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Productivity Growth and Efficiency Changes in Publicly Managed U.S. Comprehensive Universities: Data Envelopment Analysis and Malmquist Decompositions

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This paper uses data envelopment analysisand Malmquist index decompositions in estimating productivity and efficiency changes of comprehensive degree granting, publicly owned U.S. universities. Panel data for 247 universities is employed for the academic years 2005-09. Results indicate that universities incurred productivity regress on the order of 4% per annum. The regress was due to declines in technological change that overpowered the efficiency gains achieved by universities. The latter derived from both university management and scale efficiency improvements. The dynamics of annual changes suggest that the financial crisis worsened productivity regress but created positive efficiency changes. It will, however, be interesting to observe future extensions of the current research to include additional post-crisis academic years.

Keywords: *productivity, efficiency, universities, DEA, data envelopment, Malmquist*

Introduction

This paper provides estimates of productivity and efficiency changes for publicly owned and manageduniversities in the United States. The methodology relies on data envelopment analysis and panel data estimates of Malmquist productivity indices for 247 public, comprehensive universities using four academic yearsof the most recently available data. The panel data includes both pre and post global financial crisis academic years and offers potential insights into managerial responses to recession induced increases in the demand for higher education that have been accompanied by budget reductions via government funding. Those forces have created internal pressures to improve the efficiency and productivity of producing the multiple educational and research products emanating from universities. At the same time, external forces calling for management reform in the delivery of publicly provided goods and services, includinghighereducation, continue to bringadditional pressures to bear on university accountability. The combination of these forces provide the need for a better understanding of the efficiency and productivity paths taken by universities and, therefore, provide the stimulus for this paper.

The next section of the paper provides an overview of the DEA background and panel data applications to higher education. It is followed by a section outlining the efficiency and productivity methodology and then a section describing the construction of the panel data, a presentation of the empirical results, and ending with concluding remarks.

DEA Applications

The paper is in keeping with the use of data envelopment analysis (DEA) as the standard tool in evaluating the operating efficiencies of firms. It has been employed in that capacity for a large number of industries and has been equally applicable to for-profit enterprises as to non-profit firms and public agencies. The methodology is attributed to the seminal work of Charnes, et al. (1978) with roots in the production analysis contributions of Farrell (1957). Since then, DEA has become a significant part of the academic literature as attested to by themore than 4000 research papers that have been published in journals or books (Emrouznejad, et al., 2008). That volume of research, of course, renders impossible any reasonable literature review in the present paper. Instead, detailed descriptions of the theoretical and applied evolution of DEA are provided in the combined works of Cooper, et al. (2004) and Cook and Zhu (2008) andthe many references therein. An outline of its use in efficiency measurements and extensions to productivity analysis using the Malmquist index is provided in the next section of the paper. For this section, a brief recap of the basic notion of DEA is sufficient.

DEA is a non-parametric technique that employs linear programming to estimate a production frontier based on observations pertaining to decision-making units or DMUs (Charnes, et al., 1978). The DMUs are required to be fairly homogeneous in seeking parallel goals. The frontier that is estimated

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is comprised of the DMUs that operate efficiently, i.e., at 100%, and is said to envelop the other DMUs that in relative terms are inefficient, i.e., operating at less than 100%.

Empirically, thefocus of present paper rests with applications of DEA to efficiency and productivity changes in higher education. That requires the use of longitudinal data and, compared to the volume of literature noted above, that significantly narrows the published studies. In fact, it appears that there exists only four studies, all of which were published in the last five years. These studies employ DEA methodologies to estimate Malmquist productivity indices, as originally due to Malmquist (1953). The indices reveal productivity changes occurring among universities over various time periods, i.e., academic years.

For 59 Philippine universities operating over the period 1999-2003, Castano & Cabanda (2007)estimated average productivity gains of 0.2% per year. Productivity changes, however, ranged from a 7% decline to a 30%increase. Worthington and Lee (2008) sampled 35 Australian universities over 1998-2003 and found productivity growth averaging 3.3% and ranging from a regress of 1.8% to an improvement of 13%. Agasisti and Johnes (2009) compared Italian and English university productivities over the period 2001-2004 and found average productivity improvements of 9.4% and 8.5% per year in the respective countries but did not report any productivity ranges in their paper. The most recent study by Sav (2012) estimated that 133 American universities experienced average productivity regress on the order of 1.3% per year over the 2005-09 academic period; the range was from negative 15% to positive 17%.

