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Estimating the Degree Cost Functions of the Philippines Public and Private Higher Educational Institutions

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A flexible one-output and two-input cost function is estimated for the degree program offerings of public and private higher educational institutions (HEIs) of the Philippines, employing the data from a nationally representative sample of 29 HEIs. This model, called Flexible Fixed Cost Quadratic cost function includes as output – full time equivalent degree program enrollment, and the two factor inputs – teaching cost and operating cost per student. Units of observation are the degree programs being offered by the sample HEIs. Results indicate that public and private HEIs exhibit structurally different cost functions, with the public sector enjoying markedly better cost efficiency and over-all scale economy.

Key Words: Cost Function, Higher Education, Economy of Scale

It is a general perception that the Philippine public and private higher educational institutions differ markedly in their cost structures in servicing the degree programs they offer. This perception might be motivated by the well recognized differences between government-run and private HEIs with respect to a number of attributes - their sizes, their business orientations, their priorities in service provision, their funding sources and their scale and/or scope economies. Hence, in empirically establishing the cost function of the country's HEIs, it is postulated in the present study that there exist distinct cost functions for the two types of institutions. This study, which supplements the Commission on Higher Education (CHED) commissioned project entitled "A Comprehensive Analysis of Degree Programs" aims to econometrically establish the empirical cost functions for the country's higher education degree programs for public and private HEIs.

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Since the cost function of a firm provides a ready summary of all of its relevant technologies (Varian, 1992), it is more fruitful to model its cost function rather than its production or profit function. This is especially so for entities that operate in highly regulated industries and also for those that specialize in service provision. For firms like airlines, telecommunications, utilities, hospitals and educational institutions, cost function modeling generates more relevant and richer insights into the economics of the firm than what production analysis may provide. However, in order to obtain consistent parameter estimates when one is using cost functions, it is implicitly assumed that output and factor prices are exogenous and factor markets are competitive. Furthermore, each producer is also assumed to be efficient (Kumbhakar, 1991). In most applications, however, the requirement of efficiency is rarely met because of the presence of technical and allocative inefficiency in production. The usual modeling recourse is to employ flexible functional specifications, which are more robust in the face of such anomalies.

To achieve the objective of the study, the flexible cost function specification popularized by Baumol, Panzar and Willig (1982) will be employed and tested for goodness-of-fit to the available degree program cost data. This mathematical form, which is called the Flexible Fixed Cost Quadratic (FFCQ) Model, will also be used in verifying the validity of the postulated structural differences of the cost functions of public and private HEIs. A good number of studies in the literature on HEIs' cost functions employ the same model (e.g. Cohn, Rhine and Santos (1989), Hashimoto and Cohn (1997), and Koshal and Koshal (1999)).

Methodology

To facilitate the empirical determination of the cost structures of the degree provision mechanisms of Philippine universities, a single output, and two-input format for the cost function is adopted in this study. Our decision to use such a format is due, not only to our desire to simplify the modeling process, but also because of the limitations of the available data. The database constitute cross sectional information on degrees courses being offered by a nationally representative sample of 29 HEIs covered in a survey conducted by the CHED research team. HEIs costs in servicing enrollees in the various degree programs will be the main variables to be modeled. The number of full time equivalent enrollees (ENROLL) to the programs will serve as the output variable, while Teaching Cost (THCOST) and Operating Cost (OPERCOST), both are expressed on a per student basis will be the factor input costs. Total HEI Degree Cost (DEGREECOST), which is defined as the estimated outlay the HEI spends in servicing all full time equivalent enrollees of the degree, will serve as the dependent variable of the model.

