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Measuring Technical Efficiency in Research of State Colleges and Universities in Region XI Using Data Envelopment Analysis

by
Ed D. Cruz

For additional information, please contact:

Author's name:	Ed D. Cruz
Designation:	Associate Dean
Agency:	School of Applied Economics
	University of Southeastern Philippines
Address:	Obrero Campus, Davao City
Telefax:	(082) 227-2098
E-mail:	ecruz_aug@yahoo.com

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ABSTRACT

Although considered very important component of human capital formation, state colleges and universities also constitute a major expenditure component of the taxpayers. Thus, there is a growing concern on the money the government allocates to higher educational system and the results for the society as a whole in terms of accountability, equity, quality and productivity.

The objectives of this study were to benchmark research state colleges and universities (SCUs) in Region XI using Data Envelopment Analysis (DEA); and to determine the factors of technical inefficiency for transformational leadership assessment and accountability using Tobit Analysis. Four regional SCUs were included in this study: University of Southeastern Philippines (USEP), Davao del Norte State College (DNSC), Davao Oriental State college of Sciences and Technology (DOSCST), and Southern Agri-Business and Aquatic School of Technology (SPAMAST). These regional SCUs were compared with "best-practice" universities: University of Southern Mindanao (USM) and the Notre Dame of Marbel University (NDMU).

The overall results suggest that the regional SCUs were inefficient when compared with USM in terms of technical efficiency, using value grants as output. The regional SCUs, however compared favorably with NDMU. In terms of number of publications, regional SCUs especially DOSCST and USEP fared favorably with USM and outperformed NDMU. Using Tobit Analysis, findings indicated that the age of the institution and the dummy for research allocation were determinants of technical efficiency. Results of the study could provide a helpful step toward further productivity studies of SCUs.

I. Introduction

Research and Development (R and D) play a crucial role in economic growth. The connection between R and D and economic growth is overwhelming (Atkinson, 1997; Griffith, 2000; Funke and Niebuhr, 2000; Ontario Ministry of Energy, Science and Technology, 2000; Oxley and Zhu, 2000; Massachusetts Technology Collaborative, 1998). Atkinson (1997) noted that 50% of the growth in the American economy in the last 40 years has been due to investments in research and development. Todaro (2000) observed that the high rates of economic growth in many countries have been sustained by the interplay of many new technological innovations based on a rapid advancement in the stock of scientific knowledge. While there seems to be a general consensus among economists of a positive and fairly substantial social return on investment in R and D, estimates of the exact magnitude of that return vary widely.

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[1] Faculty Member, School of Applied Economics, University of Southeastern Philippines, Obrero, Davao City.

Education is a significant component of the service sector because it underlies the competitiveness of a country's economy. Universities are very important component of human capital formation. It should be noted, however, that they also constitute a major expenditure component for the taxpayers. Because large amounts of resources are utilized on education, it is not surprising that the issue of its efficient utilization is often raised. More importantly, the advancement in technology creates increasing pressure from government and the community for accountability (Cleary, 2001 by Lee, 2001), quality, productivity, and undergraduate education (Gaither, Nedwek and Neal, 2002).

The efficiency by which hired inputs produce the desired outputs is an important public policy issue. The government is confronted with the problem of providing higher education in a more effective manner that enables existing resources to be used to meet increasing demand for education.

Assessing the performance of SUCs, however, is more difficult than assessing the performance of private colleges and universities. The performance measures often used in the private schools are simply not suitable when assessing the SUCs. For instance, profit maximization is not one of the explicit aims of SUCs. Thus, their performance cannot be measured in terms of profit, return on investment, or productivity. More importantly, SUCs have wide and varied aims or objectives - they are basically service provider institutions.

II. Objectives of the Study

The purpose of this study is to benchmark research SUCs in Region XI against "best practiced" research institutions in neighboring areas. The specific objectives were:

1) To design key performance indicators of research state colleges and universities;
2) To determine the technical efficiency in research of state colleges and universities in Region XI, and,
3) To determine the sources of efficiency in the different SUCs.

III. Methodology

The study had two phases: Phase 1 measured the technical efficiency scores in research of the different state colleges and universities in Region XI using Data Envelopment Analysis (DEA). Phase II determined the causes of technical inefficiency using Tobit Regression Analysis.

