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Estimating Technical Efficiency of Academic Departments of a Philippine Higher Education Institution

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Abstract - *The main thrust of this research is to measure the relative technical efficiency of the six (6) colleges of San Pedro College from school year 2004-2014. The technical efficiency of the academic units can be derived based on its ability to produce the optimum number of output (number of research outputs, number of graduates, and number of community extension conducted) based on a given set of inputs (budget allocation and ratio of the full-time and part-time faculty) using data envelopment analysis. The Nursing/Respiratory Therapy Department is consistent as the highest for the ratio of full-time to part-time faculty while the lowest ratio was observed by Medical Laboratory Sciences Department in 2016, Arts and Sciences in 2015 and Accounting and Business in 2014. In terms of technical efficiency, all departments are technically-efficient during 2014. The Nursing/Respiratory Therapy Department, Physical Therapy Department and Medical Laboratory Sciences Department did not obtain 100% efficiency. In 2016, only the Accounting and Business Management Department did not obtain full technical efficiency score. Further, using the Tobit model, the age of the department, number of baccalaureate teachers, proportion of faculty members with doctorate degree with those who are masters' degree holders, and the dean's qualification were found to be insignificant as sources of inefficiency.*

Keywords- *technical efficiency; academic departments; data envelopment analysis; Tobit model, Philippines*

1. INTRODUCTION

With the scare resources available during the production process, the efficient management of resources becomes a central issue. Many organizations and institutions both from profit and nonprofit organization and public and private organizations use various methods in maximizing their output from the scares inputs. Also, these institutions use various methods to measure their efficiency and then search ways to improve them (Alvarez & Crespi, 2003)[2].

The classical microeconomic textbook considers firms to be homogeneous units. Accordingly, all firms are assumed to operate at the same level of productivity or technical efficiency. However, empirical studies frequently showed that in the real world, some firms are more efficient than others (Smeets et al., 2017[23]; Caves, 1989[6]; Demsetz, 1983)[12]. While some firms operate at the technological frontier and potentially earn high profits, others lag considerably behind and are barely able to survive.

Moreover, under the current financial stringency and the consequent growing pressure for diversification of funding sources by higher education institutions, accountability and cost-effectiveness became a critical topic in higher education during the most recent years. A significant number of empirical studies have hitherto considered the possibility that inefficiency exists in education, particularly in higher education sector (Johnes, 2006[16]; Worthington, 2001)[27]. This raises a concern among policymakers and institutional administrators, as good performance in higher education is believed to produce growth effects (Blanchard, 2004)[5]. Such literature has been using a variety of empirical techniques that allow the identification of efficient institutions and their comparison with the inefficient counterparts. The measurement of institutional efficiency is thus recognized as a first step for the implementation, monitoring and/or evaluation of public-sector reforms.

Various studies in technical efficiency using input and output had been conducted as basis in organizational development and policy making. Liu, Wongcha and Peng (2012)[19] analyzed the technical efficiency of 40 Teacher's colleges of Thailand by taking a multiple input-output educational production function. They find that high personnel's quality, more intensity funds and more research and development have positive impact in the technical efficiency scores of teacher's colleges, while the years of establishment of the colleges has no impact on it. In Florida, schools were studied to determine their technical efficiency and explain their efficiency. A motivation for this analysis comes from recent state and federal level educational initiatives designed to improve school accountability and reduce class sizes. Results presented here indicate that while Florida schools are not operating at efficient levels (with regional mean inefficiency estimates in the 4.1–5.1% range), they compare favorably to published results for other states (Conroya & Argueab, 2007)[10].

Studies conducted by Man and Fung (2011)[20] measures efficiency of Hong Kong Public Funded Universities by using output-oriented DEA (data envelopment analysis).

The study reveals that teaching universities are performing better than Research Universities in both teaching and researches. However, they observe that time is not a critical factor on the performances for both groups.

San Pedro College is a nonprofit organization; thus, the assessment of performance cannot be assessed through its profit and return on investment. Each department of this institution has different vision and missions which is a service provider and they allocate funding for seminar, trainings, and other professional development among six departments. In this current situation where the institution experiences low generation of income due to the implementation of K-12 program raises a concern among policymakers and institutional administrators to determine which among these six departments are technically efficient so that it will be benchmarked by the other departments. Thus, the above scenario prompted the researcher to assess the technical efficiency of six academic units in San Pedro College. Also, the researcher will further explain factors to explain the variation of technical efficiencies.