The FFCQ Model

The mathematical form of the cost function to be estimated is a second degree formulation of the untransformed variables. The specification takes the following general form:

$$C_i = \beta_1 + \sum_{j=1}^{k} \delta_j q_j + \sum_{\forall i,j}^{k} \lambda_{ij} q_i q_j + \sum_{i=1}^{m} \gamma_i c_i + \sum_{\forall i,j}^{m} \theta_{ij} c_i c_j + \sum_{\forall i,j}^{k,m} \vartheta_{ij} q_i c_j + \varepsilon_i \qquad (1)$$

Where C is the total variable cost, the q's are the outputs and the c's are the input prices. The intercept β_1 and the coefficients $\delta's, \lambda's, \gamma's, \vartheta's$ and $\theta's$ are parameters to be estimated. The stochastic disturbance term ε_i is assumed to be iid normal with mean zero and with constant variance. In this study, there is only one q which is the variable ENROLL or full time equivalent enrollees of the degree program, and there are two c's which are OPERCOST or the per student HEI operating cost of servicing the enrollees and THCOST or the per student teaching cost. The left-hand-side variable C is the DEGREECOST variable.

The FFCQ model will be implemented for both the public and private HEIs in the sample and will be subjected to the usual regression diagnostics to check for its statistical and econometric adequacy. Structural differences of the parameters will be evaluated using Chow's stability test (Chow, 1960) which is as follows:

$$F = \frac{[RSS_{public} + RSS_{private} - RSS_{fullsample}]/p}{[RSS_{public} + RSS_{private}]/(n-2p)} \qquad (2)$$

The sampling distribution of the above statistic is F with numerator degrees of freedom p, which is equal to the number of parameters of the model, and denominator degree of freedom n – 2p, with n is the total number of HEIs degree programs in the full sample.

Data

Data for the empirical analysis was drawn from a nation-wide cross sectional survey of public and private HEIs conducted by the CHED research team, which prepared the project on the normative degree program costs of Philippine universities. Using a multi-stage probability proportional to size (pps) sampling design, a total of 29 HEIs were covered by the survey. The reference period of the survey was the academic year 2000-2001, inclusive of the two semesters and the summer term. A usable sample of 1332 degree program cases, of which 774 are served by public HEIs and the rest by private institutions. Degree cases with missing information and those with grossly out of proportion data are omitted in the analysis. It was originally intended to segment the analysis on the basis of CHED's degree discipline classification, but the categories per degree were not encoded in the database provided by the research team.

Descriptive information on all of the variables used, including the squared variables and interactions are presented in Table 1. The table exhibits the variables, their descriptions with means and standard deviations for the sample of public and private institutions.

Table 1. *Descriptive Information on the Variables*

Public HEIs (Number of Cases = 794)

Variable	Description	Mean	Std. Dev
ENROLL	Total Enrollment	273.39	325.96
THCOST	HEI Per Student Teaching Cost	65,487.14	59,284.75
OPERCOST	HEI Per Student Operating Cost	14,346.7	20,172.13
THCOSTSQ	Teaching Cost Squared	$7.80 x10^{9}$	$2.36 x10^{10}$
THXOPER	Interaction of Teaching Cost and Operating Cost	$1.03 x10^{9}$	$1.87 x10^{9}$
ENROLLSQ	Enrollment Squared	180,858.3	431,879.2
THXENROLL	Interaction of Enrollment and Teaching Cost	$1.38 x10^{7}$	$1.77 x10^{7}$
ENROLLXOPER	Interaction of Enrollment and Operating Cost	3,097,019	5,578,757
DEGREECOST	Total Degree Cost	$2.83 x10^{7}$	$3.18 x10^{7}$
OPERCOSTSQ	Operating Cost Squared	$6.12e\, x10^{8}$	$2.51 x10^{9}$

Private HEIs (Number of Cases = 538)

Variable	Description	Mean	Std. Dev.
ENROLL	Total Enrollment	253.19	329.83
THCOST	HEI Per Student Teaching Cost	54,235.94	46,098.59
OPERCOST	HEI Per Student Operating Cost	9,452.05	11,100.85
THCOSTSQ	Teaching cost Squared	$5.06 x10^{9}$	$1.00 x10^{10}$
ENROLLSQ	Enrollment Squared	237,254.4	725,353
THXENROLL	Interaction of Enrollment and Teaching Cost	$1.40 x10^{7}$	$2.60 x10^{7}$
ENROLLXOPER	Interaction of Enrollment and Operating Cost	2,573,387	6,061,495
THXOPER	Interaction of Teaching Cost and Operating Cost	$5.08 x10^{8}$	$8.84 x10^{8}$
DEGREECOST	Total Degree Cost	$2.62 x10^{7}$	$3.55 x10^{7}$
OPERCOSTSQ	Operating Cost Squared	$2.12 x10^{8}$	$3.80 x10^{8}$

