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ABSTRACT

This study used the frontier cost function framework to examine cost efficiency in public higher education. The frontier cost function estimates the minimum predicted cost for producing a given amount of output. Data from the annual Almanac issues of the "Chronicle of Higher Education" were used to calculate state level enrollments at two-year and four-year public institutions, total educational and general expenditures, research expenditures, state appropriations for higher education, and average tuition rates for the 1989-90 through 1992-93 academic years. It was found that, overall, inefficiency does exist in public higher education, in that states have costs that are about 20 percent above the estimated frontier. It also found that states with higher two-year school enrollments had higher efficiency rankings than states with lower two-year enrollments, and that larger university systems tended to be more efficient than smaller systems. A significant relationship was also found between the share of total educational expenditures provided by state appropriations and the degree of efficiency, in that states with the smallest and largest shares were more efficient than states in the middle group. (Contains 31 references.) (MDM)

Cost Efficiency in Public Higher Education

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Abstract

This paper has two primary purposes. The first is to extend the literature examining costs in higher education to a frontier cost function framework. The second goal is to determine whether the source of funds in public higher education influences the degree of efficiency. A frontier cost function is estimated from state level data on higher education with "excess" costs measured as the difference between the minimum cost predicted by the frontier and actual costs. Results show that larger university systems are more efficient than smaller university systems. Also, the source of funds is important as states with the lowest and highest share of total expenditures provided by state appropriations are less efficient than states in the middle of the expenditure distribution.

Introduction

Understanding the cost structure of universities is vitally important. Many suggest that higher education institutions are inefficient in their operations. The 1996 Almanac issue of *The Chronicle of Higher Education* contains quotes from state leaders calling colleges "overfunded" (Gov. Fife Symington, Arizona) and "ripe for a hostile takeover" (Gov. Fob James, Alabama). These governors and leaders in several other states have sought to limit the growth in state appropriations for higher education, with some states actually decreasing funding in recent years. Yet other states increased state funding substantially. For example, Oklahoma increased state funding of higher education by 13 percent for 1996-97. State higher education officials called this a reward for making public colleges more efficient over the previous three years. In addition, 18 states partly base appropriations to individual public colleges on meeting specific performance measures.

Why some states are more efficient at providing public higher education to students and the relationship between efficiency and state funding has not been adequately addressed in the literature. This paper attempts to partly fill this gap. In particular the primary goal is to determine whether public university systems that receive a larger proportion of their funds from state appropriations are relatively more efficient than university systems that receive a large share of their funds from other sources such as tuition.

The standard approach used to consider efficiency in higher education is to examine the costs of providing higher education.[1] Early studies concentrate on a single output in higher education, namely undergraduate students measured by full-time equivalent students, number of credit hours, or number of students. This is problematic as colleges and universities have a variety of different outputs. As a result of focusing only on undergraduate students and ignoring other outputs from higher education such as graduate education and research, James (1978) noted that the costs of providing an undergraduate education were overstated.

Recent studies have overcome this shortcoming by considering universities to be multi-product firms that produce undergraduate students, graduate students, and research. Cohn, Rhine, and Santos (1989) use Higher Education General Information Survey (HEGIS) data on over 1,000 institutions to estimate cost functions for public and private schools. De Groot, McMahon, and Volkwein (1991) extend this research by focusing on a subset of doctoral granting universities, using a different measure of research output, and testing for any impact of the degree of state regulation on costs. Dundar and Lewis (1995) examine costs at the department level for 18 public research universities. In general, each study finds that total costs increase as enrollment increases and as research output increases, and that interactions between the various outputs are statistically important in determining institutional or departmental costs. In addition, economies of scale are generally found in higher education.

Others have estimated production functions for higher education where outputs are regressed on the inputs.[2] The relevant approach depends on the question that the researcher desires to answer and the available data. In the case of public higher education, a cost function is probably preferable since outputs are relatively exogenous compared to inputs. Also, while costs are relatively easy to measure, outputs in higher education are often difficult to measure, therefore costs are emphasized in determining the efficiency of state higher education systems.

