Review of Economics & Finance

Submitted on 02/Aug./2012

Article ID: 1923-7529-2013-01-63-11 G. Thomas Sav

Effects of Financial Source Dependency on Public University Operating Efficiencies: Data Envelopment Single-Stage and Tobit Two-Stage Evaluations

G. Thomas Sav

Department of Economics, Raj Soin College of Business

Wright State University, Dayton, OH 45435, U.S.A.

Tel: +1-937-775-3070 E-mail: tom.sav@wright.edu

Abstract: Managing publicly owned universities has necessitated year after year adjustments to shifts in the dependency on alternative financing sources. The global financial crisis bought new managerial operating challenges with an accelerated decline in government funding and a quick evaporation of investment income. But, in many cases, regulatory constraints prevented offsetting tuition increases. This paper investigates how differences in university finances potentially affect operating efficiencies. The analysis uses panel data on 331 universities for academic years 2005-2009. Because finances are only partially under the control of university management, they are treated as quasi environmental in the implementation of data envelopment estimation of efficiencies. Single stage DEA estimates are, therefore, generated with university financial environments included under one model and excluded under another model. Results are compared to a Tobit two-stage analysis in which first-stage efficiencies are used along with financial environments. Findings indicate that greater tuition dependency promotes inefficiency while increased government funding yields efficiency gains. Investment income also appears to have a slight negative effect, albeit statistically weak. Despite recent financial shocks, the results reveal public university efficiencies have improved over time.

Keywords: Data envelopment, Two-Stage DEA, Tobit DEA, University efficiency

JEL Classifications: I21, I22, I23; L32; C65

1. Introduction

This paper employs data envelopment analysis (DEA) to explore how alternative financing source dependencies affect public university operating efficiencies in the United States. Financial sources examined include revenues derived from tuition charges, government appropriations, and investment income. While two decades of reduction in governmentally funded public higher education has shifted the financial dependency of public universities, an acceleration of shifts has occurred as a result of the financial crisis and a growing interest in public management reforms. In total, new pressures have been brought to bear on university management to seek ways of improving operating efficiencies with ever tighter budgetary constraints. Thus, the issue of efficiency and the possible effects on efficiency due to the ways in which education is financed carries important managerial and public policy implications for the future of public higher education.

In order to evaluate the effects of financial sources on university performance, this study uses an output-oriented DEA along with financial variables that include revenue derived from tuition charges, government appropriations, and investment income. Along with physical inputs, these financial sources vary across universities and change over time. However, unlike physical inputs, the financing of public universities is only partially under the control of university management. State wide governing boards and political decision-making, along with external market forces, affect the ability of universities in gathering revenue from tuition charges, government funding, and investments. In the framework of DEA techniques these finances can be treated as quasi environmental factors in that they are partially exogenous and partially under the control of university management. Therefore, they could be included along with other inputs in a single stage DEA estimation of university efficiencies. Excluding them from consideration could lead to DEA misspecification and estimation error. On the other hand, if financing was purely exogenous, then conventional arguments would lead to a two-stage DEA approach whereby university first stage DEA efficiency scores are used along with a set of environmental covariates in a second stage, parametrically specified model. Given the quasi input characteristics of public university finances, this paper proceeds to estimate and compare university efficiencies using both single and two-stage DEA.

The desire to incorporate uncontrollable managerial variables in DEA efficiency estimates has led to several methodological multiple stage DEA approaches, including two, three, and four-stage implementations (e.g., see Yang and Pollitt, 2009). However, not all DEA studies have followed even a second-stage estimation path. For example, Emrouznejad, et al., (2008) found more than 4000 published DEA research studies, while Simar and Wilson (2007) note fewer than 50 articles that have used two-stage estimation. In contrast, published DEA studies related to higher education are much scarcer and appear to be only 21 in number. Of those, only 3 have employed a two-stage approach. This paper, however, is believed to be the first to apply a two-stage approach in examining the efficiencies of U.S. universities.

The paper constructs panel data pertaining to observations on 331 U.S. publicly owned universities over four academic years, 2005-09. An output-oriented DEA model is used where three outputs, including undergraduate education, graduate education, and research depend upon eight university inputs treated as direct inputs. Efficiencies are estimated under both constant and variable returns to scale DEA models. Three indirect inputs that are quasi exogenous or environmental are introduced as possible effects on university efficiencies. These include the percentage of university financing that is derived from tuition charges, government appropriations, and investment income. DEA efficiencies are then estimated with the inclusion of possible financial effects. Both single stage evaluations are used for comparison to a two-stage approach. In the second stage, financial variables are covariates to first stage DEA estimates in a Tobit regression.