These four studies include a mix of universities including those that are recognized globally as producing high levels of researchand housing some of the most prestigious doctoral programs. The American university study by Sav (2012) consisted ofthe premier publicly funded U.S. universities, including the so-called flagship universities. Those universities have amassed large endowments and annually receive substantial federal research funding. Moreover, they sit atop the public funding priority pyramid. They are of like mission and, therefore, appropriately meet the homogeneity requisites of DEA. However, they represent less than half of the American institutions that are publicly owned and chartered to offer both baccalaureate and post-baccalaureate degree programs. The present paper examines the other half of that American higher education system as defined by the universities that are classified as Master's level institutions. They produce a comprehensive package of undergraduate and graduate education along with research and represent the second tier of the U.S. higher education system.A literature search indicates that the present paper is the first to provide a rigorous productivity evaluation of these universities.

Before leaving this section of the paper, it is important that we do recognize that there are cross section DEA studies related to higher education. The academic years studied range from 1986 to 2001. Eight studies focus on efficiency at the academic department level or specific program level, e.g., chemistry departments or MBA programs: they include Beasley (1990 and 1995), Stern, et al. (1994), Cobert et al. (2000), Korhonen et al. (2001), Reichmann (2004), Casu and Thanassoulis (2006), and Leitner et al. (2007). Another six DEA cross sectional studies are conducted at the university level: they include Ahn et al. (1988), Breu et al. (1994), Athanassapoulos and Shale (1997), Avkiran (2001), Glass et al. (2006), and McMillan and Chan (2006). The efficiency estimates for the departmental type studies have minimum efficiencies ranging from 0.18 to 0.92; maximums under DEA are, of course, 1.0. The university level studies report minimum efficiencies in the range of 0.14 to 0.87. All of these studies are reviewed in more detail in Sav (2012). The brevity of their review here is based on the inability of cross sectional studies in measuring efficiency and productivity changes that constitute the thrust of the present paper.

Efficiency and Productivity Methodology

DEA models are of two varieties depending on whether one specifies an output-oriented or input-oriented envelopment. The output orientation is applicable when a firm needs to meet specified production levels but resource supplies tend to be fixed. When fixed production levels are the objective and resources are freely variable, then the input orientation is more appropriate (Coelli, 1996). Empirical results often tend to be insensitive to model choice. The panel data studies by Agasisti and Johnes (2009), Worthington and Lee (2008), and Sav (2012) all employ an output oriented model. The cross section study by McMillan and Chan (2006) used an input orientation but found that the results where invariant to alternative specifications including an output orientation. Among the comprehensive universities under study in the present paper, enrollment increases and the credit hour demands that accompany them

Journal of Business Management and Applied Economics
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are generally met with fixed resources over an academic year and, therefore, suggests that an output orientation is a more plausible modeling approach. It also conforms to three of the four previous studies and will be employed here. Returns to scale is also a matter of consideration for DEA models and has been of empirical interest in investigating higher education institutions. If universities are operating under constant returns to scale technology, then proportional output increases will lead to proportional cost increases and constant average costs. The DEA implementation that imposes the assumption of the constant returns to scale (CRS) is due to Charnes, et al. (1978). Relaxing the CRS assumption and modeling a production frontier that allows for variable returns to scale (VRS) offers greater flexibility and is due to the DEA work of Banker, et al. (1984). Technical efficiencies estimated under the CRS assumption will be smaller, or at most equal to, the efficiencies estimated under the VRS model. Thus, it is customary to estimate both and use the results to determine the scale efficiency as is discussed below.

Allowing for variable returns to scale (VRS) among *N* universities engaged in producing *G* outputs and utilizing *H* inputs, the output-oriented DEA for the *ith* university is expressed using fairly standard notation (e.g., Cooper, et al. 2004 and Cook and Zhu, 2008) as:

$$\max_{\phi_i \lambda_j} \phi_i$$

subject to

$$\sum_{j=1}^{n} \lambda_j y_{gj} - \phi_i yg_{gi} - s_g = 0 \quad g = 1,\ldots,G \text{ outputs}$$

$$\sum_{j=1}^{n} \lambda_j x_{hj} + s_h = x_{hi} \qquad h = 1,\ldots H \text{ inputs}$$

$$\sum_{j=1}^{n} \lambda_j = 1 \quad j = 1,\ldots,N \text{ universities}$$

$$\lambda_j \geq 0, s_r \geq 0, \text{ and } s_k \geq 0$$

where srepresentsoutput (*g*) and input (*h*) slacks, respectively. The value of *N* measures the relative increase in output potential for each university. A value equal to one refers to a university that rests on the production frontier and, therefore, is deemed efficient. Inefficient universities will generate theta values greater than one depending upon their “distance” from the frontier. Technical efficiency scores (TE) are computed by *1/N* and vary in the range 0≤TE≤1 for individual universities.Thus, TE is the ratio of the observed or actual output to the DEA projected potential output. The TE scores pertaining to the CRS model are obtained by dropping the constraint imposed by equation (4). Thus, a measure of the extent to which universities are scale efficient (SE) is obtained from the ratio of TE under CRS to TE under VRS. A university is operating at its efficient scale if SE=1 and is inefficient if SE<1. Scale inefficiency can be due to either decreasing returns or to increasing returns to scale, i.e., over production and increasing average costs or under production and decreasing average costs. To estimate the nature of returns to scale, Coelli (1996) suggests computing the TE scores under non-increasing returns to scale and comparing those to TE under variable returns to scale. If the scores are unequal (equal), then increasing (decreasing) returns to scale prevail for that university.