DEA is a deterministic way of constructing a "piecewise linear" convex hull to the observed or available set of output and input data. In this approach, the efficiency of a firm is measured relative to the efficiency of all the other firms, subject to the restriction that all firms are on or below the frontier. DEA is an extreme point method and compares each decision-making unit (DMU) with only the "best" DMU. The following SUCs were included in the study: USEP; DNSC; DOSCST; and SPAMAST. These SUCs were then compared with "best practice" research academic institutions such as USM and NDMU.

Technical efficiency is the ability of the firm to produce the maximum amount of outputs using specific amounts of inputs, and/or conversely, the use of minimum amount of inputs to produce specific amounts of outputs. To measure technical efficiency of the different public academic institutions, there is a need to specify the inputs and the outputs. Three (3) DEA models were used. The first model used total number of academic staff, total number of non-academic staff, and combined expenditures on MOOE and 10% of the Capital Outlay expenditures as inputs; and, value of research grants received by the institution from various funding agencies as output. The first model is a slight modification of the input-output specifications by Abbott and Doucougliagos (1995) which used research grants as output; and, total number of academic staff, total number of non-academic staff, expenditure on all other inputs other than labor inputs, and value of non-current assets as inputs. The second model used national budget allocation for research; total number of academic staff; and, total number of non-academic staff as inputs; and, research grants as output. The third model is a modification of the first model. It used the same inputs as in Model 2 but utilized the weighted number of publications as output.

These DEA models were estimated under the assumptions of Constant Returns to Scale (CRS), and Variable Returns to Scale (VRS). DEA 2.1 was used to calculate the technical efficiency scores of the different academic institutions.

Phase II determined the causes of technical inefficiency using the Tobit Regression Analysis. To facilitate the Tobit framework, the dependent variable used technical inefficiency rather than technical efficiency. Technical inefficiency was calculated by subtracting the technical efficiency scores. The regression model took the form:

$$y^* = x\beta + \varepsilon_t$$

where:

- y^* is a T x 1 vector of observations on the dependent variable
- x is a T x k matrix of observations on the explanatory variables
- β is a k x 1 vector of parameters
- ε is a T x 1 vector of error terms for T observations

If y^* is unobserved and we observe y instead, then the Tobit model can be defined with the use of a latent variable as (Maddala, 1992):

$$y_t = \begin{cases} y_t^* & \text{if} \quad y_t^* > 0 \\ 0 & \quad\;\; y_t^* \le 0 \end{cases}$$

SHAZAM Version 9.0 was used to compute for the estimates of Tobit Regression using Maximum Likelihood Estimation (MLE). The likelihood function is the joint density function of the dependent variable y_t. In the case of Tobit model, the likelihood function is also the joint probability density of the y_t but this joint probability density is now broken up into two parts. The likelihood function for the Tobit model, under the distributional assumptions of the model, is:

$$L\left(\beta, \sigma^2 \mid (y_1, \ldots, y\right) = \Pi\left(1 - F_t\right)\Pi\left(\frac{1}{\sigma}\right)\phi\left(\frac{y_t - x_t\beta}{\sigma}\right)$$

where:

L is the likelihood function,

$\Pi(1 - F_t)$ the joint probability density of y_ts equal to zero,

$\Pi\left(\frac{1}{\sigma}\right)\phi\left(\frac{y_t - x_t\beta}{\sigma}\right)$ the joint probability density of y_ts greater than zero.

The technical inefficiency scores from the three DEA models were used as the dependent variable with number of academic staff; proportion of academic staff with a PhD; number of campuses; number of years since its establishment; student population; research allocation from GAA; total number of students enrolled in and graduated from the PhD program; number of graduate and undergraduate degree programs as the explanatory variables.

The number of academic staff and the proportion of academic staff with a PhD were used as possible indicators of the quality of academic staff. The total number of academic staff was used as an indicator of the size of administration. Because it is often alleged that “old” institutions are more efficient than “new” ones, the number of years since establishment of the institution is also included. In addition, the number of campuses was also included as a possible indicator of efficiency. It is assumed that as an institution grows in size the expansion of campuses may allow the institutions to specialize in their activities.