The paper proceeds with a review of the DEA applied literature pertaining to higher education followed by an outline of the DEA methodology, a section describing the data, and then the empirical results. Concluding remarks make for the final section of the paper.

2. DEA Applications to Higher Education

DEA has its roots in the seminal works of Charnes et al. (1978) and Banker et al. (1984). Here, the focus is on applications of DEA to higher education. Of what appears to be 21 DEA related studies of universities, 14 are cross sectional in nature and the remaining seven employ longitudinal data. As mentioned in the introductory remarks, only 3 of the latter employ a two-stage approach.

The cross sectional studies are of two varieties. On the one hand, there are six studies at the very micro departmental or program level. These include studies based in the United Kingdom (including Beasley, 1990 and 1995 and Casu and Thanassoulis, 2006), the Ben-Gurion University (Sinuany-Stern, et al., 1994), the U.S. (Cobert et al., 2000 and Reichmann, 2004), the Helsinki School (Korhonen et al., 2001), and Austria (Leitner et al., 2007). The emphases of these studies vary from eighteen departments in a single university (Korhonen et al., 2001) to over nine hundred departments spread across 12 universities (Leitner et al., 2007).

Other cross sectional studies employed DEA to investigate university level efficiency. These include two U.S. studies that used 1984 academic year data (Ahn et al., 1988) and 1992 academic year data (Breu et al., 1994) and two United Kingdom studies using 1992 (Athanassapoulos and Shale, 1997) and 1996 university data (Glass et al., 2006). Avkiran's (2001) study of Australian universities relied on a 1995 cross section. A later study of Canadian universities by McMillan and Chan (2006) relied on a 1992 sample of universities. The number of universities studied ranged from the Breu et al. (1994) sample of 25 universities to 161 universities used in Ahn et al. (1988).

More recently to arrive in the literature is the use of university panel data in DEA. These include the Carrington et al. (2005) evaluation of Australian universities over the 1996-2000 academic years, the Castano and Cabanda (2007) 1999-2003 sampling of Philippine universities, Worthington and Lee's (2008) 1998-2003 study of Australian universities, and the Agasisti and Johnes (2009) intercountry comparison of 2001-04 Italian and English university efficiencies.

None of the above studies employ two-stage DEA evaluations. Yet, university operating efficiencies might be affected by factors external to managerial control, to factors that do not directly serve as inputs into the production processes, or to certain institutional or input characteristics. Three very recent studies implement such a two-stage approach. After obtaining output-oriented DEA efficiency scores for a 1998-2003 panel of 72 German universities, Kempkes and Pohl (2010) use a Tobit model in exploring the effects on efficiency due to university characteristics, including the presence of medical and engineering departments and the number of technical and research personnel employed. Kounetas et al. (2011) study efficiency differences among departments in a Greek university for the 2001-04 academic years. They utilize an input-oriented DEA model and, like Kempkes and Pohl, implement a Tobit regression in the second stage. The regression includes school dummy variables, departmental age, building ownership characteristics, and the personnel in each department. Wolszczak-Derlacz and Parteka (2011) use 2001-05 data to estimate output-oriented DEA efficiencies for 259 universities housed in seven European countries. In the second stage, they employ a truncated regression model using a country GDP variable, a medical school dummy variable, the proportion of academic women employed, and the proportion of university revenues derived from non-government sources.

The second stage of the two-stage approach is designed to account for efficiency determining factors that are exogenous to producer control, i.e., so-called environmental factors. Empirical implementations, however, have diverged from the pure sense of environmental influences and have incorporated some factors that are (arguably) only quasi environmental or quasi uncontrollable by management. In review of the three studies just noted, research personnel employment in German universities must be partially under the control of university management. In Greek universities, departmental level decision-making is likely to have some control over departmental employment. Similarly, European university decision-makers are likely to influence employment outcomes pertaining to the proportion of women employed and in revenue derived from non-government sources. One would be hard pressed to characterize these factors as purely environmental. Yet, these studies find such factors to have statistically significant value in accounting for differences in operating efficiencies across departments and universities. In that sense, they are justifiably critical in evaluating higher education efficiencies. The present paper follows along this line of research in maintaining that public university finances as measured by the dependency upon different revenue sources are not direct inputs in university production but rather are quasi environmental factors, partially controllable by management and partially exogenous to the institution. Thus, their efficiency impacts should be investigated from the perspective of both a single stage and a two-stage DEA implementation. Following the work of McCarty and Yaisawarng (1993) and Bhattacharyya (1997), the Tobit regression has been the most often used in two-stage empirical applications. The present methodology will follow with that convention.