This paper takes a different approach than previous studies by estimating a frontier cost function. Frontier cost functions are a frequently utilized tool for looking at production costs in manufacturing plants and industries. The frontier estimates the minimum predicted cost for producing a given amount of output, which in the case of universities is measured by students and research. The difference between the predicted minimum cost and actual cost is considered to be "excess" cost. The goal of this paper is to examine several factors that may lead to states being more or less efficient at providing higher education. In particular the relationship between the size of the university system and efficiency is examined. As mentioned above, previous research finds economies of scale exist in the provision of higher education, thus larger university systems are expected to be more efficient than smaller university systems.

Previous research on state appropriations has emphasized factors that influence the level of state spending.[3] Given that state leaders often call for reduced growth or reductions in state appropriations as a reaction to perceived inefficiency, it is important to determine if there is a link between funding sources and efficiency. Thus this paper determines whether there is a relationship between the share of expenditures from state appropriations and the level of efficiency. No attempt is made to rigorously explain why there may be a relationship between state appropriations and efficiency, rather the question is whether state leaders are correct in assuming such a relationship exists.

Government agencies are often accused of being inefficient in their provision of public goods. Also, similar to the flypaper effect, an increase in state appropriations may lead to greater expenditures by university systems and unless accompanied by an increase in output can lead to greater inefficiency. On the other hand, states may be in a position to better oversee the provision of education. As a state provides a larger share of a university system's budget, the state has a greater incentive to make certain the money is well spent. In addition, states that provide a greater share of the university's costs are likely to be able to influence spending by the university system.

The remainder of the paper is organized as follows. The next section discusses the data used in the paper. This is followed by a discussion of the methodology. Last the results and some concluding remarks are provided.

Data

An interesting question is the appropriate level of aggregation for this study. Costs can be examined at the department level, institution level, or the state level. Since the primary goal of this paper is to examine the relationship between costs and *state* appropriations, the natural place to start is at the *state* level. This does not imply that consideration of institutions and even departments is not worthwhile, indeed, it may be very important.

The data used in this paper are derived from *The Chronicle of Higher Education*. In each year the Chronicle publishes a special Almanac issue which includes substantial data on higher education in the United States. Data are available at the state level on student enrollments at 2-year and 4-year public institutions, total educational and general expenditures at public institutions, research expenditures, state appropriations for higher education, and average tuition rates at public institutions. Some information is published with a several year lag, thus the sample covers the 1989-1990 through 1992-1993 academic years with variable means reported in Table 1. The average state spent over $1.9 billion dollars on higher education (in 1990-91 dollars) per academic year, of which almost $800 million came from state appropriations. On average, there are almost as many students enrolled in 2-year schools as 4-year schools.

Methodology

Stochastic frontier estimation, first developed by Aigner, Lovell, and Schmidt (1977), is well established in the literature as a means of examining costs. We begin by considering the following equation:

$$C_{it}^{p} = X_{it}\beta + v_{it} \leq C_{it}^{o} , \qquad \textbf{(1)}$$

where the dependent variable represents the university system's minimum potential cost, X is a vector of variables measuring output, v is a disturbance distributed as $N(0,\sigma^2_v)$, i represents states, and t denotes time. The minimum cost (C^p) is less than or equal to the actual general and educational expenditures (C^o) on public higher education, with a state operating at the most efficient level having costs equal to the minimum predicted cost. However, the vast majority of university systems operate above the frontier.

By reconsidering equation (1) we can see:

$$C_{it}^{o} = C_{it}^{p} + u_{it} , \qquad \textbf{(2)}$$

where $u_{it} \geq 0$. If $u_{it} = 0$ the university system has achieved its minimum cost. Thus u_{it} is considered a state specific estimate of "excess" costs at time t. Combining equations (1) and (2) leads to:

$$C_{it}^{o} = X_{it}\beta + \epsilon_{it} , \qquad \textbf{(3)}$$

where $\epsilon_{it} = v_{it} + u_{it}$ and X contains the following:

- total students enrolled at 2-yr public institutions in the fall semester
- total students enrolled at 4-yr public institutions in the fall semester
- total research expenditures.