The impact of the size of the university on technical efficiency was investigated by including the number of students serviced by the university including the total number of PhD students. A dummy variable was used to capture differences in budget allocation for research to help identify the impact of the budget on efficiency. The dummy variable for research allocation, D_t, took on the following values:

$$D_t = \begin{cases} 0 & \text{if} \quad y < 1{,}000{,}000 \\ 1 & \quad otherwise \end{cases}$$

The choice of PhP1,000,000 as a discriminating value was based on the assumption that this amount intended for research might be large enough to make an impact.

IV. Results and Discussion

Table 1 shows the relative efficiency scores of the four SUCs in Region XI using three (3) DEA models from 1997 to 2001. The third column of the table, labeled CRS, presents the technical efficiency scores assuming Constant Returns to Scale. The fourth column, labeled VRS, presents the technical efficiency scores assuming Variable Returns to Scale. A fully efficient DMU is rated 1.0, whereas a fully inefficient firm is rated 0.0.

Model 1 used total number of academic staff; number of non-academic staff; and cost of inputs other than labor as inputs, with research grants as output. Using this model, USEP was identified to be relatively more technically efficient than all other SUCs. In 1997 to 1998, the different regional SUCs (except USEP) were rated fully efficient because these SUCs have not received any research grant. Changes in the technical efficiency scores became evident only in 1999 when the SUCs in the region began to receive small grants from different sources. USEP was rated fully efficient, with SPAMAST catching up. Technical efficiency deals with the usage of inputs to produce outputs relative to best practice in a given sample of the DMUs.

Table 1. Technical efficiency scores of the different state colleges and universities in Region XI using three (3) DEA models.

Year	University/ College	Model 1		Model 2		Model 3	
		Technical Efficiency (CRS)	Technical Efficiency (VRS)	Technical Efficiency (CRS)	Technical Efficiency (VRS)	Technical Efficiency (CRS)	Technical Efficiency (VRS)
1997	DNSC	1.000	1.000	0.911	0.911	0.000	0.911
	DOSCST	1.000	1.000	1.000	1.000	0.000	1.000
	SPAMAST	1.000	1.000	1.000	1.000	0.000	1.000
	USEP	0.421	0.421	0.544	0.544	1.000	1.000
	Mean	0.855	0.855	0.864	0.864	0.250	0.978
1998	DNSC	1.000	1.000	1.000	1.000	0.000	1.000
	DOSCST	1.000	1.000	0.827	0.827	1.000	1.000
	SPAMAST	1.000	1.000	1.000	1.000	0.000	1.000
	USEP	0.421	0.421	0.563	0.563	0.486	0.647
	Mean	0.855	0.835	0.847	0.847	0.372	0.912
1999	DNSC	0.000	1.000	0.000	1.000	1.000	1.000
	DOSCST	0.162	1.000	0.162	0.930	1.000	1.000
	SPAMAST	0.104	1.000	0.223	1.000	0.721	1.000
	USEP	1.000	1.000	1.000	1.000	0.571	0.571
	Mean	0.316	1.000	0.346	0.982	0.823	0.893
2000	DNSC	1.000	1.000	1.000	1.000	0.000	1.000
	DOSCST	0.821	1.000	1.000	1.000	1.000	1.000
	SPAMAST	0.000	1.000	0.000	1.000	0.548	1.000
	USEP	1.000	1.000	1.000	1.000	0.462	0.516
	Mean	0.705	1.000	0.750	1.000	0.502	0.879
2001	DNSC	0.274	1.000	0.238	1.000	0.000	1.000
	DOSCST	0.112	0.975	0.660	1.000	1.000	1.000
	SPAMAST	1.000	1.000	1.000	1.000	0.000	1.000
	USEP	0.262	0.412	0.262	0.412	0.652	1.000
	Mean	0.412	0.847	0.540	0.853	0.413	1.000

From 1999 to 2001, SUCs in the region were quite technically inefficient, which is primarily caused by its inefficient operation. This implies that the SUCs have the potential to improve their efficiency by scaling up their research activities.

Model 2 utilized number of non-academic staff, number of academic staff, and research budget allocation as inputs with total research grants received as output. Using these inputs and outputs, DOSCST and SPAMAST were noted to have improved with time.