Economy of Scale Estimation

Taking the cue from Baumol, et al. (1982), the Ray Economies of Scale is determined when one uses the model given in (1) by the following results:

Let $C(q_j)$ be the total cost of producing output q_j and let $C'(q_j)$ be the marginal cost of producing the output q_j, that is:

$$C'(q_j)=\frac{\partial C(q_j)}{\partial q_j}=\delta_j+2\lambda_{jj}q_j+\sum_{i=1}^{m}\vartheta_{ij}c_i \quad (3)$$

The Ray economy of scale for the kth output is provided by the formula (Glass, et al., 1995):

$$S_k(q)=\frac{C(q)}{\sum_{j=1}^{k}q_jC'(q_j)} \quad (4)$$

The above economy of scale formula will be applied separately for public and private HEIs as soon as it is empirically recognized that there exist structural differences between the two categories of educational institutions and statistically adequate estimates of their cost functions are established.

Since there is only one output specified in the format of the cost function used in the study, the above prescription will take on the enrollment specific economy of scale formula:

$$S(q)=\frac{C(q)}{qC'(q)}=\frac{AC(q)}{MC(q)} \quad (5)$$

Results

The FFQC model was estimated using three different data sets – Public HEIs (n = 794), Private HEIs (n = 538) and the Full Sample (n = 1332) using the ordinary least squares procedure. Table 2 shows the outcome of the estimation process. The basic information coming from these estimated equations are used in evaluating the structural differences of the public and the private cost functions through Chow's Test in (2). Furthermore, the VIF multicollinearity diagnostic procedure and a state-of-the-art heteroscedasticity test were also implemented to avoid the possibility of imprecise estimation of the models' standard errors. All regressions in Table 2 reflect very good fit indicators particularly their coefficients of determination R^2 , the t-values of the coefficients .The algebraic signs of the parameter estimates

Table 2. *Preliminary Estimates of the FFCQ Cost Function Models*

Independent Variables	OLS Estimation of the FFCQ Cost Function Model for					
	Public HEIs		Private HEIs		All HEIs	
	Coefficient	*t*-value	Coefficient	*t*-value	Coefficient	*t*-value
ENROLL	37124.75	11.79	68277.95	23.15	45719.58	17.08
THCOST	31.21214	2.60	251.5522	8.10	37.88378	3.33
OPERCOST	167.0532	3.35	456.2843	2.90	46.34958	0.52
ENROLLSQ	-5.963401	-3.38	-7.324739	-7.00	-9.606836	-6.29
THCOSTSQ	-0.0001867	-7.42	-0.0007127	-5.44	-0.0001238	-4.57
OPERCOSTSQ	-0.0017191	-4.93	-0.0152076	-3.24	-0.0012507	-3.78
THXENROLL	1.251631	36.56	0.3863453	13.06	0.9982879	36.15
OPERXENROLL	0.3518419	3.92	1.942605	13.92	1.231831	16.08
THXOPERCOST	0.0016222	4.29	-0.0004029	-0.38	0.0017825	4.60
INTERCEPT	-2686859	-2.80	-1.07e+07	-7.19	-2373415	-2.88
R^2	0.9246		0.8868		0.9023	
RSS	$6.0617 x10^{17}$		$7.6711 x10^{16}$		$1.4399 x10^{17}$	
No. of Cases	794		538		1332	

appear to be in line with theoretical expectations.

Chow's Test of Structural Difference of Public and Private HEIs Cost Functions

Using the regression results presented in Table 2, the empirical evaluation of the structural stability of the estimated cost functions across the two categories of higher educational institutions can now be performed. Under the null hypothesis of no difference in structure, the test statistic (2) is computed to have an empirical value of F = 6.1146 which is significant at the 1% level (critical value is $F_{10,1312} = 2.32$)

The significance of the computed F value for the Chow's test indicated the rejection of the null hypothesis of parameter stability of the public and private cost functions. This test result empirically confirms our assertion at the outset that the two categories of higher education entities operating in the Philippines exhibit different cost structures, thus estimating their separate cost functions is warranted.