1.1 Research Objectives

The main thrust of this research is to measure the relative technical efficiency of the six (6) colleges of San Pedro College from school year 2004-2014. Specifically, it aims to (1) determine the distribution of inputs and outputs for technical efficiency of the six colleges in terms of budget allocation, ratio of full-time and part-time faculty, number of research outputs, number of graduates, and number pf community extensions conducted; (2) assess the technical efficiency performance of six departments; and determine the factors to explain the variation of technical efficiencies, which may include qualification of the deans, number of baccalaureate faculty, proportion of doctors to masters and age of the department.

2. THEORETICAL FRAMEWORK

2.1 Theoretical Underpinnings of Technical Efficiency

This study is anchored on the theory of production that a firm utilizes different kinds of resources (inputs) and produces tangible goods or intangible services (outputs) to satisfy the needs of its customers. The inputs are also termed production factors and usually include capital, labor, materials, etc. The transformation of inputs into outputs is a production process. The production frontier, which characterizes the relationship between inputs and outputs, species the maximum output achievable by employing a combination of inputs. The distance between the maximum output or the production frontier) and the actual output is regarded as its technical inefficiency. Thus, a firm either operates below the frontier when it is technically efficient (Shao & Lin, 2000).

Furthermore, the study hinged on the concept of technical efficiency (Tung, 2013[25]; Farrell, 1957[13]; Debreu, 1951). Technical efficiency reflects the ability of a firm to obtain maximum output based on a given set of inputs, and/or conversely, the use of minimum amount of inputs to produce specific amounts of outputs (Tung, 2013)[25]. As adopted in this study, the technical efficiency of the academic units can be derived based on its ability to produce the optimum number of output (research output, number of graduates and number of community extension conducted) based on a given set of inputs (budget allocation and ratio of the full time and part time faculty).

Suppose there are N firms each producing M outputs using K inputs. The DEA method essentially tries to determine for each firm, what set of output and input weights yields maximum efficiency given the outputs and inputs of the other firms in the sector (Valderrama & Bautista, 2009)[26]. The dual formulation which is the easiest to compute numerically can be written as:

$$\max_{\phi_i, \lambda} \phi_i \text{ for } I = 1, \ldots, N$$

subject to

$$Y\lambda - \phi_i y_i \geq 0$$

$$x_i - X\lambda \geq 0$$

$$\lambda \geq 0 \qquad (1)$$

$$\sum_{j=1}^{N} \lambda_j = 1$$

where X and Y are the K x N input and M x N output matrices, respectively; x_i and y_i are the input and output vectors of firm i. λ is an N x 1 vector of constants and ϕ_i is the efficiency index of firm i. This output–oriented DEA formulation assumes variable returns to scale (VRS). A constant returns-to-scale (CRS) formulation can be obtained by simply removing the last constraint. Note that $1 < \phi_i < \infty$ is an index whose inverse, E_i, is a measure of the technical efficiency of firm i relative to the most efficient firm in the group:

$$0 < E_i = \frac{1}{\phi_i} \leq 1 \qquad (2)$$

where $E_i = 1$ indicates that firm I is at the boundary of the technical frontier and hence, is the most efficient among the group of firms to which it belongs. Note that the linear program is applied N times, once for each DMU/firm.

3. METHOD

This study utilized a non-parametric econometric modeling technique also known as data envelopment analysis (DEA) in determining the technical efficiency of academic units in San Pedro College. DEA measures the relative efficiency in the presence of single input-output and multiple inputs and outputs factors of firms or decision-making units (Akter, 2010)[1]. When the weights are restricted, efficiency of DMUs could be defined as the ratio of the weighted sum of outputs over the weighted sum of inputs (Talluri, 2000)[24], as:

$$\text{Efficiency} = \frac{\Delta y}{\Delta x} \qquad (3)$$

The data of the input (budget allocation and ratio of the full time and part time faculty) and output (research output, graduates, and community extension conducted) will be gathered from the Nursing and Respiratory Therapy department, Pharmacy department, Physical Therapy department, Arts and Sciences department, Management and Business department, Medical Laboratory Sciences department from 2004-2104.

The study adopted the complete enumeration method for data collection. All the department of in San Pedro College will be part of the study. Dataset of the study were collected from the secondary sources from the record of the human resource, finance, registrar, community extension services and research and publication office. The data were gathered through data mining of these offices that will include variables of the input and output as identified by the researcher.