Model 3 used total number of academic staff; total number of non-academic staff and research allocation as inputs with weighted number of publications and approved patents as outputs. Among the four SUCs in Region XI, USEP and DOSCST were found to be efficient when the weighted number of published articles and patents were utilized as research outputs. USEP has regularly published articles locally and has published a number of scientific articles nationally and internationally. On the other hand, DOSCST has published only twice locally. It has published, however, a number of scientific articles in the national and international publications in the later part of the study.

USEP was rated fully efficient in 1997 and its efficiency rating fluctuated over the 50% mark until 2001. SPAMAST and DNSC were inefficient for different reasons. SPAMAST has no journal but was able to publish 2 articles internationally in 1999 and 2000. On the other hand, DNSC has a local journal but has only published once in 1998.

Table 2 presents the changes in the technical efficiency scores of the different SUCs in Region XI when compared to the “best practice” research institutions such as USM and NDMU under three (3) DEA models. On a yearly basis, only USM was rated fully technical and all other academic institutions were rated inefficient. Earlier, it was noted that USEP was rated fully efficient when compared to other academic institutions in Region XI, whereas now it is rated inefficient. This means that USEP is locally technical efficient, but not “globally” efficient.

Under Model 2 DOSCST and SPAMAST were noted to have improved with time. However, when compared with USM, the different regional SUCs were rated technically inefficient. NDMU was rated relatively efficient when compared with the regional SUCs.

Under Model 3,among the four SUCs in Region XI, USEP and DOSCST were found to be efficient when the weighted number of published articles and patents were utilized as research outputs. When compared with USM and NDMU, the regional SUCs compared favorably with USM and NDMU. In fact, he regional SUCs outperformed NDMU in terms of output. DOSCST performed comparably with USM. USEP’s performance was not very far behind from that of USM. It should be pointed out quickly that the output does not reflect quality. The study only considered the number of published articles without consideration to the quality of the journal. It could also be recalled that majority of the outputs were published locally.

Table 2. Technical efficiencies of the different state colleges and universities in Region XI relative to "best practice" institutions under three (3) DEA models.

Year	University/ College	Model 1		Model 2		Model 3	
		Technical Efficiency (CRS)	Technical Efficiency (VRS)	Technical Efficiency (CRS)	Technical Efficiency (VRS)	Technical Efficiency (CRS)	Technical Efficiency (VRS)
1997	DNSC	0.000	1.000	0.000	0.911	0.000	0.911
	DOSCST	0.000	1.000	0.000	1.000	0.000	1.000
	SPAMAST	0.000	1.000	0.000	1.000	0.000	1.000
	USEP	0.000	0.421	0.000	0.544	1.000	1.000
	USM	1.000	1.000	1.000	1.000	1.000	1.000
	NDMU	0.027	0.703	0.146	0.703	0.000	0.681
	Mean	0.171	0.854	0.191	0.860	0.333	0.932
1998	DNSC	0.000	1.000	0.000	1.000	0.000	1.000
	DOSCST	0.000	1.000	0.000	0.827	1.000	1.000
	SPAMAST	0.000	1.000	0.000	1.000	0.000	1.000
	USEP	0.000	0.421	0.000	0.563	0.486	0.647
	USM	1.000	1.000	1.000	1.000	1.000	1.000
	NDMU	0.260	0.885	0.754	1.000	0.348	0.867
	Mean	0.210	0.884	0.292	0.898	0.472	0.919
1999	DNSC	0.000	1.000	0.000	1.000	1.000	1.000
	DOSCST	0.059	1.000	0.138	0.896	1.000	1.000
	SPAMAST	0.032	1.000	0.223	1.000	0.721	1.000
	USEP	0.508	0.832	1.000	1.000	0.571	0.571
	USM	1.000	1.000	1.000	1.000	0.467	1.000
	NDMU	0.157	0.812	0.615	0.865	0.000	0.702
	Mean	0.293	0.941	0.496	0.960	0.627	0.879
2000	DNSC	0.097	1.000	0.252	1.000	0.000	1.000
	DOSCST	0.059	1.000	1.000	1.000	1.000	1.000
	SPAMAST	0.000	1.000	0.000	1.000	0.548	1.000
	USEP	0.094	0.499	0.263	0.499	0.462	0.516
	USM	1.000	1.000	1.000	1.000	0.958	1.000
	NDMU	0.165	0.849	1.000	1.000	0.861	0.907
	Mean	0.236	0.891	0.586	0.916	0.638	0.904
2001	DNSC	0.059	1.000	0.113	1.000	0.000	1.000
	DOSCST	0.024	0.975	0.660	1.000	1.000	1.000
	SPAMAST	0.331	1.000	1.000	1.000	0.000	1.000
	USEP	0.087	0.412	0.138	0.412	0.652	1.000
	USM	1.000	1.000	1.000	1.000	1.000	1.000
	NDMU	0.152	0.761	0.488	0.774	0.241	0.826
	Mean	0.275	0.858	0.567	0.864	0.482	0.914

