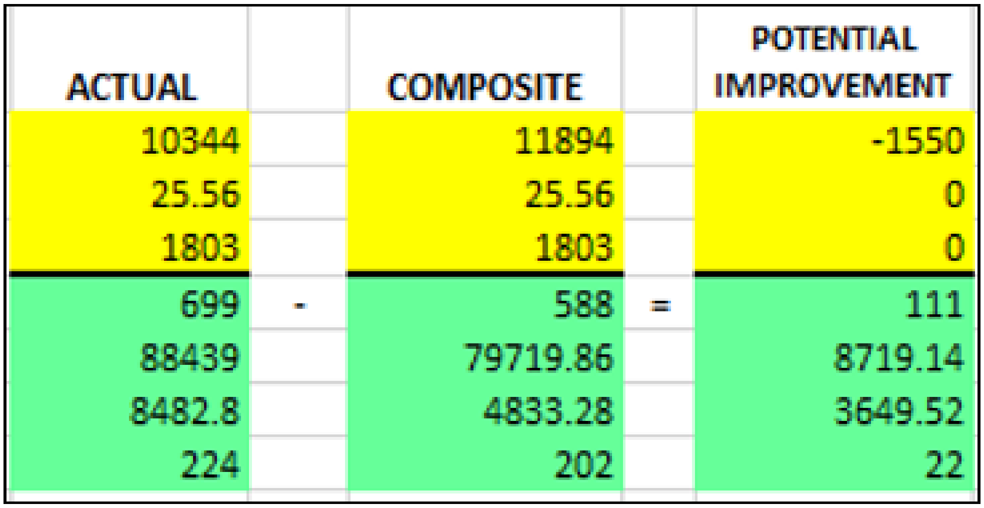


Fig 4. The actual, composite and potential improvement results for DMU 1 calculated using input-oriented CRS DEA model

The values above the lines are the output parameters and below are the input parameters of DMUs. The sum product of the actual inputs and outputs of ERS and the obtained weights by DEA yields the composite schools that will produce as much or more outputs and use lesser inputs which will lead a path to improve the efficiency of the less efficient school.

Figure 3 illustrates that a combination of the parameters used by DMU 3, DMU 8, and DMU 15 would result in a composite theoretical school producing the same or a greater number of outputs as DMU 1. In adopting the combination of the actual parameters utilized by DMU 3, DMU 8 and DMU 15, DMU 1 may reduce its number of faculty by 111, PS+MOOE by P879.14, estimated cost per student by 3649.52 and tuition by P22 in order to become efficient. When this recommendation is followed, this would result to an increase of 1550 in enrolment.

Similarly, potential improvements for DMU 2, DMU 4, DMU 5, DMU 7, DMU 9, DMU 10, DMU 11, DMU 12, DMU 16, DMU 19, DMU 21, DMU 23, DMU 24, DMU 25, and DMU 26 are calculated using input-oriented CRS DEA as shown in Table 5 .

Table 5. Potential improvement results for each DMU calculated using input-oriented CRS DEA

	ENROLLMENT	PRC PASSING RATE	GRADUATES	FACULTY	PS+MOOE	ESTIMATED COST PER STUDENT	TUITION
DMU 1	-1550	0	0	111	8719.14	3649.52	22
DMU 2	-22	0	0	42	82312.95	8635.94	20.45
DMU 4	0	-7.29	0	49	22493.12	5816.36	47.6
DMU 5	0	0	-139	9	43429.41	5207.53	10.95
DMU 7	0	-10.9	-229	22	10936.67	8557.3	27.79
DMU 9	-206	0	0	2	7733.08	2938.1	4.37
DMU 10	0	0	-70	112	224219.34	9489.79	152.83
DMU 11	-1	0	-264	89	28924.69	2830.32	164.66
DMU 12	0	0	-214	5	5436.65	19487.39	162.14
DMU 16	0	0	-57	66	27862.09	8455.81	155.75
DMU 19	0	0	0	51	49916.07	12212.87	145.24
DMU 21	0	-55.37	0	25	176905.41	1819.23	20.44
DMU 23	0	0	-164	16	24750.8	4468.41	47.75
DMU 24	0	0	-246	86	39746.72	5076.69	129.33
DMU 25	0	-16.48	0	39	45198.61	1723.22	35.32
DMU 26	0	0	-244	35	33603.55	1749.25	104.22

Figure 5 shows the ERS weights of the efficient DMU against the less efficient DMUs evaluated for the VRS DEA model. These values are used in calculating the composite values of less efficient DMUs in order to determine the potential improvement of the less efficient DMUs that were identified to become efficient.