With the passage of academic years, the operating efficiency of universities can change due to changes in inputs and changed in input productivity as well as managerial decision-making. This efficiency change can move the university closer or farther away from the efficient frontier. In addition, technological changes can shift the production frontier and, as a result, also move theuniversity closer or farther away from the efficient frontier. In both cases, a university's distance (*D*) from the production frontier can change. The combined effect of these changes on university productivity is captured by the Malmquist index (Malmquist, 1953). That index is computed by comparing two time periods t and t+1(Fare et al., 1994) as follows (e.g., Cooper, et al., 2004 and Cook and Zhu, 2008):

$$M_0(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} \left[\left(\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^{t+1}, y^{t+1})} \right) \left(\frac{D_0^t(x^t, y^t)}{D_0^{t+1}(x^t, y^t)} \right) \right]^{\frac{1}{2}} \quad (6)$$

where thex inputs and y outputs are in the designated academic years t and t+1. The first term in (6) is a measure of the efficiency change between academic years. In the empirical work to follow it is further decomposed into the scale efficiency changes referred to above and pure technical or managerial efficiency changes. The geometric mean in the bracketed term captures the frontier shifts due to technological changes. Equation (6) results in *M*≥0. A value exceeding one indicates productivity growth. Values less than one represent productivity regress.

In the empirical analysis to follow, the DEA efficiency estimateswill be presented for both the CRS and VRS models and will be used to provide scale efficiency estimates. The Malmquist productivity indices will follow with all four efficiency and productivitydecompositions, i.e., pure technical or management efficiency change, scale efficiency change, technical efficiency change (as determined by the product of the two), technological change, and the total productivity change (as determined by the product of technical and technological change). Taking full advantage of the panel data, the dynamics of efficiency and productivity changes will be explored over four academic years.

Panel Data

A panel data set was assembled and consists of 247 public U.S. universities overfour academic years, 20 05-06 through 2008-09. The data are drawn from the U.S. National Center for Education Statistics, Integrated Postsecondary Data System (IPEDS). Lags in data availability and changes in data definitions were contributing factors in assembling the data. The universities are classified as public Master's Colleges and Universities and annually award at least 50 master's degrees but fewer than 20 doctoral degrees and exclude specialized institutions and American Indian Tribal Colleges. The constraint on doctoral degrees separates these comprehensive universities from the U.S. research and doctoral classified universities. As a group, these comprehensive universities are considered to have common missions and goals and, therefore, should be accepted in meeting the homogeneity requirements of the DEA methodology. In some cases universities did not report certain information for a particular year. In those cases, missing values were replaced using the nearest neighbor method for that specific university. Universities had to be excluded in cases where all four years of data where missing for a given variable. The final sample of 247 universities is a balanced panel.

Three university outputs have their basis in previous multiproduct models and empirical studies of higher education beginning with the seminal work of Cohn et al. (1989) and extensions by Koshal and Koshal (1999), Sav (2004), and Lenton (2008).The outputs include undergraduate education, graduate education, and research. Since the public education funding model is largely driven by credit hour production, the educational outputs are measured by the university's total academic year production of undergraduate and graduate credit hours (Sav, 2012). Using these measures accounts for the variations in student credit hour enrollments, different academic calendar systems, and summer or intersession terms. The vast majority of higher education DEA, as well as non-parametric, studies that have undertaken large samples of institutions as herein have relied on university receipts related to research grants and private donations as a proxy for research output. Given the absence of superior data related to an institutional wide research measure, the present study must rely on the same proxy derived from the IPEDS data.

Previous studies reviewed in the literature background section of this paper are also used as a guide for measuring university inputs. Since credit hours are educational outputs, it is students that enroll to produce such credit hours and faculty that are employed to offer the courses that make available the credit hours. The student inputs included are total undergraduate student enrollments and total graduate student enrollments. To account for some measure of quality, the percentage of undergraduate students enrolled and receiving low income government tuition grants is included. Using that variable is based on the notion that lower income students receive lower quality primary and secondary education as may be produced in lower income underfunded school districts. The faculty input is based on the number of full-time faculty employed. There was no measure available for teaching loads or teaching release for research. However, as a possible quality measure, the average faculty salary is included as wage variable.A reliable measure was not available for the inclusion of staff employment. There was no mechanism for accounting for academic staff support and different types of unclassified staff. Therefore, the annual expenditure on academic support is used as a substitute measure.