3. Single Stage and Two-Stage DEA Efficiency

In the DEA single stage or first stage of a two-stage implementation, efficiency can be defined in general as the ratio of outputs to inputs as

$$Efficiency = \sum_{i=1}^{s} a_i y_i \,/\, \sum_{j=1}^{m} b_j x_j \qquad (1)$$

where an institution is employing *m* inputs to produces *s* outputs and the coefficients *a*,*b* are output and input weights, respectively. The assumption is that the managerial objective is to obtain maximum efficiency. In this ratio form, the efficiency problem can be stated as one of finding the *a*,*b* that maximizes (1) for each decision-making unit, DMU. For *n* DMUs, the linear programming envelopment can be expressed using standard notation for the output-oriented variable returns to scale (VRS) model that is due to Banker et al. (1984):

$$\begin{aligned} & Max_{\phi\lambda}\phi \\ & Y\lambda \geq \phi y_0 \\ & X\lambda \leq x_0 \\ & \lambda_i \geq 0 \\ & \sum \lambda_i = 1 \end{aligned} \qquad (2)$$

where *Y* is a *s* x *n* output matrix and *X* is a m *x n* input matrix and the input and output slacks are omitted for presentation convenience. The constant returns to scale (CRS) model originally due to Charnes et al. (1978) is obtained by dropping the last constraint. Scale efficiencies are determined by the ratio of the CRS to VRS efficiencies. The *n* ratios $1/\phi$ determine the efficiency scores (*EFF*) for the DMUs. Institutions that are efficient are operating on the frontier and obtain an efficiency score of one. The frontier envelopments the inefficient units evaluated as having scores below the value of one.

The efficiency scores obtained via the above DEA are assumed to arise from managerial efficiency or inefficiency in organizing and managing production. Therefore, the inputs are generally thought to be endogenous and under the control of management. Yet, there may be factors that either positively or negatively affect efficiency but are either fully or partially beyond the control of management. These factors can be included in the above *m* inputs and efficiencies determined in a single stage DEA. In contrast, excluding them from the above, a second stage analysis can be performed in an attempt to capture their efficiency effects. Normally, the second stage employs these environmental factors along with the first stage DEA efficiency scores in a parametric formulation. Since the DEA efficiencies are less than or equal to one in value, the censored Tobit model comes into play for use in the majority of research. The second stage regression can be expressed as

$$EFF_k = z_k \beta + \varepsilon_k \qquad (3)$$

where *z* represents the vector of environmental influences along with the beta coefficients to be estimates and the university efficiencies, *EFF*, are not observable but rather determined in the first stage DEA . The framework allows one to examine the significance of uncontrollable influences on operating efficiencies. In addition, following McCarty and Yaisawarng (1993), the second stage residuals can be used as adjusted efficiency estimates for comparison to the DEA efficiency scores. The residuals then lie in the interval $(-\infty, 1)$ with the upper bound representing full efficiency.

As with the three DEA university studies that have explored two-stage implementations, the present study uses variables that can be considered to be partly controlled by university management and partly exogenous to the institution, i.e., quasi environmental. These are the three variables that pertain to the universities financial environment and are neither purely exogenous nor purely under the discretion of management. For example, a university's investment income and the subsequent portion of revenue derived from investments are determined by both external market forces and by the financial astuteness of university management. The extent to which public universities generate revenue from tuition charges is partially determined by state governing boards that can regulate and have capped annual tuition increases. And government funding can vary across institutions depending upon external decision-making via government authorizations and local and state politics but also through university generated lobbying, the level of which is controlled by university management. Thus, the university financial variables have some exogenous and endogenous qualities. To explore how they might affect efficiency, empirical implementation will include two separate single stage DEA specifications: one with the financial environment included as university inputs and one without environmental influences. The latter DEA efficiencies will then be used in a second stage implementation using a Tobit model estimation.