EFFICIENCY REFERENCE SETS (ERS)												
	DMU 2	DMU 4	DMU 5	DMU 7	DMU 9	DMU 12	DMU 16	DMU 19	DMU 23	DMU 24	DMU 25	DMU 26
DMU 1	0	0	0	0	0	0	0	0	0	0	0	0
DMU 2	0	0	0	0	0	0	0	0	0	0	0	0
DMU 3	0.25339883	0.05505243	0	0.06313196	0	0	0	0	0	0	0	0
DMU 4	0	0	0	0	0	0	0	0	0	0	0	0
DMU 5	0	0	0	0	0	0	0	0	0	0	0	0
DMU 6	0	0	0	0	0.22631298	0	0.1910851	0.0343772	0	0	0.15352657	0
DMU 7	0.16509819	0	0	0	0	0	0	0	0	0	0	0
DMU 8	0	0	0	0	0	0	0	0	0	0	0	0
DMU 9	0	0	0	0	0	0	0	0	0	0	0	0
DMU 10	0	0	0	0	0	0	0	0	0	0	0	0
DMU 11	0	0	0	0	0	0	0	0	0	0	0	0
DMU 12	0	0	0	0	0	0	0	0	0	0	0	0
DMU 13	0	0.22709368	0.01494354	0	0.61223508	0.96162403	0.73277559	0.00619701	0.50374806	0.20222416	0	0
DMU 14	0	0	0	0	0.08706051	0.03837597	0	0.01395399	0	0	0	0
DMU 15	0.35863654	0.34022237	0.41108379	0	0.07439143	0	0.07613931	0.1384708	0	0.70583743	0.08489714	0.03370986
DMU 16	0	0	0	0	0	0	0	0	0	0	0	0
DMU 17	0	0	0	0	0	0	0	0	0	0	0	0.06776748
DMU 18	0	0	0.14546987	0	0	0	0	0	0.16437251	0	0.08089002	0.45861692
DMU 19	0	0	0	0	0	0	0	0	0	0	0	0
DMU 20	0	0	0	0	0	0	0	0	0	0	0	0.43990575
DMU 21	0	0	0	0	0	0	0	0	0	0	0.51760015	0
DMU 22	0.22286643	0.37763152	0.4285028	0.93686804	0	0	0	0.80700101	0.33187944	0.09193841	0.16308612	0
DMU 23	0	0	0	0	0	0	0	0	0	0	0	0
DMU 24	0	0	0	0	0	0	0	0	0	0	0	0
DMU 25	0	0	0	0	0	0	0	0	0	0	0	0
DMU 26	0	0	0	0	0	0	0	0	0	0	0	0

Fig 5. The efficiency reference sets of input-oriented VRS DEA Model for less efficient SUCs

Figures 6 and 7 illustrate that a combination of the parameters used by DMU 3, DMU 6, DMU 15 and DMU 22 would result in a composite theoretical school producing the same or a greater number of outputs as DMU 2. Thus, in adopting the combination of the actual parameters by DMU 3, DMU 6, DMU 15 and DMU 22, DMU 2 may reduce its number of faculty by 31, PS+MOOE by Php76015.33, estimated cost per student by Php6449.75 and tuition fee by Php15.27 Thus, an increase of 556 in its enrolment can be obtained as shown in Figure 7.

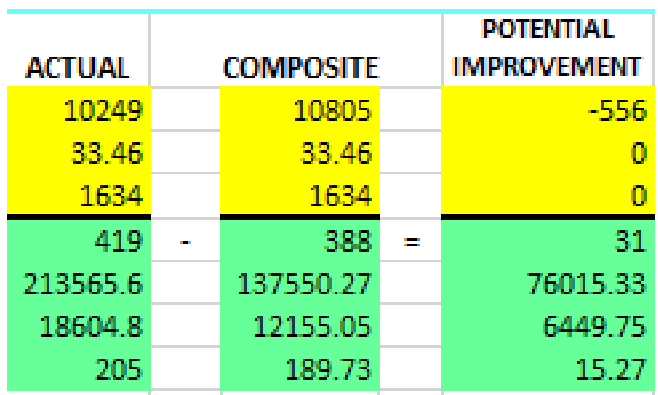
	3			6			15			22		COMPOSITE
	25818			4232			8521			2280		10805
	36.8			15.9			53.98			9.65		33.46
	3201			1463			1373			399		1634
0.2534	1057	+	0.1651	150	+	0.3586	253	+	0.2229	20	=	388
	355944			59927.8			89920.8			23393.6		137550.27
	12785.6			11265.6			10791.8			14290.2		12155.05
	200			246.67			196.5			125		189.73