Determinants of Technical Inefficiency

The causes of technical inefficiency are many and varied. In order 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 three models were used as the dependent variable. The determinants of technical efficiency in Model 1 included age of the institution, i.e. the years since the establishment of the institution; and, dummy variable for research allocation, at the 5% level of significance (Table 3). The result implied that "older" and well-funded institutions were likely to be more efficient than "newer" institutions with very low research budget. The model accounted for about 95% of the total variability in technical inefficiency. This means that the model can explain 95% of the variability in the technical inefficiency scores. This is quite an encouraging result considering that earlier studies (Abbott and Doucouliagos, 1995; and, Coelli,1996) obtained a very low level of coefficient of determination ranging from 3% - 25% only.

Tobit analysis using the technical inefficiency from number of academic staff, number of non-academic staff, and research allocation as inputs and total grants as output (Model 2), yielded age of the academic institution as the only significant determinant of technical inefficiency. It accounted for 62% of the variability in the technical inefficiency scores. Model 3 used number of scientific publications and patents as outputs with number of academic, non-academic staff and research allocation as inputs. Only the number of academic staff entered as a significant contributory variable to explain technical inefficiency. The model accounted for only 44% of the variability in the inefficiency

It appeared that Model 1 (value of grants as output with number of academic staff, number of non-academic staff, and cost of inputs other than labor as inputs) was appropriate to describe the performance of academic research institutions in Region XI.

Table 3. Normalized coefficients from Tobit Regression Analysis.

Independent Variables	Coefficients Model 1[a]	Coefficients Model 2[b]	Coefficients Model 3[c]
Number of academic staff	0.0060 [ns] [0.0120]	0.0111 [ns] [0.0126]	-0.222* [0.0096]
Proportion of PhD to total no. of academic staff (%)	-0.1248[ns] [0.0884]	-0.1147[ns] [0.0891]	0.1784[ns] [0.0870]
Number of campuses	0.4181[ns] [0.3309]	-0.0788[ns] [0.3328]	-0.5192[ns] [0.3456]
Age of the academic institution	-0.2121* [0.0549]	-0.1227* [0.0514]	0.0592[ns] [0.0439]
Number of graduate degree programs	0.3104[ns] [0.1714]	0.0828[ns] [0.1757]	0.1317[ns] [0.1290]
Number of under-graduate degree programs	0.1539* [0.0865]	0.0699[ns] [0.0843]	-0.0658[ns] [0.0764]
Total number of student population	0.00045[ns] [0.0004]	0.00017[ns] [0.0004]	0.00038[ns] [0.0004]
Total number of students enrolled in the PhD program	-0.0181[ns] [0.0329]	-0.0132[ns] [0.0335]	0.0057[ns] [0.0241]
Number of graduates in the PhD program	-0.5510* [0.2551]	-0.2225[ns] [0.2593]	0.0920[ns] [0.2363]
Dummy for research allocation	-10.334* [2.2937]	-3.2357[ns] [2.4454]	-0.2004[ns] [1.0820]
Constant	9.0293* [1.6067]	2.3241* [1.0123]	2..8767* [0.9306]
R^2	0.9532	0.6155	0.4350

[a] Grants as output and number of academic staff, number of non-academic staff and cost of inputs other than labor as inputs,
[b] Grants as output and number of academic staff, number of non-academic staff and research budget allocation as inputs,
[c] Weighted number of publications and patents as outputs and number of academic staff, number of non-academic staff and research allocation as inputs
*Significant at the 5% level of significance,
[ns]Not significant at the 5% level of significance.
Figures in square backets are the associated standard errors.