4. Data Construction

The study investigates operating efficiencies of U.S. public universities operating during the four academic years, 2005-09. Data is acquired from the U.S. Department of Education, Integrated Postsecondary Education Data System (IPEDS). The interest lies in public universities engaged in both undergraduate and graduate education and research. In this case, universities are drawn from IPEDS based on their Carnegie classifications; master's colleges and universities and doctoral/research universities. After excluding institutions that did not report undergraduate or graduate education activity or critical financial and institutional data, a balanced panel was obtained for 331 universities, resulting in 1,324 observations over four years.

Three university outputs are included in the analysis. They are used in the previous studies reviewed above and, therefore, make final results somewhat comparable. The two educational outputs include the total annual undergraduate (UGRAD) and graduate (GRAD) credit hour production. As with Sav's (2004 and 2012 a,b) studies of U.S. universities, annual credit hours are used to account for production during normal academic terms as well as intersessions and summer terms. In addition, credit hour production accounts for different academic course loads carried by both full-time and part-time students. Institution wide research output is proxied by the university's receipt of research grants and contracts (RES) and is routinely employed in multiproduct studies of higher education.

University inputs for the DEA model are also tied to the previous empirical research reviewed above. However, here, as with previous research, the availability of data governs the selection of variables. From IPEDS, eight input variables are selected. For student inputs, the total twelve month unduplicated undergraduate enrollment (UROLL) and graduate enrollment (GROLL) are chosen. Both classifications of students produce credit hours but graduate teaching and research assistants can also produce undergraduate credit hours and research. Unfortunately, the data do not permit any such refinements. Of course, also included is the total faculty employment (FAC) as an input in producing both education and research. There is an absence of a physical staff employment measure that can be associated with different university professional or support functions. As a substitute for student support services, included is the university annual expenditure for student service support expressed as dollar expenditures per student (STUSER). For academic support, the substitute measure is the annual expenditure on academic support expressed as a percentage of total university expenditures (ACDSER). There are two capital variables: the value of equipment (EQUIP) and buildings (BUILD). The annual total university expenditure (TEXP) is included as the final DEA input that is assumed to be under the control of university management.

As previously described, there are three financial quasi environmental factors. All are derived as a financial revenue source relative to total annual university revenue and expressed as a percentage. Specifically, these are the percentage of total revenue stemming from tuition charges (TUIT), state and local government appropriations (GOVT), and investment income (INVES). Again, it is recognized that these are partially under the control of university management and partially subject to external regulatory decision-making by state governing boards (e.g., tuition charges and caps), state political machineries (tax and expenditure legislation), and market forces (financial market fluctuations or crises). Yet they vary across universities and with time. The purpose here is to determine the extent to which differences therein affect overall operating efficiencies of universities.

Table 1 presents the variable descriptive statistics and the annual percentage changes.

As indicated, undergraduate credit hour production is more than six times that of graduate credit hour production, but the undergraduate student enrollment is just over four times as large as the graduate enrollment. The percentage increase in graduate enrollment, especially in 2008-09, can be attributed to the increased unemployment of baccalaureate degree holders that accompanied the recession. Also noticeable is the slowdown in university expenditures associated with student and academic support services.

Table 1 Variable means, deviations, and annual changes

Variable	Mean	Std. Dev.	% Chg. 2006-07	% Chg. 2007-08	% Chg. 2008-09
UGRAD (#)	329,937	244,090	2.02	2.14	1.67
GRAD (#)	49,998	58,586	2.03	2.27	6.63
RES ($)	1.64E+08	2.13E+08	5.77	1.82	-1.79
UROLL (#)	11,973	8,219	1.66	1.85	2.38
GROLL (#)	2,805	2,693	1.77	5.33	9.19
FAC (#)	500	365	1.92	2.41	0.07
STUSER ($)	1,316	575	6.40	10.79	3.50
ACDSER (%)	8.11	2.86	-0.13	4.89	2.92
EQUIP ($)	1.17E+08	1.96E+08	5.50	4.35	3.33
BUILD ($)	3.80E+08	4.77E+08	9.28	7.67	8.91
TEXP (%)	3.59E+08	5.31E+08	6.50	9.01	4.53
TUIT (%)	25.23	9.69	-1.57	1.06	7.28
GOVT (%)	32.44	9.35	-0.51	2.00	-5.19
INVES (%)	1.23	-3.92	51.98	-60.41	-182.90

To some extent that may have been occurring with respect to reductions in support staff. For the financial variables, tuition charges and government appropriated support comprise nearly sixty percent of total university revenues on average. And although investment income only averages just over one percent, it can also serve as a combined internal-external barometer potentially affecting university decision-making and subsequent operating efficiencies. The decline in investment revenue is quite dramatic and is a reflection of the financial crisis impact but can also be tangled up with a university's withdrawal of investment funds. Mirroring the crisis impact is the increase in tuition revenues and the decline in tax supported government appropriations.