Quadratics for each variable are included to account for possible nonlinearities and interactions between the three outputs are also included in the specification. Wages are not included in the specification as the labor market for faculty is typically assumed to be a national market where little differences in salary exist once adjustments are made for productivity.[4]

Several changes to the specification would be desirable, but cannot be incorporated with these data. It would be useful to divide the number of students at 4-year institutions into two groups; undergraduate students and graduate students. It would be helpful to have a better measure of research output or a measure of the quality of output. Research expenditures are an imperfect proxy for research output, however I am not aware of a cumulative measure of research output for states.[5] The cost of higher education may depend on the quality of schooling offered by the state, with states offering a higher quality education incurring higher costs. Koshal and Koshal (1995) use SAT scores as a measure of the quality of higher education, however SAT scores are more likely to capture the quality of incoming students or elementary and secondary schooling, not the quality of higher education. Output from public service and capital inputs to the production process are also difficult to measure and not included in the analysis. Previous research has also lacked these data.

Estimation of equation (3) is achieved through the use of maximum likelihood. The distribution of u is assumed to be half-normal $u_{it} \sim N(0,\sigma^2_u)$, and truncated at zero from below, $u_{it} \geq 0$.[6] The distribution of ϵ is parameterized as:

$$f(\epsilon) = \frac{2}{\sigma} f(\frac{\epsilon}{\sigma})[1 - F(\epsilon\lambda\sigma^{-1})] \ , \tag{4}$$

where

$$\sigma^2 = \sigma_u^2 + \sigma_v^2, \quad \lambda = \frac{\sigma_u}{\sigma_v} \ . \tag{5}$$

The estimate of u is obtained via maximum likelihood and the following likelihood function:

$$\ln L(w_o/\beta,\lambda,\sigma^2) = N \ln\frac{\sqrt{2}}{\sqrt{\pi}} + N \ln\sigma^{-1} + \sum_{it} \ln[1 - F(\epsilon_{it}\lambda\sigma^{-1})] - \frac{1}{2\sigma^2}\sum_{it} \epsilon_{it}^2 \tag{6}$$

From these results, we obtain estimates of β, λ, and σ^2.

The techniques of Jondrow, Lovell, Materov, and Schmidt (1982) are used to obtain state specific estimates of u_{it}:

$$E(u_{it}/\epsilon_{it}) = \frac{\sigma_u^2\sigma_v^2}{\sigma^2}[\frac{f(\epsilon_{it}\lambda\sigma^{-1})}{1 - F(\epsilon_{it}\lambda\sigma^{-1})} - (\frac{\epsilon_{it}\lambda}{\sigma})] \ , \tag{7}$$

One problem with this measure of "excess" costs is that states with large educational expenditures are likely to have larger one-sided error terms. Studies looking at only one output, such as undergraduate students, generally consider per student costs. However it is unclear how to calculate an "average" cost or inefficiency with multiple outputs. In order to adjust the one-sided error term for the amount of output, inefficiency is defined as the one-sided error term divided by the predicted minimum potential cost estimated by the frontier:[7]

$$Inefficiency_{it} = u_{it} \ / \ C_{it}^p \tag{8}$$

Several different questions are considered. First, the relationships between each output and the level of inefficiency are considered. Second, the relationship between the source of funds and the degree of inefficiency is examined. This issue is considered in two steps, first by comparing state appropriations and inefficiency, and second by considering inefficiency and the proportion of total expenditures for higher education covered by state appropriations (SHARE). For each comparison, the sample is ranked based on the variable under consideration and broken into three groups of almost equal size. The average level of inefficiency is computed for each group and ANOVA tests are performed under the null hypothesis that all means are equal. When the null hypothesis is rejected, t-tests are performed to determine which means are significantly different.