V. RECOMMENDATIONS

A more pro-active government policies on research and development. It is imperative that the government promotes a sustained, positive, and consistent R and D policies to encourage research activities. Revised center of excellence and center of development framework. The study supports the center of excellence and center of development strategy of CHED. A more focused and directed framework for center of excellence and center of development should consider the role of the SUC in the development of the region and of the country as a whole. Monitoring of the utilization of research funding for R and D. Increased funding for R and D activities should be accompanied by serious monitoring and auditing on how this fund is actually used. Provide adequate time and incentives for SUC faculty to conduct research. Among the deterrents of serious research activity in the SUCs are: (a) overloaded faculty; (b) lack of venue for publication; (c) over-emphasis on the under-graduate program; (d) inadequate library facilities; (e) inadequate laboratory facilities, and (f) treatment of research activity as secondary to teaching responsibilities of the faculty. Hiring of highly qualified and trained administrators, and R and D managers. SUCs with their highly trained professionals need to be managed effectively in order to optimize their potentials. Management of highly skilled faculty members should include freeing these faculty members from non-productive activities and providing an atmosphere conducive for the conduct of research. Utilization of graduate programs and graduate students for productive research. SUCs or the government should provide research funds solely for the support of graduate students. Continuing upgrading of research skills of faculty members in terms of short-term training programs on their areas of specialization. Promising young faculty members should be given priority for advanced studies and be sent to academic institutions renown for their research activities.

REFERENCES

Abbott, Malcolm and Chris Doucougliagos. 1995. “The Efficiency of Australian Universities: A Data Envelopment Analysis”.

Atkinson, Richard C. 1997. “Present Challenges of a Research University”. http://www. acop.edu/ucophonme/pres/challenge.html

Coelli, Tim. 1996. “Recent Developments in Frontier Modeling and Efficiency Measurement”, Australian Journal of Agricultural Economics. Vol. 19. No. 5.

Funke, Michael and Annekatrin Niehbur. 2000. “Spatial R and D Spillovers and Economic Growth–Evidence from West Germany”, HWWA Discussion Paper 98. Hamburg Inst. of International Econ. http://www.stat.fi/ tk/kk/ uutuu5600.pdf

Gaither, G, B. P. Nedwek and J. E. Neal. 1994. “Measuring Up”. ASHE-ERIC Higher Education Report No.5. Washington, D. C. Summary Notes by J. T. P. Yao. http://lohmann.tamu.edu/summarypapersrewards/measuringup. html.

Griffith, Rachel. “How Important is Business R and D for Economic Growth and Should the Government Subsidize It?” Briefing Note No. 12, October 2000. London: The Institute for Fiscal Studies. http://www.ifs.org.uk

Lee, Tammy. May 2001. “Benchmarking Academic Key Performance Indicators for Higher Education Transformational Leadership in Assessment and Accountability. http://www.ctl.mnscu/pdf/May2001kelloggeventagenda.pdf

Maddala, G. S. 1992. Introduction to Econometrics. 2nd ed. New Jersey: Prentice Hall International, Inc.

Massachusetts Technology Collaborative. “Analysis of the Impact of Federal R and D Investment Scenarios on Economic Growth.”, Massachusetts. July 1998. http://www.mtpc.org/NewsandReports/fedfund/ FY2001RDUpdate.pdf

Ontario Ministry of Energy, Science and Technology. 1998. “The R and D Opportunity”.Ontario Challenge Fund. http://www.ontariochallengefund.com/ english/ opportunity.

Oxley, Les and Shengxiu Zhu. “Human Capital, R and D, Investment and Economic Growth in New Zealand, 1955-1998. Department of Economics, University of Waikato. http://www.mngt.waikato.ac.nz/ depts/econ/staff/les/pdf files/growthNZAE.pdf.

Todaro, Michael P. Economic Development. 7th ed. 2000. New York: Addison Wesley Longman.