Use of Stochastic Production Frontiers for Measuring Learning Efficiency: Evidence from a State University in Sri Lanka

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Key words: *Education production, Learning efficiency, State university education, Stochastic frontier analysis*

Introduction

Efficiency of State education is a significant research issue since it consumes a substantial amount of public money in developing countries. Therefore, investigating the efficiency of State higher education systems is essential in the context of accountability of State funds and Sri Lanka is no exception. Recently, the performance of Sri Lankan State university education has been the subject of considerable scrutiny. The system has undergone significant changes over the years, in the process of improving undergraduates' performance. However, undergraduates' performance in social sciences stream is still lagging behind the accepted standards (World Bank, 2009). One explanation is that students and educational institutions are not utilising resources efficiently. There may be productive or technical inefficiencies in teaching or in the learning processes. The emphasis of this study is the latter since no such studies has been carried out for Sri Lankan.

Farrell (1957) provided the definition and conceptual framework for technical efficiency (TE) which refers to failure to operate on the production frontier. Stochastic Frontier Analysis (SFA) is one of the techniques[1] widely used for the estimation of TE which is used in this study. Aigner et al (1977), Kumbhakar and Lovell (2000), and Battese and Coelli (1988, 1995) demonstrated the development of SFA and its uses in estimating TE. The basic idea behind the SFA is that the error term is composed of two parts: (i) systematic component that captures the effect of measurement error, statistical noise, and (ii) one-sided error component that captures the effects of inefficiency (Knox and Lovell, 2000). This study utilises Battese and Coelli's (1995) approach which estimate the stochastic frontier and inefficiency effect model simultaneously. Chakraborty (2009) is a significant application of this model for the education sector.

[1] DEA (Data Envelopment Analysis) is also widely used technique for measuring educational efficiency.

Objectives

Since there is an important research interest for the assessment of efficiency of university education, the broader objective of this study is to investigate the level of learning efficiency and attempt to explore possibilities of increasing study efficiency of the education (training) system in state universities in Sri Lanka. Because it is not possible to neglect the students' role in university education process since students' performance is one of the integral components of institutional performance. Efficiency studies within higher education sector focused on institutional levels and no consideration of the efficiency variation among individuals within degree programs. Such studies are crucial since individuals' educational achievements are a result of students' own effort and qualities of faculty teaching. Therefore, this study further investigates the determinants of efficiency to deepen the insights.

Methodology

The primary data used for this study were collected at a faculty of humanities and social sciences. 276 students of Special degree from all social sciences[2] (including Special Degree part I, II and III) were involved. Survey method was employed for data collection. Definitions and the descriptive statistics for each of these variables are reported in Table 1.

SFA was chosen since it would enable test the hypothesis that there is inefficiency in the study process. Battese and Coelli's (1995) specification was used assuming Cobb–Douglas production function with m inputs for the analysis of the learning process. The empirical model estimated was :

$$\ln y_i = \beta_0 + \sum_{j=1}^{m} \ln x_{ji} + \nu_i - u_i \qquad (1)$$

Where, y_i is the output and x_i is a vector of inputs pertaining to i^{th} student. β is a vector of unknown parameters to be estimated. ν_i s are assumed to be $iid\ N(0, \sigma_v^2)$ random errors, independently distributed of the u_i where the u_i s are non-negative random variables assumed to be accounted for the inefficiency effects in learning process. The u_i s are assumed to be independently distributed as truncations at zero of the $N(\mu_i, \sigma^2)$.

[2] Social sciences includes Economics, Social Statistics, Political Science, Geography and Sociology

Table 1: Descriptive Statistics and the Definition of Variables used in the Study

Description of the Variables	Mean	Standard Deviation	Minimum	Maximum
Output (Y)				
Current grade point Average (*CGPA*)	3.1395	0.2623	1.8500	3.9000
Variable Inputs (Xs)				
Formal lecture hours attended (*Formal*)	18.040	8.702	3.000	21.000
Hours devoted on self-study (*Self*)	12.080	10.853	1.000	35.000
Average hours on sleeping (*Sleep*)	52.801	8.597	18.000	84.000
Efficiency determinants (*ds*)				
Z-score reached at A/L exam (*Z-score*)	1.3937	0.2294	1.1876	3.6000
Entrance quality for a special degree – First year GPA (*GPAFY*)	3.0708	0.2795	2.3500	3.8000
Age of the respondent (*Age*)	23.496	1.495	21.000	27.000
Gender of the respondent (*Sex*)	Dummy variable: 1=Male; 0=Female			
Class size (*Class*)	22.913	7.435	3.000	35.000
Father's education (*Fedu*)	Dummy variable with 5 categories			
Mother's education (*Medu*)	Dummy variable with 5 categories			
Peer activities (*Group*)	Dummy variable 1=Yes; 0=No			
Academic level (*Level*)	Dummy variable 0=Part I; 1=Part II; 2=Part III			
Time used for leisure (*Leisure*)	19.174	13.509	0.000	18.000
Employability (*Employ*)	Dummy variable 1= Yes; 0=No			