Results

The results from both OLS and frontier estimation are provided in Table 2. Similar to other higher education cost functions, both 2-year and 4-year students are positively related to total costs. The cost of educating a student at a 2-year institution is lower than the cost at a 4-year school. Research expenditures are also positively related to total expenditures. The statistical significance of Γ implies that inefficiency does exist in the provision of higher education. On average states have costs that are 20 percent above the minimum estimated frontier.

The first question we seek to answer is whether there is a relationship between the outputs and the level of inefficiency. The sample is ranked by enrollments at 2-year schools, with average inefficiency calculated for each group. ANOVA tests reject the null hypothesis of equal means for all three groups. The means are reported in Table 3 and show that the degree of inefficiency varies considerably across states and falls as enrollments increase.[8] States with the fewest enrollments at 2-year schools had an inefficiency level of .4027. Thus actual expenditures were 40 percent above the predicted minimum frontier and on average, states had costs $150 million above their predicted minimum. The states with the highest 2-year enrollments have an average inefficiency level of .0803, with expenditures only 8 percent above the predicted minimum. On average, $200 million in costs were incurred above the estimated frontier. While states with larger enrollments in 2-year schools are farther above the frontier ($200 million vs. $150 million), the amount is a far smaller proportion of predicted minimum costs.

Similar patterns are found when considering enrollments at 4-year schools and research expenditures. Given, that the rankings of states are quite similar across the three outputs, the results do not necessarily show that higher research expenditures or enrollments directly lead to less inefficiency. However, larger university systems tend to be more efficient than smaller university systems.

An alternative method is to use regression analysis to examine these relationships. Separate regressions were estimated where the level of inefficiency is regressed on each output individually. In each case, efficiency increases as the output measure increases. A quadratic specification for the output measure was also tested and in each case the coefficient on the quadratic term was positive and significant. By examining the coefficients, it can be shown that the degree of inefficiency falls as university systems become larger, but actually begins to increase for the largest university systems.

These results are interesting but are not really relevant for public policy. Montana and Wyoming have smaller university systems than New York and there is little those states can do about the size differential.

Next the level of efficiency is related to the source of the school system's funds. The level of state appropriations is also inversely related to the degree of inefficiency. States with the smallest appropriations have an average degree of inefficiency of .4134, while states with the largest appropriations average .0717. Again this provides some support that larger university systems are more efficient than smaller university systems.

Last, and most important from a policy perspective, the relationship between inefficiency and the share of total funds from state appropriations (SHARE) is examined. The state rankings based SHARE are quite different than the other comparisons, thus it is not simply another comparison of university system size. States with the smallest SHARE have an average level of inefficiency of .2465, with this figure falling to .1499 for the middle group. However, states with the highest SHARE are quite similar to the states with the smallest SHARE. The degree of inefficiency is regressed on the SHARE and SHARE squared, and the point calculated that minimizes the level of inefficiency. Inefficiency is minimized when the state SHARE is approximately 45 percent of total expenditures.[9]

Based on these results, states need to be cautious about simply reducing state appropriations as a reaction to perceived inefficiency. For states with a high state SHARE, a reduction in state appropriations may result in greater efficiency if the state SHARE falls as a result of the reduction. This is likely to be the case, even if none of the loss in state appropriations is offset by an increase in tuition revenue, the state SHARE will still fall. However, if a university system reduces its total expenditures such that the state has a smaller university system, then efficiency may not increase. Any positive effect on efficiency from reductions in the state SHARE decreases as the state SHARE approaches 45 percent, and if the state share falls below 45 percent the degree of inefficiency may actually increase. States that already provide a small SHARE of total expenditures are unlikely to increase efficiency through further reductions. These states are more likely to increase efficiency by exerting pressure on the university system to reduce expenditures. Thus legislators need to consider the ramifications of a change in state appropriations on revenues from other sources and total expenditures before being able to claim that a reduction in spending will create a more efficient system.