5. Efficiency Estimates

The single stage DEA estimates of university efficiencies are presented in Table 2. For comparative purposes, the evaluations are performed under two modeling assumptions. Model I provides efficiency estimates based on the inclusion of only direct production inputs, excluding the financial environmental variables. Model II estimates are derived based on the inclusion of all efficiency variables, including the three quasi financial environmental variables. In each case, both CRS and VRS efficiencies are estimated, along with the scale efficiencies. Due to scale effects, the CRS efficiencies are smaller than the VRS estimates.

Table 2 DEA single stage efficiency, scale, and returns estimates

Estimate	Model I: No Environment			Model II: Environment		
	CRS	VRS	Scale	CRS	VRS	Scale
Mean	0.867	0.894	0.970	0.879	0.932	0.943
Median	0.877	0.922	0.987	0.890	0.968	0.963
Std. Dev.	0.108	0.103	0.041	0.105	0.081	0.064
Skewness	-0.347	-0.629	-2.104	-0.472	-1.046	-1.568
Minimum	0.594	0.613	0.781	0.599	0.682	0.671
No. Full Eff=1	54	89	54	64	118	64
Annual Percentage Changes						
2006-07	-2.88	-1.78	-1.13	-2.11	-0.01	-2.08
2007-08	2.64	1.38	1.26	1.94	0.21	1.71
2008-09	3.16	1.83	1.31	2.75	0.75	2.00
Returns to Scale Distribution						
Decrease	15.41%			0.30%		
Constant	26.89%			29.61%		
Increase	57.70%			70.09%		

A quick scan of the results indicates that university operating efficiencies, based on mean CRS and VRS estimates, hover around 0.9. Overall, that suggests university outputs could increase about 10% with the current endowment of inputs. However, both CRS and VRS efficiencies are greater under Model II compared to Model I. Moreover, the null hypothesis that the means are equal is rejected at the one percent level of statistical significance (the t values are 7.76 and 13.09 for the CRS and VRS tests, respectively). The same, of course, holds for scale efficiency difference (the t value is 10.51) but the mean scale is lower under Model II than under Model I due to the fact that the VRS efficiency increase outweighs the CRS efficiency increase. On all accounts, the results support the notion that the three financial measures under consideration affect university efficiencies.

Other differences in the model estimates require note. For example, Model I VRS estimation results in 89 or 27% of the 331 universities being fully efficient while Model II increases that to 118 or 36% of the universities. A smaller difference in fully efficient universities occurs under CRS estimation; 54 or 16% under Model I vs. 64 or 19% under Model II. Also of interest are the annual changes in university efficiencies that are summarized in Table 2. Under both models, there is efficiency deterioration in the 2006-07 from the 2005-06 academic year. The decline is larger under CRS estimation, negative 2.88% and 2.11%, compared to VRS estimation, 1.78% vs. 0.01%. Each of following academic years, however, reveal efficiency gains. Comparing models, the 2006-07 efficiency decline and subsequent academic year rebounds are substantially larger under Model I compared to Model II. In Model II relative to Model I there are substantially more universities that are fully efficiency and, given the distributional results, the inefficient universities are closer to the frontier. Thus, the resulting percentage gains in efficiency are smaller under Model II relative to Model I.

To round out the analysis, the returns to scale are estimated using the individual university four year output and input means. Table 2 lists the percentage of universities operating under the estimated decreasing, constant, and increasing returns to scale. Approximately the same percentage of universities is estimated to be operating optimally, i.e., at constant returns, under both models. And under both models, the majority of universities are operating in the range of increasing returns, indicating that average costs are declining with increased production.

Turning to the stage-two evaluations, Table 3 contains the Tobit regression results using the CRS and VRS university efficiency scores obtained from the first stage DEA. So as to secure the efficiency changes over time, time dummies are included along with the financial environmental variables. Overall, both models perform well; the likelihood ratios are significant at the one percent level and better. In addition, the coefficients carry the same signs in both models but have marginally better statistical significance in the CRS vs. VRS results. The time variables are measuring efficiency relative to the 2005-06 academic year and, therefore, differ from the year to year percentage changes previously presented in Table 2.