Three capital input measures are included. They are: the value of academic type buildings, the value of equipment, and the value of auxiliary buildings. The first is considered to be a measure of the capital devoted to academic instruction and administration. The second is an attempt to measure the capital related to laboratories and scientific research, as well as technology, including computer equipment employed in the production of education and research. Auxiliary buildings include dormitories, sports arenas, and other campus facilities used to produce services for student, employees, and the external community.

Table 1 presents a summary of the descriptive statistics for the outputs and inputs. As shown, credit hour production in undergraduate education is on average nearly ten times larger than graduate credit hour production. However, on the input side, undergraduate enrollment is only five times larger than graduate enrollment. On average, approximately one third of students receive low income government grants. The variability in credit hour production is matched by variations in faculty input. Buildings devoted to education and administration are the largest capital input followed by equipment and then auxiliary buildings.

Table 1. University Outputs and Inputs: Descriptive Statistics

	Mean	Std. Dev.	Min	Max
Undergraduate Edu., Cr. Hrs.	227,202	153,034	30,038	837,227
Graduate Edu., Cr. Hrs.	24,225	22,805	322	160,016
Research, $	6.36E+07	4.07E+07	8537421	2.52E+08
Students Undergrad, #	8,257	5,371	1,136	31,750
Students Grad, #	1,516	1,433	8	13,063
Students Low Income, %	34.34	15.47	0.00	94.00
Faculty Employed, #	325	181	45	980
Faculty Salary, $	63,170	9,905	35,393	100,316
Academic Support, $	1.16E+07	8.60E+06	1.33E+06	5.38E+07
Academic Buildings, $	1.73E+08	1.18E+08	1.90E+07	7.32E+08
Equipment, $	3.25E+07	2.35E+07	2.20E+06	1.41E+08
Auxiliary Buildings, $	1.51E+07	1.27E+07	1.12E+05	9.35E+07

Efficiency and Productivity Results

The DEA efficiency results are presented in Table 2 for both the CRS and VRS technology models. Scale efficiencies as determined by CRS relative to VRS technical efficiencies are also presented. Thus, the smaller CRS efficiencies are due to the inclusion of scale efficiencies. The first four rows present the mean efficiencies for each academic year. Those are followed by DEA efficiencies as determined at the university's average four year outputs and inputs.

Table 2. DEA University Efficiency Results

	Constant Returns	Variable Returns	Scale
Academic Year Means			
2005-06	0.89	0.95	0.93
2006-07	0.87	0.94	0.92
2007-08	0.89	0.94	0.94
2008-09	0.91	0.96	0.96
At Mean Outputs & Inputs			
Mean	0.89	0.95	0.94
Median	0.93	1.00	0.97
Minimum	0.56	0.63	0.67
Maximum	1.00	1.00	1.00
Std. Dev.	0.11	0.09	0.07
Percent Efficient	36%	61%	37%
Decreasing Returns			2%
Constant Returns			37%
Increasing Returns			61%

The results indicate that over the four academic years there has occurred an overall improvement in the technical efficiency with which the 247 comprehensive degree granting universities have produced post-secondary education. For 2005-06, efficiency hovered just below 90% and then declined during the 2006-07 academic year. However, universities showed a strong rebound in the 2007-08 academic year and generated another efficiency improvement in 2008-09. In this last academic year, average university efficiency rose to 96% for the VRSestimate. The 2008-09 mean scale efficiency was also at 96%.

When evaluated at the university mean operating values, the CRS technical efficiency is estimated to be 89% while the VRS efficiency without the scale effect is the higher 95%. As indicated by the minimum university efficiencies and the standard deviations, the efficiency distribution is somewhat tighter under the VRS model compared to the CRS model. Moreover, under the VRS technology, 61% of universities rest on the frontier and are efficient; i.e., efficiency scores of 1.0 or 100%. The results for scale efficiencies show that only 2% of the universities are operating under decreasing returns, while 37% are in the area of constant returns to scale. Thus, the 61% operating under increasing returns to scale indicates that for the vast majority of universities, a proportional increase in university inputs leads to more than proportional increases in educational and research outputs. From a policy perspective, that suggests that average production costs are decreasing for these universities and, therefore, they have not yet reached long-run optimal production scale.