In the analysis of the data, the study used descriptive statistics to determine the relative distribution of output such as research output, number of graduates and community extension conducted and input in terms budget allocation and ratio of the full time and part time faculty. In determining the efficiency of the academic units, the data envelopment analysis was utilized using Coelli's (1996)[9] DEAP 2.1.

After DEA was introduced as a good tool in measuring efficiency, there were econometricians seeking econometric model to explain the variations of efficiency scores. Most of the econometricians found out that the Tobit regression is the appropriate model in determining the variables associated with the fluctuations of the efficiency scores. Tobit regression is one of the models with limited dependent variable. Specifically, this model is applied when the dependent variable is continuous, but its range may be constrained. This model was originally introduced by James Tobin, a laureate economist, in 1958. The standard Tobit model is given by:

$$Y^*i = X'i\beta + \varepsilon i, \qquad i = 1, 2, \ldots N$$
$$Yi = y^*1 \qquad \text{if } y^*i > 0$$
$$Yi = 0 \qquad \text{if } y^*i \; ? \; 0$$

where X is k^*n vector of observations; εi error term is assumed to be normally identically distributed (0, o^2) and independent of Xi, β is a k * 1 vector of parameters; y* is a T*1 vector of observation on dependent variable. This model is also referred to as the censored regression model where all negative values are mapped to zeroes, that is, observation are censored to zero. The model describes the probability (e.g., probability of observing a zero outcome) and the distribution.

4. RESULTS

Essentially, there are two main methodologies for measuring technical efficiency: the econometric (or parametric) approach, and the mathematical (or non-parametric) approach. The two techniques use different methods to envelop data, and in doing so they make different accommodation for random noise and for flexibility in the structure of production technology (Porcelli, 2009)[21]. DEA is a state of the art benchmarking technique which is particularly useful for multi-criteria benchmarking studies. In DEA, the productivity of a unit is evaluated by comparing the amount of output(s) produced in comparison to the amount of input(s) used. The performance of a unit is calculated by comparing its efficiency with the best observed performance in the data set.

The first two table of this section is the distribution of the input and output of the production. As shown in table 1 is the distribution of input of the six departments from 2014-2016. The inputs of this analysis were the budget allocation, ratio of the full-time faculty to part time faculty and the total enrollees. In terms of budget allocation, the Arts and Sciences Department got the highest budget allocation from 2014-2016 amounting to P782, 000.00 to P961, 000.00

Table 1. Distribution of Inputs of the Six Academic Departments from 2014-2016

Year	Department	Budget Allocation	Ratio (F/P)	Total Enrollees
2016	Accounting/Business Management	290,000	1.467	709
	Arts and Sciences	782,000	2.083	960
	Medical Laboratory Sciences	435,000	0.7500	2,878
	Nursing/Respiratory Therapy	547,500	12.667	1,878
	Pharmacy	192,500	10.250	1,023
	Physical Therapy	145,000	1.3125	686
2015	Accounting and Business Management	230,000	1.417	851
	Arts and Sciences	992,000	0.545	1,211
	Medical Laboratory Sciences	519,000	6.000	3,782
	Nursing/Respiratory Therapy	870,000	1.479	1,642
	Pharmacy	319,500	0.893	1,381
	Physical Therapy	272,000	1.536	807
2014	Accounting and Business Management	755,00	0.450	872
	Arts and Sciences	961,500	1.404	1,297
	Medical Laboratory Sciences	386,500	0.558	3,513
	Nursing/Respiratory Therapy	822,000	21.000	1,403
	Pharmacy	249,500	9.250	1,415
	Physical Therapy	245,500	1.000	753

while the lowest budget allocation was observed by two departments Accounting and Business Management in 2014 and 2015 and Physical Therapy in 2016. The Nursing/Respiratory Therapy Department is consistent as the highest among six departments for the ratio of full time to part time faculty while the lowest ratio was observed by the three departments, Medical Laboratory Sciences Department in 2016, Arts and Sciences in 2015 and Accounting and Business in 2014. In terms of total enrollees, included as input because of its potential source of income in the college, the Medical Laboratory Sciences Department got the highest enrollees from 2014- 2016 while the Physical Therapy Department got the lowest.