The results indicate that operating efficiencies of public universities decline with increased dependency on tuition charges as a source of revenue. Using either the CRS or VRS models, there is nearly a 0.004 or 0.4% point decline in university efficiency scores for a 1% increase in tuition revenue as a percentage of total revenue.

Table 3 Tobit second stage estimates

Variable	CRS from DEA Model I		VRS from DEA Model I	
	Coefficient	S. E.	Coefficient	S. E.
Constant	1.0422***	0.1054	0.9785***	0.1156
TUIT	-0.0035***	0.0004	-0.0038***	0.0005
GOVT	0.0018	0.0004	0.0027	0.0005
INVES	-0.0013	0.0011	-0.0004	0.0012
2006-07	-0.0304***	0.0112	-0.0232*	0.0122
2007-08	-0.0052	0.0112	-0.0079	0.0122
2008-09	0.0417***	0.0116	0.0259**	0.0127
Sigma	0.13897	0.00333	0.1477	0.0039
No. Rt./ Censored	337/1324		476/1324	

Note: Significance at 1% (***), 5% (**), and 10% (*).

On the other hand, a 1% shift to government funding as a revenue source creates a university efficiency improvement of 0.18 to 0.27 percentage points depending upon CRS or VRS first stage estimation. That finding is in support of previous research that isolated government funding effects on university efficiencies in a stochastic modeling framework (Sav, 2012). The results also suggest that increases in investment as a proportion of university revenue generates inefficiency; but the effect is the smallest of the three finances and is statistically insignificant in using either CRS or VRS efficiency measures.

Table 4 Spearman rank correlations

Model		Model I No Environment		Model II Environment		Tobit Second Stage From Model I	
		CRS	VRS	CRS	VRS	CRS	VRS
Model I No Environment	CRS	1.00					
	VRS	0.93	1.00				
Model II Environment	CRS	0.97	0.89	1.00			
	VRS	0.82	0.89	0.84	1.00		
Tobit Second Stage From Model I	CRS	0.94	0.87	0.94	0.80	1.00	
	VRS	0.84	0.90	0.84	0.86	0.92	1.00

Overall, the second stage estimates imply that increased government funding and greater insulation from market forces tend to improve the operating efficiencies of public universities. However, as is well known and is borne out by the summary statistics presented in Table 1, higher education revenue shifts have moved in the opposite direction. Thus, to the credit of public universities, inefficiency improvements have moved counter to those effects.

To check the robustness of results, universities were ranked based the efficiency scores obtained from the six different models. The Spearman rank correlations are summarized in Table 4. In the single stage DEA there is a high correlation, 0.97, between efficiency rankings based on the CRS model regardless of excluding or including financial environments. When universities are ranked according to the single stage VRS efficiencies, the correlation is only 0.89. Of somewhat greater interest, are the correlations between single stage and two-stage results. Under the CRS model, the correlation between single stage CRS rankings and two-stage CRS Tobit based rankings is 0.94. That is somewhat better than the 0.90 correlation between the VRS single and two-stage rankings.

Thus, for the current universities and time frame, it matters less as to the inclusion or exclusion of environmental variables if one proceeds with CRS in contrast to VRS in a single stage DEA evaluation. The findings also indicate that the CRS efficiency rankings without the inclusion of environmental effects are on mark with the same rankings that would result in a two-stage Tobit regression approach using CRS first stage efficiencies. Somewhat poorer results obtain if VRS first stage efficiencies serve in the second stage regression.

6. Conclusions

This paper provided evaluations of the efficiency performance of U.S. public universities with a specific focus on the efficiency effects created by differences in university dependencies on alternative financing sources. DEA was employed along with four years of panel data on 331 U.S. universities. Single stage DEA efficiency estimates were generated when (1) the financial environments are excluded from DEA inputs and (2) when financial dependency is included in the input matrix. That was followed by a two-stage approach where first stage DEA estimates were used along with the financial variables in a Tobit regression.