Changes in university operating efficiencies combined with technological changes translate into productivity changes as defined by the Malmquist index. Total factor productivity changes along with the component parts are presented in Table 3. Thus, the total productivity changes appearing in Table 3 are decomposed into technological changes and efficiency changes. The former measures the possible shifts in the university production frontier and the latter measures the movement to or away from the frontier. That movement is further decomposed into changes created by pure technical efficiency or management and that which is due to changes in scale efficiency. The upper portion of Table 3 contains the indices as derived for the overall four academic years, while the lower portion is the summary of dynamics of change as related to the annual mean indices.

Table3. University Total Productivity and Efficiency Change Indices

	Total	Technological	Efficiency	Management	Scale
Mean	0.963	0.951	1.013	1.003	1.010
Median	0.965	0.951	1.000	1.000	1.000
Minimum	0.834	0.834	0.903	0.851	0.945
Maximum	1.206	1.206	1.238	1.225	1.105
Std. Dev.	0.047	0.035	0.035	0.030	0.026
Percent <100%	85%	97%	22%	22%	21%
Percent Efficient	2%	0%	32%	52%	34%
Percent>100%	14%	3%	46%	26%	45%
Academic Year					
2006-07	1.005	1.03	0.977	0.99	0.987
2007-08	0.951	0.929	1.024	0.994	1.03
2008-09	0.931	0.899	1.036	1.022	1.013

Over the four year period, the total productivity index of 0.963 indicates that universities experienced productivity regress of approximately 4%. As shown, productivity index declines and advances ranged from 0.834 to 1.206. As Table 3 shows only 14% of the universities generated a productivity index above 1.0 and only 2% can be deemed efficient with an index equal to 1.0. The dynamics of productivity changes are captured in the lower portion of Table 3 and show that there was productivity growth, albeit slight at 0.5%, in 2006-07 relative to the 2005-06 academic year. Each of the following two academic years, however, reveal a continuous decline in productivity. Certainly, it is possible that those declines can in part be an effect brought upon universities as a result of the financial crisis. The decomposition of the productivity index can help shed some light on the issue.

The decomposition presented in Table 3 clearly shows that productivity declines are not attributed to changes in university efficiencies but rather to declines in technological changes. On average, university efficiency increased 1.3% with 46% of the institutions yielding efficiency gains above 100% and another 32% being 100% efficient. It is the technological change that worked in the opposite direction and, in magnitude, large enough to overpower the efficiency gains. The 0.951 index for technological change indicates about a 5% decline in technological progress. In addition, 97% of universities fall below a productivity index value of 1.0. When examined on an academic year basis, it is also evident that the productivity erosion in 2007-08 and 2008-09 derives from technological changes and not from efficiency changes. Thus, the outward shift in the production frontier more than offset the efficiency improvements that attempted to move universities toward the frontier.

Those university efficiency improvements are further decomposed into pure technical efficiency changes that can be attributed to management and to scale efficiency changes. As the results in Table 3 show, these forces did not work in opposing directions. Both management and scale indices averaged slightly above 1.0. For management efficiency, 52% of universities are at 100% efficiency and another 26% achieved efficiency improvements. In complement to such changes, 34% of universities were operating at an efficient scale while 45% showed gains in scale efficiency. The academic year means show steady gains in both management and scale efficiencies with both ending in fairly strong positive territory for 2008-09; a 2.2% management efficiency gain and a 1.3% scale efficiency gain.

In attempt to better understand the effect of different efficiency changes on overall university productivity changes, universities were placed in rank order according to each index score. The Appendix Table A presents the rank order of universities according to their Malmquist total productivity index. In addition, the university's rank for efficiency measure is listed. Turning first to those universities that have the lowest productivity index, it is generally true that they also rank lowest across all other indices. It is of course critical to recall that changes over time are the measures at hand so that universities ranking lowest in efficiency changes are also ranking lowest in productivity changes. The absence of efficiency improvements clearly leads to productivity regress. At the top end of the total productivity ranking, a somewhat fogger picture emerges. The number one ranked productivity indexed university is also the first ranked technological improvement university but comes in as 115th ranked with regard to efficiency improvements and 113th with scale improvements. Somewhat the opposite exists with respect to the 2nd ranked productivity university; i.e., the 69thrank on technological change but the 1st ranked on the efficiency improvement. There are also anomalies scattered throughout the rankings. For example, the 79th ranked productivity university is 4th ranked with respect to efficiency improvement. And the 226th ranked productivity university is 3rd ranked with scale efficiency gains.

To summarize the index ranking relationships, Table 4 presents the rank correlation coefficients.