Table 2 Distribution of Outputs of the Six Academic Departments from 2014-2016

Year	Department	Research Output	Extension	Total Graduates
2016	Accounting/Business Management	0	0	68
	Arts and Sciences	0	0	120
	Medical Laboratory Sciences	0	1	294
	Nursing/Respiratory Therapy	2	1	145
	Pharmacy	0	1	150
	Physical Therapy	0	1	27
2015	Accounting/Business Management	0	0	96
	Arts and Sciences	0	4	129
	Medical Laboratory Sciences	0	1	205
	Nursing/Respiratory Therapy	0	1	150
	Pharmacy	0	1	130
	Physical Therapy	0	1	15
2014	Accounting/Business Management	0	0	77

	Arts and Sciences	0	2	100
	Medical Laboratory Sciences	1	1	253
	Nursing/Respiratory Therapy	0	1	256
	Pharmacy	0	1	132
	Physical Therapy	0	1	29

Shown in table 2 is the distribution of output of the six departments from 2014-2016. In terms of research outputs, only the Medical Laboratory Sciences produced one research in 2014, all departments do not have research output in 2015 and the nursing department produced two researches output in 2016. The Arts and Sciences department dominated the Community and Extension services in the year of 2014-2015 having 2 and 4 CES activities; however, Arts and Sciences department got zero activity in 2016. The Accounting and Business Management do not have any departmental CES activities from 2014-2016. The Medical Laboratory Sciences got the highest number of graduates from 2015-2016 and Nursing/Respiratory Therapy got the highest number of graduates in 2014. The Physical Therapy department got the lowest graduates from 2014-2016.

The DEA technique uses the linear programming methods to construct a non-parametric piece-wise surface (or frontier envelopment) for all sample observations, which provides a yardstick for all DMUs in a sample. This surface is determined by those units that lie on it, that is the efficient DMUs. Efficiency measures are then calculated relative to this surface. A unit on the efficient frontier is given a score of 1. Units that do not lie on that surface can be considered as inefficient and an individual inefficiency score will be calculated for each one of them, given a score between 0 and 1 (Hanh, 2009). Furthermore, it follows that the policy or decision in the DMUs during that year will result to three conditions, equal increase of output resulting from the same increase in input, an increase in input will result to more increase in output and an increase input will result to a lesser increase in output.

The analysis of the technical efficiency is categorized into Constant Returns-to-Scale (CRS) where an increase in unit in any inputs will correspond to same increase in unit in any output. Another basis for the analysis for technical efficiency is the Variable Returns-to-Scale (VRS) that combines the increasing returns to scales and decreasing returns to scales (Charnes, Cooper & Rhodes, 1978)[7]. The technical efficiency is measured as the ratio between the observed output and the maximum output, under the assumption of fixed input, or, alternatively, as the ratio between the observed input and the minimum input under the assumption of fixed output (Koopmans, 1951)[18]. There are two approaches for the data envelopment analysis the first one is the input oriented where one is considering the ability to avoid waste by producing as much output as input usage allows, i.e. we evaluate the ability to minimize inputs keeping outputs fixed and second one is the output oriented where one is considering the ability to avoid waste by using as little input as output production allows, i.e. evaluating the ability to maximize outputs keeping inputs fixed. In this study, the researcher used the output-oriented approach (Debreu, 1951[11]; Farrell, 1957)[13].

Shown in table 3 is the technical efficiency performance of the six academic departments in year 2014. All the academic departments were found to be technically-efficient in 2014 using the CRS and VRS assumption. This means that all of the departments produced same level of combined output with the same level of combined input (Karimzadeh, 2012)[17]. In year 2015, The Accounting and Business Management, Arts and Sciences and Pharmacy are technical efficient while Medical Laboratory Science, Nursing/Respiratory Therapy and Physical Therapy are not technically efficient in the context of CRS. In terms of the VRS assumptions all departments are technically efficient. To make the Nursing, Physical Therapy and Medical Laboratory Sciences Department efficient, they should increase output by 14.3%, 8.8% and 3.8%, respectively. In 2016, the Arts and Sciences, Medical Laboratory Sciences, Nursing/Respiratory Therapy, Nursing/Respiratory Therapy, Pharmacy, Physical Therapy are technically efficient while the Accounting and Business Management is not technically efficient in terms of CRS while all of the department are technically efficient in terms of VRS. The Accounting and Business Management Department should increase their output by 17% to be technically efficient.