Source: Authors' calculations based on survey data

Battese and Coelli's (1995) inefficiency effect model, with p exogenous variables that influence learning, can be written as:

$$\mu_i = \delta_0 + \sum_{l=1}^{p} z_l \delta_{l_i} \qquad (2)$$

The equations (1) and (2) were simultaneously estimated using maximum likelihood method assuming half normal and exponential specifications. Learning efficiency for individual i was defined by, $E_i = \exp\left(-u_i\right)$ which takes the value one if $u_i = 0$.

Results

Empirical results of the parsimonious models[3] are reported in Table 2.

Table 2: Stochastic Frontier Parameter Estimates-Dependent Variable: ***ln (CGPA)***

Stochastic frontier model	MLE (half-normal)	MLE (exponential)
Constant	1.4357 (0.0998)***	1.4294 (0.1004)***
ln(Formal)	-0.0222 (0.0100)**	-0.0231 (0.0099)**
ln(Self)	0.0132 (0.0047)**	0.0123 (0.0047)***
ln(Sleep)	-0.0475 (0.0228)**	-0.0497 (0.0230)**
		Inefficiency Model
Constant	5.2563 (1.7010)**	7.6639 (2.4791)**
FYGPA	-2.8603 (0.5459)***	-3.9064 (0.8172)***
Class	-0.0541 (0.0213)***	-0.0684 (0.0288)**
Level		
Part II	0.0161 (0.2845)	0.0085 (0.4233)
Part III	-0.7455 (0.3162)***	-0.9683 (0.4547)**
Employ	0.9453 (0.5499)*	0.9748 (0.8097)
N	276	276
Log Likelihood	335.756	309.1352
LR for one-sided error	36.72***	50.24***
σ_v	0.0423 (0.0053)***	0.0497 (0.0048)***
σ_u	0.1209 (0.0089)***	0.0684 (0.0075)***
σ^2	0.0164 (0.0019)***	0.0071 (0.0086)***
λ	2.8602 (0.01263)**	1.3762 (0.0108)**
Average efficiency prediction	0.93	0.94

Notes : Standard errors are in parentheses.
*,** and *** Indicate coefficient is significant at the 10%, 5% and 1% or lower probability levels.

The signs of the coefficients of stochastic frontiers are as expected with the exception of a negative estimate for variable *Formal*. Variables *FYGPA*, *Class*, *Level* and *Employee* are statistically significant. Positive significant coefficient of λ which provides an indication for the relative contribution of u and v to ε, implies that one-sided error component dominates the asymmetric error component in determining ε. This produces evidence for the validity of using inefficiency model to explain the determinants of efficiency.

[3] First unrestricted models were estimated and then moved to the parsimonious models excluding insignificant variables.

Conclusion and Policy recommendations

Mean efficiency of 0.93 and 0.94, under half-normal and exponential specifications imply higher learning efficiency among social sciences. No significant variation of efficiency among degree programs could be observed except in economics degree which appears comparatively less efficient than others. This may be due to the specific nature of the subject. Students in Economics comparatively archive lower GPA (mean is 3.0). First year GPA, which reflects entrance quality to a special degree program, turns out to be highly significant and positive, while A/L Z score, which reflects entrance quality to a university, turns out to be insignificant (0.1921 with SE of 0.3968)[4]. Both model specifications are appropriate for modelling learning efficiency. Cobb-Douglas specification is preferred over Translog representation. Student being an employee worsens the learning efficiency in higher education.

These results have several important policy implications. Firstly, the findings suggest the necessity of a policy change pertaining to university admission in social sciences, in the direction of increasing student enrolment through bringing down cut-off Z – score to an acceptable level. This also answers the question of limited number of students being admitted to State universities, a major criticism on higher education sector. Secondly, the university authorities need to pay attention to improve first year instructional quality in any mode. Policy makers are motivated towards student centred higher education policy and university authorities need to modify their teaching processes. Finally, the students should have a well-planned time budget.

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[4] Results of unrestricted models are not reported

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