Tests for Heteroscedasticity and Multicollinearity

To verify the occurrence of heteroscedasticity in the estimated models, the Szroeter test for heteroscedasticity was applied to all OLS regression runs. This test is a state-of-the-art procedure, which evaluates the potential of each right-hand side variable to cause a variance-destabilizing influence on the stochastic error term of the model. The test, which is part of a regression diagnostics suite of commands of Stata 8.0, was run in evaluating both the public and private HEIs degree cost functions.

Even before any formal inference is conducted to check the existence of heteroscedasticity, there is a strong suspicion that this data irregularity is present in our cost function models not only because of our use of cross sectional data, but also because of the size variation of the Philippine HEIs, especially the public HEIs. Hence, despite segmenting our analysis into public and private school cost functions, the problem is not expected to be mitigated. In this study, we used White's heteroscedasticity consistent OLS estimation method (White, 1980) to produce robust estimates of the models' standard errors.

The possibility of the occurrence of multicollinearity in the estimated equations is handled by the Variance Inflation Factor (VIF) diagnostic procedure. Immediately after estimating the cost models exhibited in Table 2, the VIF

Table 3. *Multicollinearity and Heteroscedasticity Diagnostic Tests*

Variable	VIF Multicollinearity Diagnostics for			Szroeter's Heteroscedasticity Diagnostic Test			
				Public Cost Function		Private Cost Function	
	Public	Private	All Sample	χ^2 -value	p-value	χ^2 -value	p-value
ENROLL	10.81	3.50	9.40	190.91	0.0000	338.60	0.0000
THCOST	5.19	7.58	4.73	97.48	0.0000	10.40	0.0151
OPERCOST	10.40	11.27	7.82	19.01	0.0002	20.04	0.0001
ENROLLSQ	5.94	2.13	5.62	190.91	0.0000	388.17	0.0000
THCOSTSQ	3.63	6.37	3.36	97.48	0.0000	10.40	0.0151
OPERCOSTSQ	7.88	11.75	5.18	19.01	0.0002	20.04	0.0001
ENROLLXOPER	5.57	2.64	2.40	180.17	0.0000	206.83	0.0000
THXENROLL	3.78	2.19	3.25	403.92	0.0000	368.35	0.0000
THXOPER	5.10	3.27	4.51	45.62	0.0000	36.21	0.0000
Mean VIF	6.14	5.63	5.14	H_o : Variance Constant H_a : Variance Monotonic in Variable			

Table 4. *Final Estimates of the HEIs Degree Cost Functions*

Independent Variable	Private HEI Degree Cost Function			Public HEI Degree Cost Function		
	Coefficient	*t*-value	*p*-value	Coefficient	*t*-value	*p*-value
Enrollment (q)	68277.95	10.30	0.0000	37124.95	9.04	0.0000
Teaching Cost (C_1)	251.55	5.06	0.0000	31.21	4.28	0.0000
Operating Cost (C_2)	456.28	1.63	0.1030	167.05	3.28	0.0010
Enrollment Squared (q^2)	-7.32	-3.51	0.0000	-5.96	-1.99	0.0470
Teaching Cost Squared (C_1^2)	-0.0007	-2.91	0.0040	-0.0002	-7.40	0.0000
Operating Cost Squared (C_2^2)	-0.015	-1.57	0.1160	-0.0017	-3.92	0.0000
Interaction of Enrollment and Teaching Cost (qC_1)	0.3864	4.43	0.0000	1.2516	23.62	0.0000
Interaction of Enrollment and Operating Cost (qC_2)	1.9426	4.85	0.0000	0.3518	3.91	0.0000
Interaction of Teaching Cost and Operating Cost ($C_1\ C_2$)	-0.0004	-0.28	0.7810	0.0016	2.41	0.0160
Intercept	$-1.07x10^7$	-5.61	0.0000	-2686859	-3.79	0.0000
R^2		0.8868			0.9246	
F value		161.48			790.58	
RMSE		$1.02x10^7$			$8.8x10^6$	
No. of Cases		538			794	

procedure was implemented. The VIF is a statistic computed for each of the regressors of the model to check the extent to which the variance of each parameter estimate for the variable expand because of the explanatory impact of the other independent variable on this regressor. (Gujarati, 2004). Table 3 shows the results of the heteroscedasticity and multicollinearity diagnostics.