Table 3. Technical Efficiency Performance of the Six Academic Departments in 2014-2016

Departments	2014		2015		2016	
	CRS	VRS	CRS	VRS	CRS	VRS
Accounting and Business Management	1.00	1.00	1.00	1.00	0.83	1.00
Arts and Sciences	1.00	1.00	1.00	1.00	1.00	1.00
Medical Laboratory Sciences	1.00	1.00	0.962	1.00	1.00	1.00
Nursing/Respiratory Therapy	1.00	1.00	0.857	1.00	1.00	1.00
Pharmacy	1.00	1.00	1.00	1.00	1.00	1.00

Physical Therapy	1.00	1.00	0.912	1.00	1.00	1.00

The uncontrolled or discretionary variables are an important weakness of model developed in Charnes, Cooper, and Rhodes (1978)[7]. Some variables are outside the control of manager. Maximization of equi-proportionate contraction should be made by omitting these variables to obtain more precise efficiency scores. However, to get more realistic individual efficiency scores, one might isolate in some way this type of variable, known as non- discretionary variables, and their effects on the final performance of the observed units. Banker and Morey (1986) adapt the mathematical programming treatment of DEA models to allow a partial analysis of efficiency based on what they initially termed exogenously and non-exogenously fixed inputs and outputs.

Adjusting for the environmental variables is another extension of the basic DEA model to evaluate some factors that could influence the efficiency of a firm, where such factors are not traditional inputs and are assumed not under the control of the manager. There are several possible approaches to the consideration of environmental variables such as the "three stages" method proposed by Charnes, Cooper and Rhodes (1981)[8], the possible method is to include the environmental variable(s) directly into the linear programming formulation (Ferrier & Lovell, 1990). The two-stage approach involving a DEA problem in the first stage analysis and regressing the efficiency score from the first stage in the second stage by OLS or Tobit regression is recommended in most cases. Some considerable advantages of this approach are that both continuous and categorical variables can be easily accommodated in the second step and hypothesis test to see if the variables have a significant influence upon efficiency can be conducted.

The causes of technical inefficiency vary (Betonio et al., 2016[4]; Cruz, 2004). To identify some of the key determinants of the differences in the technical efficiency scores, the Tobit regression analysis was used. The technical efficiency scores derived from the previous analysis are used as the dependent variable and the qualification of the deans, number of baccalaureate faculty, proportion of doctors to masters and age are used as explanatory variables.

Table 4 shows the test of significant factors to explain the variation of technical inefficiency of the six academic departments. It was found out that qualification of the deans, number of baccalaureate faculty, proportion of doctors to masters and age of the department are not significant factors to explain the variability of the technical inefficiency. This means that these variables cannot determine the technical inefficiency.

Table 4. Test of significant factors to explain the variation of technical efficiency of the six academic departments

Inefficiency Sources	Coefficient	SE	z
(Intercept)	-0.0665045	0.194155	-0.343
Dean's Qualification	-0.0134789	0.095435	-0.141^{ns}
Number of faculty members with bachelor's degrees	-0.00582429	0.007728	-0.754^{ns}
Proportion of doctors to masters	0.240225	0.212908	1.128^{ns}
Age of the department	0.000802113	0.003688	-0.218^{ns}

5. CONCLUSION

The researcher utilized the data envelopment analysis (DEA) to determine the technical efficiency of the six departments. The inputs are the budget allocations, number of enrollees, and ratio of fulltime to part time faculty. The Nursing/Respiratory Therapy Department is consistent as the highest among six departments for the ratio of full time to part time faculty while the lowest ratio was observed by the three departments, Medical Laboratory Sciences Department in 2016, Arts and Sciences in 2015 and Accounting and Business in 2014.

The Arts and Sciences department dominated the Community and Extension services in the year of 2014 to 2015 having two and four community extension activities; however, Arts and Sciences department got zero activity in 2016. The Accounting and Business Management do not have any departmental CES activities from 2014-2016. The Medical Laboratory Sciences got the highest number of graduates from 2015-2016 and Nursing/Respiratory Therapy got the highest number of graduates in 2014. The Physical Therapy department got the lowest graduates from 2014 to2016.

In terms of technical efficiency, all departments are technical efficient during 2014. The Nursing/RT Department, Physical Therapy Department and Medical Laboratory Sciences Department do not obtain 100% efficiency. In 2016, only the Accounting and Business Management Department is not technically efficient. Further, the age of the department, number of teachers with bachelor's degree, proportion of doctors to masters and the dean's qualification are not considered sources of inefficiency.

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