Table 4. University Ranked Correlation Coefficients

	Total	Technological	Efficiency	Management	Scale
Total	1.00				
Technological	0.60	1.00			
Efficiency	0.78	0.05	1.00		
Management	0.75	0.23	0.78	1.00	
Scale	0.49	0.06	0.59	0.15	1.00

As indicated, the weakest effect on total productivity ranking comes from a university's performance regarding scale improvements. The strongest effect comes from the technical efficiency improvements, i.e., the university's movement toward the efficient frontier. That efficiency change along with scale efficiency change has little influence on a university's technological efficiency; the correlation coefficients are 0.05 and 0.06, respectively. In addition, management efficiency has little correlation (0.15) with scale efficiency. By far, it is management efficiency improvements that produce university technical efficiency improvements. That is evidenced by the 0.78 correlation coefficient between the two rankings.

Conclusions

The results presented in this paper indicate that productivity regress rather than gains prevailed among public comprehensive universitiesoperating in the U.S. during the four academic years 2005-09. The average productivity decline was on the order of 4% per year but individual university productivity ranged from a regress of approximately 17% to a gain of around 21%.

The estimates are based on data envelopment analysis (DEA) and panel data pertaining to 257 master degree granting universities to derive Malmquist productivity indices. The decomposition of productivity changes revealed that the average regress occurred despite continuous four year improvements in university managerial and scale efficiencies. Thus, outward shifts in the production frontier caused by technological declines overpowered the technical efficiency improvements achieved by universities. Those technical efficiency gains were accomplished as more than 75% of universities were operating at either 100% efficiency or actually achieving efficiency improvements with regard to both managerial changes and scale changes. With regard to the latter, DEA estimates revealed that constant or increasing returns to scale ruled among 98% of the universities with approximately 60% operating under increasing returns and, therefore, declining average costs. Upon exploring individual university performances and subsequent performance rankings associated with the Malmquist productivity estimates and its components, rank correlations indicated that technological changes are weaker than pure efficiency changes in driving productivity. Moreover, as opposed to changes in scale efficiency, it is management efficiency that that correlates more highly with the technical efficiency improvements of universities.

Research pertaining to productivity estimates for universities in other countries all predate the academic years undertaken in this paper. The three published studies reviewed at the beginning of this paper include various academic years during 1999 through 2004 and indicate average productivity growth of 0.2%, 3.3%, 8.5% and 9.4% among Philippine, Australian, English, and Italian universities, respectively. Thus, it is uncertain as to what extent the 4% productivity decline found in the present study is due to the differential effect of time, including effects that could be attributed in part to the financial

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crisis, or due to structural changes occurring in the U.S. public higher education system relative to other countries. The study by Sav (2012) that finds an average 1.3% productivity regress for the elite research and doctoral granting U.S. universities over exactly the same academic years as this study is supportive of the current results but cannot offer any additional insights into the possible effects of the financial crisis or possible inter-country structural differences. To disentangle such effects will have to await additional research stemming from other countries and from additional academic year data pertaining to U.S. universities.

Appendix Table A. Productivity and Efficiency Rankings

Rank	TFP	Institution	TECH	EFF	MGT	SC
1	1.206	U West Al	1	115	65	113
2	1.198	Henderson St U	69	1	1	81
3	1.097	U TX Permian Basin	67	2	8	12
4	1.093	U Baltimore	6	11	61	9
5	1.092	Francis Marion U	2	116	66	114
6	1.044	U MN-Duluth	94	8	2	218
7	1.043	Ferris St U	12	33	35	62
8	1.039	Morgan St U	42	15	7	115
9	1.038	Keene St Coll	3	117	67	116
10	1.037	U WI-Superior	124	9	68	7
11	1.031	James Madison U	186	3	69	1
12	1.029	U MD-U Coll	4	118	70	117
13	1.028	Southern U & A&M	14	53	71	37
14	1.027	Towson U	136	10	5	63
15	1.026	GA Coll& St U	172	7	72	6
16	1.024	Wayne St Coll	79	16	56	17
17	1.022	Cheyney U PA	5	119	73	118
18	1.021	Worcester St Coll	207	5	74	4
19	1.018	U Northern IA	27	54	53	43
20	1.018	Northwest MO St U	105	14	17	67
21	1.016	Frostburg St U	54	38	18	197
22	1.016	Appalachian St U	71	32	28	65
23	1.014	Southeast MO St U	24	68	9	239