On the basis of the information provided by Table 3, contrasting results of the diagnostic tests were noted. Multicollinearity is deemed to be of tolerable variety per VIF statistics results. Heteroscedasticity on the other hand, appears to be present in both the public and private degree cost functions. As a consequence, there is a need to re-estimate the FFCQ cost function models for both public and private HEIs employing White's more appropriate estimation procedure. The results of the robust estimation of the cost functions are presented in Table 4 below.

Discussion

The cost functions, which can be extracted from the information provided by Table 4 constitute the realization of the main objective of this study. It is deemed appropriate to use the heteroscedasticity consistent (robust) estimates because of the overwhelming evidence for the presence of heteroscedasticity provided by Szroeter's test as shown in Table 3. No corrective measure was implemented for multicollinearity since it is inferred to be tolerable. Summarized in the table are the final estimates of the degree cost functions for both the private and public HEIs of the Philippine educational system. In both equations, the dependent variable is the Total Degree Cost.

In the estimated functions, total degree costs (C) are specified as a function of a single output – full time equivalent enrollment of the degree programs handled by the sample HEIs, and two-factor inputs – teaching cost and operating cost. These public and private HEIs' degree cost functions are estimated using the Flexible Fixed Cost Quadratic (FFCQ) model which involves quadratic and interaction terms of these variables.

With very few exceptions, especially in the case of private schools, the coefficients of the variables exhibit overwhelming statistical significance, implying the statistical desirability of the estimated cost functions. Coefficients of multiple determination (R^2) are very high and with extremely significant F values. Also noted are the obvious differences in magnitude of all coefficient estimates in both functions, giving ocular evidence to our a-priori contention that the two sectors' cost functions have different structures.

Despite their differences in magnitude, however, the two estimated cost functions exhibit the same algebraic signs of their respective parameter estimates. Both functions have positive output and factor input coefficients, signifying their being monotonic in outputs and factor prices. The negative coefficients of the quadratic terms of the variables suggest concavity of the two cost functions (that is, enrollments and factor inputs increase costs at decreasing rates. The concavity evidence, though, is not that strong for operating cost in the private case). The estimated equations can also be mathematically represented as follows:

Table 5. *Economy of Scale Computation under Different Enrollment Scenarios*

Enrollment Scenario for the Degree	Total Degree Cost	Marginal Cost	Average Cost	Economy of Scale
For Public HEIs:				
10% of Average	1,824,178.25	77,797.36	66,724.40	0.8577
50% of Average	10,367,317.76	76,493.09	75,842.70	0.9915
100% of Average	21,046,242.15	74,862.75	76,982.49	1.0283
200% of Average	42,404,090.93	71,602.09	77,552.38	1.0831
300% of Average	63,761,939.70	68,341.42	77,742.35	1.1376
400% of Average	85,119,788.48	65,080.75	77,837.33	1.1960
500% of Average	106,477,637.26	61,820.08	77,894.32	1.2600
600% of Average	127,835,486.04	58,559.42	77,932.31	1.3308
For Private HEIs				
10% of Average	3,381,658.98	176,917.53	133,562.11	0.7549
50% of Average	21,336,722.96	175,433.90	168,543.17	0.9607
100% of Average	43,780,552.94	173,579.36	172,915.81	0.9962
200% of Average	88,668,212.88	169,870.28	175,102.12	1.0308
300% of Average	133,555,872.83	166,161.19	175,830.89	1.0582
400% of Average	178,443,532.78	162,452.11	176,195.28	1.0846
500% of Average	223,331,192.72	158,743.03	176,413.91	1.1113
600% of Average	268,218,852.67	155,033.95	176,559.67	1.1388