As is usually the case, several caveats apply to the results presented in this paper. As discussed above, all of the outputs from higher education cannot be controlled for and thus the measure of inefficiency is likely to be measured with some error. In particular the absolute dollar figures for "excess" costs should not be interpreted as saying that expenditures should be reduced by the estimated "excess". On average, costs may be above the frontier due to factors not taken into account.[10]

Conclusion

The goal of this paper was twofold. The first aim was to extend the literature on the costs of higher education to a stochastic frontier framework. Second, the relationship between a state's efficiency in providing higher education and various characteristics is examined. Consistent with previous research that finds economies of scale in higher education, a positive relationship is found between efficiency and the outputs of the university system. Larger university systems tend to be more efficient than smaller university systems. The link between state appropriations and the degree of efficiency is examined with a positive relationship found between state appropriations and efficiency. More importantly a significant relationship is found between the share of total educational expenditures provided by state appropriations and the degree of efficiency. When the sample is divided into three groups based on the state SHARE, states with the smallest and largest SHARES are more inefficient than states in the middle group.

These results have potentially important policy implications. First, the standard assumption among state leaders that reductions in appropriations make universities more efficient may not be true. States that provide a high share of total expenditures may increase efficiency by reducing the state share of costs, but states that in the middle or lowest groups might not benefit by reducing the state share further. There are many questions that should be answered by future research. For example, it would be interesting to determine if similar results hold within colleges and universities. Also a longitudinal analysis that is able to examine the changing patterns of state support for higher education would be useful.

Endnotes

1. See Brovender (1974), Verry and Davies (1976), Adams, Hankins, and Schroeder (1978), Tierney (1980), Brinkman (1981), Brinkman and Leslie (1986), Hoenack, Weiler, Goodman, and Pierro (1986), and Koshal and Koshal (1995).

2. For example, Polachek, Kneisner, and Harwood (1978), Manahan (1983), Dolan and Schmidt (1994), Douglas and Sulock (1995).

3. For example Clotfelter (1976), Peterson (1976), Coughlin and Erekson (1986), Hoenack and Pierro (1990), and Strathman (1994).

4. Cohn, Rhine and Santos (1989) estimate cost functions with and without wages, withotu substantial differences in the parameter estimates.

5. Cohn, Rhine, and Santos (1989) consider a sample of research universities for which research output measures are available. They find a .7 correlation between research expenditures and research output, thus they conclude that expenditures are not an unreasonable proxy for output. However, De Groot, McMahon, and Volkwein (1991) find their results are sensitive to whether research expenditures or research output is used in the analysis.

6. Aigner, Lovell, and Schmidt (1977), Cowing, Reifschneider, and Stevenson (1983), and Hofler and Murphy (1994) find the distribution of u to have little impact on the estimated coefficients.

7. The one-sided error was also divided by actual educational expenditures with very similar results to those reported below.

8. The results are based on all 200 observations from the pooled cross-section time-series sample. We also examined individual years and found similar relationships.

9. Attempts were also made to compare changes in state shares with changes in inefficiency. Many states reduced their state share of total expenditures in the sample period, however, little

change in estimated efficiency occurs within most states. It is quite likely that changes in efficiency are slow to occur since higher education cannot restructure its workforce as quickly as most industries.

10. See Newhouse (1994), Skinner (1994), Dor (1994), Hadley and Zeckerman (1994), and Vitaliano and Toren (1994) for an interesting exchange on the use of stochastic frontiers to estimate "excess" costs in hospitals and nursing homes. In particular criticism is focused on the use of frontier estimation to set absolute dollar amounts of inefficiency.