24	1.014	U NC Charlotte	18	79	39	119
25	1.013	Coppin St U	19	74	46	79
26	1.012	Marshall U	7	120	75	120
27	1.011	TX A & M U-C Christi	34	69	36	100
28	1.009	SUNY Inst Tech Utica	66	43	76	29
29	1.009	U Mary Washington	26	75	77	51
30	1.004	NC A & T St U	29	83	42	107
31	1.003	Westfield St Coll	116	24	78	19
32	1.003	U NE Omaha	170	12	4	104
33	1.002	Longwood U	11	103	79	93
34	1.001	NC Central U	89	39	20	121
35	1.000	Jacksonville St U	135	20	80	15
36	1.000	Delta St U	49	71	59	56
37	1.000	MT St U-Northern	100	37	81	25
38	1.000	SUNY Geneseo	8	121	82	122
39	0.999	Auburn U-Montgomery	48	76	83	52
40	0.998	IN U-Northwest	127	26	50	26
41	0.998	SUNY Coll Purchase	9	122	84	123
42	0.998	U TX Tyler	97	41	85	27
43	0.997	U WI-Plteville	17	106	27	240
44	0.996	LA St U-Shreveport	232	6	37	10
45	0.996	U WI-Stout	141	25	14	94
46	0.995	Central CT St U	188	13	86	11
47	0.995	U Central MO	125	34	41	44
48	0.994	SUNY CollCortl&	16	110	220	57
49	0.994	U WI-La Crosse	139	30	16	95
50	0.993	U NC Pembroke	33	98	54	105
51	0.993	U WI-Eau Claire	150	31	87	21
52	0.992	Western CT St U	113	44	197	22
53	0.992	CUNY Lehman Coll	15	123	88	124
54	0.992	SUNY Coll New Paltz	44	93	89	71
55	0.992	SUNY CollPltsburgh	46	92	48	101
56	0.992	Northwestern OK St U	130	36	90	24
57	0.991	Saginaw Valley St U	10	200	63	214

58	0.990	Metropolitan St U	20	124	91	125
59	0.988	Bemidji St U	192	18	3	238
60	0.987	Eastern CT St U	131	42	92	28
61	0.987	MT St U-Billings	99	59	19	224
62	0.987	NM Highl&s U	22	125	93	126
63	0.987	Western Carolina U	23	126	94	127
64	0.986	Augusta St U	104	61	30	108
65	0.986	Winona St U	200	17	11	89
66	0.985	William Person U NJ	62	94	38	221
67	0.985	Eastern NM U-Main	106	62	51	58
68	0.985	Sam Houston St U	181	22	29	50
69	0.984	U North AL	206	19	58	16
70	0.984	SUNY Coll Oneonta	28	127	95	128
71	0.982	U Montevallo	167	35	96	23
72	0.982	AR St U-Main	50	100	198	72
73	0.982	Southern IL U Edwardsville	37	108	222	47
74	0.982	IN U-Purdue U-Fort Wayne	32	128	97	129
75	0.982	U MD-Eastern Shore	41	107	98	102
76	0.982	MO St U	149	47	99	30
77	0.982	Western NM U	117	63	100	42
78	0.982	U TN Chtanooga	180	27	33	53
79	0.982	U WI-Stevens Point	240	4	57	5
80	0.981	Peru St Coll	153	48	101	31
81	0.981	VA St U	21	204	200	198
82	0.980	SUNY-Potsdam	36	129	102	130
83	0.979	Southern OR U	30	196	103	209
84	0.979	Western OR U	88	85	104	66
85	0.979	TX St U-San Marcos	39	130	105	131
86	0.978	U NE Kearney	112	72	31	204
87	0.977	Purdue U-Calumet	45	131	106	132
88	0.977	Fort Hays St U	147	55	107	38
89	0.977	Gr& Valley St U	92	87	52	84
90	0.977	Central WA U	47	132	108	133
91	0.976	Armstrong Atlantic St U	208	23	196	14

92	0.976	Coll NJ	70	101	109	86
93	0.976	U WI-Whitewer	103	84	21	234
94	0.976	FL Gulf Coast U	151	56	110	39
95	0.975	Pittsburg St U	119	77	25	223
96	0.975	Northern MI U	59	109	62	111
97	0.975	Lincoln U	163	51	6	236
98	0.975	Chadron St Coll	111	81	111	59
99	0.975	Tarleton St U	179	40	13	215
100	0.974	Southern CT St U	76	99	47	202
101	0.974	U West FL	51	133	112	134
102	0.974	Norfolk St U	52	134	64	199
103	0.973	U Central AR	177	45	60	35
104	0.973	GA Southern U	142	66	204	33
105	0.973	Western IL U	160	58	44	69
106	0.973	Saint Cloud St U	143	67	43	82
107	0.973	U TN-Martin	219	21	26	54
108	0.973	Midwestern St U	156	60	12	232
109	0.973	Eastern WA U	58	135	113	135
110	0.972	U NC-Wilmington	60	136	114	136
111	0.971	Southern AR U Main	93	95	115	73
112	0.971	U Southern ME	61	137	116	137
113	0.970	DE St U	63	138	117	138
114	0.970	Salisbury U	173	52	118	36
115	0.970	U WI-River Falls	182	49	34	76
116	0.969	MI St U-Manko	193	46	23	106
117	0.969	SUNY Coll Buffalo	68	139	119	139
118	0.969	Youngstown St U	175	57	22	205
119	0.968	IN U-South Bend	190	50	32	80
120	0.967	AL St U	31	216	214	200
121	0.967	Grambling St U	53	201	201	140
122	0.966	Rowan U	72	140	120	141
123	0.966	Mansfield U PA	168	70	55	60
124	0.965	North GA Coll& St U	114	97	121	77
125	0.965	Lander U	73	141	122	142