Private HEI Degree Cost Function:

$$C = 68277.95q + 251.5522c_1 + 456.2843c_2 - 7.324739q^2 - 0.0007127c_1^2 - 0.0152076c_2^2 + 0.3863453qc_1 + 1.942605qc_2 - 0.0004029c_1c_2 - 10700000 \tag{6}$$

$$AC = \frac{C}{q} \text{ and}$$

$$MC = 68277.95 - 14.649478q + 0.3863453c_1 + 1.942605c_2 \tag{7}$$

Public HEI Degree Cost Function:

$$C = 37124.95q + 31.21214c_1 + 167.0532c_2 - 5.963401q^2 - 0.0001867c_1^2 - 0.0017191c_2^2 + 1.2516131qc_1 + 0.3518419qc_2 + 0016222c_1c_2 - 2686859 \tag{8}$$

$$AC = \frac{C}{q} \text{ and}$$

$$MC = 37124.95 - 11.926802q + 1.2516131c_1 + 0.3518419c_2 \tag{9}$$

Economies of Scale Computations

In investigating how the firm's costs behave when the scale of its operation vary with all input prices remaining fixed, conducting what-if simulations on the basis of the estimated cost relationships can be very useful in gaining additional insights into the economics of the firm (Besanko, et.al., 1996). In the present study, the simulation is implemented by using the estimated cost functions and some descriptive information from Table 1. Summarized in Table 5 are the results of the simulation under various enrollment scenarios (with teaching and operating costs per student assumed constant). The HEI costs analyzed are the total, marginal and average degree costs. The highlight of the simulation is the anticipated level of over-all or ray economies of scale for the two types of HEIs. Our computations are based on the formulas specified in equations (6), (7), (8) and (9).

It may be gleaned from the above table that the level of ray economies increases monotonically as enrollment level increases for both public and private institutions. It appears that the public sector has a better comparative performance over the private sector. Scale economies in the public sector were evident even at the 50 percent mean level of enrollment, whereas the private sector only began to exhibit economies of scale at the mean enrollment level. Interestingly, it is noted that the scale economy figure of 1.14 was attained by the public HEIs under 3 times mean enrollment, while the private HEIs reached this level only when its scale of operation is at 6 times its average enrollment.

In terms of the pattern of the marginal costs under various enrollment scenarios, both sectors show decreasing tendencies as enrollment levels increase. Average costs, on the other hand, exhibit an increasing trend in tandem with enrollment. Again, the public sector seems to enjoy the cost advantage since both its marginal and average costs are less than half of the corresponding figures for the private sector.

Summary and Conclusions

The main objective of this study is to show that public and private higher educational institutions (HEIs) in the Philippines exhibit different cost structures in servicing the degree programs that they both handle. It also aims to empirically establish the unique cost functions for the two types of HEIs. Employing a flexible functional form called Flexible Fixed Cost Quadratic (FFCQ) Model and the database developed by the Commission on Higher Education (CHED) consisting of a workable sample of 1,332 HEI degree cases (794 public and 558 private), various insights were gleaned from the analysis.

Through the Chow's Test of structural change adopted in a cross-sectional framework, the hypothesized difference in cost structure was empirically affirmed ($p<0.01$). Robust estimation of the FFCQ Cost Function Models for public and private HEIs generated statistically adequate results and were subsequently used in counterfactual simulations which helped in drawing some of the conclusions of this study. The estimated cost functions are both monotonic and concave in output and input prices, subscribing to the postulates of cost function theory.

The general conclusion drawn from the simulation results is that public HEIs operate in a more cost-effective manner than private sector HEIs in servicing the various degree programs they offer. Ray economies of scale exist in both sectors even at lower levels of operation, but the public sector's scale economies increases at a faster rate as enrollment increases. Furthermore, marginal costs and average costs for public HEIs are less than half of the corresponding cost figures for private HEIs in all enrollment scenarios.

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