On one level, the empirical results indicate that university efficiency averages around 87% to 93% with anywhere from 16% to 36% of universities being fully efficient. Minimum efficiency was found to be approximately 60% to 68%. The variability in results was due to differences in returns to scale modeling assumptions and whether or not financial sources were included or excluded from the single stage DEA estimation. However, the average results for the present U.S. universities compare favorably to those found in other studies and for other countries, including, for example, the mean efficiencies of 86% to 94% for Australian universities (Carrington, et al., 2005), the 81% to 89% efficiencies for English and Italian universities (Agasisti and Johnes, 2009), and the 95% to 97% mean efficiencies for Philippine universities (Castano and Cabanda, 2007).

On another level, the findings support the notion that financial sources affect university operating efficiencies. When a single stage DEA is employed, the inclusion of financial environments was found to have a significant effect on the estimated university efficiencies. University efficiencies increased with financial inputs treated as endogenous in the single stage DEA. The efficiency increase turned out to be larger under the CRS compared to the VRS estimations. However, the increase in the percentage of universities found to be fully efficient was larger under VRS compared to CRS. Implementation of the two-stage Tobit approach provided parametric support to the analysis. Using either CRS or VRS first stage efficiency scores, the second stage regression revealed a negative efficiency effect associated with reliance on both tuition revenue and investment income but a positive efficiency effect that accompanied revenue increases derived from state and local government funding. The efficiency effects due to tuition and government funding were statistically significant.

The second stage allowed a determination of the strength of individual financial sources on university efficiencies but also provided a robustness check on the single stage results. An additional assessment of robustness was performed by ranking university efficiency results and calculating the rank correlations. The two-stage rankings showed higher correlations with the single stage rankings generated from the exclusion of financial environments. Simar and Wilson (2011) recommend against the use of second-stage regression. If the second stage is abandoned in the present analysis, the correlation results indicate that CRS and VRS rankings with or without environmental variables correlate at 0.97 and 0.89, respectively. Without a second-stage, the difference in university efficiencies found in this paper lies in the selection of the DEA returns to scale model.

On a final note, it was encouraging that the findings presented in the paper led to the conclusion that public university efficiencies increased over the four academic year period, 2005-09. Moreover, the efficiency improvement was apparent regardless of underlying modeling assumptions or single-stage vs. two-stage DEA implementation. The efficiency gains occurred despite the financial dependency shifts toward tuition revenue and in the face of decreases in state appropriated funding. For the academic years under the present study, the efficiency improvements also occurred despite the impacts imposed by the global financial crisis. Whether or not the accomplished level of efficiency can be sustained over time, however, carries important policy implications for the future of higher education. That clearly calls for continued research. As more academic years of observation become available, it will be important to continue monitoring university operating efficiencies as higher education potentially undergoes additional financial funding changes.

References

[1] Agasisti, T. and Johnes, G. (2009), "Beyond frontiers: comparing the efficiency of higher education decision-making units across more than one country", *Education Economics*, 17(1): 59-79.

[2] Ahn, T., Charnes, A. and Cooper, W.W. (1988), "Some statistical and DEA evaluations of relative efficiencies of public and private institutions of higher learning", *Socio-Economic Planning Sciences*, 22(6): 259-269.

[3] Athanassopoulos, A. D. and Shale, E. (1997), "Assessing the comparative efficiency of higher education institutions in the UK by means of data envelopment analysis", *Education Economics*, 5(2): 117-134.

[4] Avkiran, N. K. (2001), "Investigating technical and scale efficiencies of Australian Universities through data envelopment analysis", Socio-*Economic Planning Sciences*, 35(1): 57-80.

[5] Banker, R.D., Charnes, A. and Cooper, W. W. (1984), "Some models for estimating technical and scale inefficiencies in data envelopment analysis", *Management Science*, 30(9): 1078-1092.

[6] Beasley, J.E. (1995), "Determining teaching and research efficiencies", *Journal of the Operational Research Society*, 46(4): 441-452.

[7] Bhattacharyya, A., Lovell, C.A.K. and Sahay, P. (1997), "The impact of liberalization on the productive efficiency of Indian Commercial banks", *European Journal of Operational Research*, 98(2): 332-347.

[8] Breu, T.M. and Raab, R. L. (1994), "Efficiency and perceived quality of the nation's 'top 25' National Universities and National Liberal Arts Colleges, An application of data envelopment analysis to higher education", *Socio-Economic Planning Sciences*, 28(1): 33-45.

[9] Carrington, R., Coelli, T. and Rao, D.S.P. (2005), "The performance of Australian universities: conceptual issues and preliminary results", *Economic Papers*, 24(2): 145-163.