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Table 1. Variable means[a]

	Mean	Std Dev
Total expenditures	1,861,984	2,012,376
4-year students	115,907	102,515
2-year students	102,421	174,818
Research expenditures	325,320	393,666
State appropriations	789,976	917,503
State share	.4210	.0907
Number of observations	200	

Data: Chronicle of Higher Education, 1989-1990 through 1992-1993 academic years.
a. All dollar figures are in thousands of dollars deflated using the Higher Education Price Index (1990-91=100). Variable definitions: Total expenditures = total general and education expenditures at public institutions in the state; 4-year students = the number of students enrolled in the fall semesters at 4-year public institutions; 2-year students = the number of students enrolled in the fall semesters at 2-year public institutions; Research expenditures = research expenditures in the state during the fiscal year; State appropriations = state appropriations on higher education during the academic year; State share = State appropriations divided by total expenditures.

Table 2. Cost Function Results[a]

	OLS	Frontier
Constant	-41,279	-208,030**
	(44,838)	(86,059)
2-year students	3.358 **	3.269 **
	(.804)	(.694)
2-year squared	-.00001**	-.0000045**
	(.000002)	(.000002)
4-year students	11.792 **	11.953 **
	(1.26)	(1.08)
4-year squared	-.000004	-.000004
	(.000007)	(.000007)
Research expenditures	1.032 **	.9205 **
	(.338)	(.415)
Research squared	-.000002**	-.000002**
	(.0000004)	(.0000006)
2-year * 4-year	-.00002**	-.00002**
	(.000008)	(.000006)
2-year * Research	.000011 **	.000010 **
	(.000002)	(.000002)
4-year * Research	.0000047 **	.0000048
	(.000002)	(.000003)
$\Gamma = \sigma_u/\sigma_v$	-----	1.128 **
		(.446)
$\sigma^2 = \sigma^2_v+\sigma^2_u$	-----	294,360 **
		(49,839)
$\sigma^2_v=$	-----	129,538
$\sigma^2_u=$	-----	164,822
N	200	200
R-squared	.9848	----
Log-likelihood	----	-2762.8

a. See Table 1 for variable definitions. Standard errors are in parentheses.
** denotes the coefficient is significant at the 5 percent level, * 10 percent.

Table 3. The Relationship between Inefficiency and Various Characteristics

Variable	N	Mean	Std Dev	T-stat[b]
Total	200	.2069	.1980	
Students at 2-year schools				
(1) < 31,800	66	.4027	.2175	
(2) 31,800 - 77,000	67	.1357	.0876	
(3) > 77,000	67	.0803	.0565	
			(1) vs (2)	9.32 **
			(2) vs (3)	4.34 **
			(1) vs (3)	11.74 **
Students at 4-year schools				
(1) < 60,700	66	.4219	.1968	
(2) 60,700 - 126,000	67	.1398	.0826	
(3) > 126,000	67	.0621	.0349	
			(1) vs (2)	10.75 **
			(2) vs (3)	7.10 **
			(1) vs (3)	14.62 **
Research expenditures (in thousands)				
(1) < 94,000	66	.4128	.2077	
(2) 94,000 - 298,000	67	.1393	.0908	
(3) > 298,000	67	.0716	.0437	
			(1) vs (2)	9.81 **
			(2) vs (3)	5.50 **
			(1) vs (3)	13.06 **

Table 3. The Relationship between Inefficiency and Various Characteristics (contd.)

Variable	N	Mean	Std Dev	T-stat[b]
State appropriations for higher education (in thousands)				
(1) < 329,000	66	.4134	.2067	
(2) 329,000 - 820,000	67	.1386	.0907	
(3) > 820,000	67	.0717	.0448	
			(1) vs (2)	9.91 **
			(2) vs (3)	5.42 **
			(1) vs (3)	13.13 **
State share of total expenditures				
(1) < .373	66	.2465	.2148	
(2) .373 - .462	67	.1497	.1133	
(3) > .462	67	.2250	.2340	
			(1) vs (2)	3.25 **
			(2) vs (3)	-2.37 **
			(1) vs (3)	-0.55

a. The t-statistics determine whether the means are significantly different. ** indicates significance at the 5 percent level, * at the 10 percent level.

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