Fig 6. The calculation of composite in DMU 2 assigned using input-oriented VRS DEA model

In computing the other less efficient schools, similar calculation is done. Hence, we obtain potential improvements for DMU 2, DMU 4, DMU 5, DMU 7, DMU 9, DMU 12, DMU 16, DMU 19, DMU 23, DMU 24, DMU 25, and DMU 26 are calculated using input-oriented VRS DEA, as shown in Table 6.

Table 6. Potential improvement results for each DMU calculated using input-oriented VRS

	ENROLLMENT	PRC PASSING RATE	GRADUATES	FACULTY	PS+MOOE	ESTIMATED COST PER STUDENT	TUITION
DMU 2	-556	0	0	31	76015.33	6449.75	15.27
DMU 4	-19	-14.95	0	34	22622.89	2550.41	32.54
DMU 5	0	0	-136	9	43108.65	5263.38	10.78
DMU 7	0	-6.68	-227	25	9744.28	2955.74	7.77
DMU 9	-86	0	0	2	5262.22	1762.33	3.59
DMU 12	-1044	0	-188	4	22574.91	28734.53	179.77
DMU 16	0	-7.68	-216	53	24637.6	6776	111.31
DMU 19	0	0	0	50	49375.09	12072.2	145.77
DMU 23	0	0	-142	14	22531.46	5603.19	51.72
DMU 24	0	-4.57	-272	82	42057.63	4813.71	126.16
DMU 25	0	0	0	30	13792.11	2206.51	31.55
DMU 26	0	0	-225	34	25604.96	1695.02	110.59



ACTUAL		COMPOSITE		POTENTIAL IMPROVEMENT
10249		10805		-556
33.46		33.46		0
1634		1634		0
419	-	388	=	31
213565.6		137550.27		76015.33
18604.8		12155.05		6449.75
205		189.73		15.27

Fig 7. The actual, composite and potential improvement results for DMU 2 calculated using input-oriented VRS DEA model

In cases when improvements suggested by this study involve reduction of resources, such can also be viewed as a hint for the SUC to increase the other input parameters in order to increase efficiency of the entire DMU. For example, when it is found that there is an excess in the number faculty members, it may be viewed as a hint for the SUC to improve its enrolment, performance in the board exams and number of graduates in order to increase its efficiency. It does not necessarily mean literally reducing the current number of teachers.

5 Conclusions

In this study, the input minimizing DEA approach utilizing the structure of return to scale of DEA model which are the input-oriented CRS model and VRS model is used to measure the relative efficiency of SUCs in Southern Philippines. The two scale models are used in this study because it is uncertain that SUCs operate at optimal scale. The DMUs of this study are select SUCs in Southern Philippines covering the period 2012-2016 using four input and three output parameters.

Results of the study showed that among the 26 SUCs considered in this study, only ten (10) SUCs are found to be efficient while the sixteen (16) SUCs are less efficient under the input-oriented CRS model. On the other hand, in the input-oriented VRS model, thirteen (13) SUCs are identified efficient and the remaining thirteen (13) are less efficient. The distinction of results obtained from the two scale models are due to the fact that CRS tends to lower the efficiency score while the VRS tends to raise the efficiency score. Potential improvements are needed for less efficient SUCs to adopt the Efficiency Reference Set (ERS) weights of the identified efficient SUCs against the less efficient SUCs in order to improve efficiency.

It may be interesting to consider other parameters to better assess the efficiency of the SUCs. Unfortunately, this poses a challenge in the procurement of data. Moreover, just recently, the Philippines implemented RA 10931 (Free Higher Education for Filipinos), which gives free education to students enrolling in SUCs around the country. Evaluating the effect of RA 10931 is hereby mentioned as a possible future work for this paper. This is due to the fact that for DEA to give better results, there is a need to work with a data set obtained for at least 5 years in the implementation of this act.

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