[10] Castano, M. C. and Cabanda, E. (2007), "Sources of efficiency and productivity growth in the Philippine state universities and colleges, a non-parametric approach", *International Business and Economics Research Journal*, 6(6): 79-90.

[11] Casu, B. and Thanassoulis, E. (2006), "Evaluating cost efficiency in central administrative Services in UK universities", *Omega*, 34(5): 417-426.

[12] Charnes, A., Cooper, W.W. and Rhodes, E. (1978), "Measuring the efficiency of decision making units", *European Journal of Operational Research*, 2(6): 425-444.

[13] Cobert, A., Levary, R.R. and Shaner, M.C. (2000), "Determining the relative efficiency of MBA programs using DEA", *European Journal of Operational Research*, 125(3): 656-669.

[14] Emrouznejad, A., Parker, B.R., and Tavares, G. (2007), "Evaluation of research in efficiency and productivity: A survey and analysis of the first 30 years of scholarly literature in DEA", *Socio-Economic Planning Sciences*, 42(3): 151-157.

[15] Glass, J.C., McCallion, G., McKillop, D.G., Rasarantnam, S. and Stringer, K.S. (2006), "Implications of variant efficiency measures for policy evaluations in UK higher education", *Socio-Economic Planning Sciences*, 40(2): 119-142.

[16] Kempkes, G. and Pohl, C. (2010), "The efficiency of German universities – some evidence from nonparametric and parametric methods", *Applied Economics*, 42(16): 2063-2079.

[17] Korhonen, P., Tainio, R., and Wallenius, J. (2001), "Value efficiency analysis of academic research", *European Journal of Operational Research*, 130(1): 121-132.

[18] Kounetas, K., Anastasiou, A., Mitropoulos, P., and Mitropoulos, I. (2011), "Departmental efficiency differences within a Greek university: An application of a DEA and Tobit analysis", *International Transactions In Operational Research*, 18(5): 545-559.

[19] Leitner, K. H., Prikoszovits, J., Schaffhauser-Linzatti, M., Stowasser, R., and Wagner, K. (2007), "The impact of size and specialization on universities' department performance: a DEA analysis applied to Austrian universities", *Higher Education*, 53(4): 517-538.

[20] McCarty, T. and Yaisawarng, S. (1993), "Technical efficiency in New Jersey school districts", In: H.O. Fried, C.A.K. Lovell, and S.S. Schmidt (Eds.), *The Measurement of Efficiency: Techniques and Applications*, New York: Oxford University Press.

[21] McMillan, J. and Chan, W. H. (2006), "University Efficiency: A Comparison and Consolidation of Results from Stochastic and Non-stochastic Methods Education", *Economics* 14(1): 30.

[22] Reichmann, G. (2004), "Measuring university library efficiency using data envelopment analysis", *Libri*, 54(2): 136-146.

[23] Sav, G. T. (2004), "Higher education costs and scale and scope economies", *Applied Economics*, 36(6): 607-614.

[24] Sav, G. T. (2012a), "Managing operating efficiencies of publicly owned universities: American university stochastic frontier estimates using panel data", *Advances in Management and Applied Economics*, 1(2): 1-23.

[25] Sav, G. T. (2012b), "Stochastic cost frontier and inefficiency estimates of public and private universities: does government matter?", *International Advances in Economic Research*, 18(2): 187-198.

[26] Simar, L. and Wilson, P. (2007), "Estimation and inference in two-stage, semi-parametric models of production processes", *Journal of Econometrics*, 136(1): 31-64.

[27] Simar, L. and Wilson, P. (2011), "Two-stage DEA: caveat emptor", *Journal of Productivity Analysis*, 36(2): 205-218.

[28] Sinuany-Stern, Z., Mehrez, A. and Barboy, A. (1994), "Academic departments' efficiency via DEA", *Computers and Operations Research*, 21(5): 543-556.

[29] Wolszczak-Derlacz, J. and Parteka, A. (2011), "Efficiency of European public higher education institutions: a two-stage multi-country approach", *Scientometrics*, 89(3): 887-917.

[30] Worthington, A. C. and Lee, B. L.(2008), "Efficiency, technology and productivity change in Australian universities 1998-2003", *Economics of Education Review*, 27(3): 285-298.

[31] Yang, H. and Pollitt, M. C. (2009), "Incorporating both undesirable outputs and uncontrollable variables into DEA: the performance of Chinese coal-fired power plants", *European Journal of Operational Research*, 197(3):1095-1105.