126	0.965	TN Tech U	222	28	123	20
127	0.965	Western WA U	74	142	124	143
128	0.964	GA Southwestern St U	25	225	224	96
129	0.963	Boise St U	161	78	125	55
130	0.963	Plymouth St U	43	213	24	246
131	0.962	Truman St U	84	143	126	144
132	0.962	U WI-Parkside	140	88	127	70
133	0.961	East Central U	87	144	128	145
134	0.960	U MI-Dearborn	38	221	246	2
135	0.960	CA U PA	90	145	129	146
136	0.960	Slippery Rock U PA	155	89	49	87
137	0.959	SUNY Coll Brockport	55	212	203	213
138	0.959	RI Coll	101	111	218	61
139	0.958	AR Tech U	145	96	130	74
140	0.958	Bloomsburg U PA	154	91	205	48
141	0.958	Shippensburg U PA	165	86	45	97
142	0.957	Lamar U	102	146	131	147
143	0.956	SUNY Fredonia	35	230	207	226
144	0.955	Albany St U	64	214	219	103
145	0.955	Kennesaw St U	108	147	132	148
146	0.955	Chicago St U	109	148	133	149
147	0.955	Washburn U	234	29	10	206
148	0.955	Bowie St U	78	206	244	18
149	0.954	Eastern IL U	189	73	243	8
150	0.954	U Southern IN	209	64	225	13
151	0.954	Emporia St U	80	207	134	219
152	0.954	MS U for Women	110	149	135	150
153	0.954	Winthrop U	96	197	208	98
154	0.953	U LA Monroe	83	209	136	222
155	0.953	Souastern LA U	115	150	137	151
156	0.953	U TX-Pan American	118	151	138	152
157	0.952	Fitchburg St Coll	120	152	139	153
158	0.952	Angelo St U	122	153	140	154
159	0.951	KY St U	123	154	141	155

160	0.951	SUNY Coll Oswego	82	211	194	220
161	0.950	West Chester U PA	201	80	40	156
162	0.949	McNeese St U	148	104	202	78
163	0.949	Coll Charleston	128	155	142	157
164	0.949	Citadel Military SC	56	231	143	237
165	0.949	Stephen F Austin St U	126	156	199	92
166	0.948	Valdosta St U	198	82	212	40
167	0.948	CUNY Stn Island	129	157	144	158
168	0.948	Eastern OR U	86	215	210	207
169	0.947	Framingham St Coll	132	158	145	159
170	0.947	Fayetteville St U	133	159	146	160
171	0.947	Minot St U	157	105	147	99
172	0.946	Alcorn St U	137	160	148	161
173	0.946	U TX San Antonio	138	161	149	162
174	0.945	Murray St U	40	236	231	163
175	0.944	San Jose St U	146	162	150	164
176	0.944	Morehead St U	65	233	236	83
177	0.944	NJ City U	121	208	226	64
178	0.943	Northern St U	159	112	234	34
179	0.941	Salem St Coll	162	114	151	112
180	0.940	Eastern MI U	226	65	15	227
181	0.939	MI St U-Moorhead	152	198	228	49
182	0.939	U WI-Oshkosh	166	194	206	90
183	0.938	U West GA	98	224	211	217
184	0.937	Northwestern St U LA	195	102	152	88
185	0.935	CA St U-Long Beach	178	163	153	165
186	0.935	U North FL	183	113	154	109
187	0.935	Columbus St U	217	90	221	32
188	0.933	Montclair St U	95	232	230	91
189	0.933	TX A&M Intl U	185	164	155	166
190	0.933	U WI-Green Bay	169	202	156	216
191	0.932	CA St Polytech U-Pomona	187	165	157	167
192	0.932	Souastern OK St U	85	235	209	231
193	0.932	Southern UT U	57	239	158	243

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194	0.930	Fort Valley St U	194	166	159	168
195	0.929	CA St U-Northridge	197	167	160	169
196	0.929	Prairie View A&M U	176	205	195	210
197	0.929	West TX A&M U	144	218	238	41
198	0.928	CA St U-Bakersfield	202	168	161	170
199	0.928	CA St U-San Bernardino	203	169	162	171
200	0.928	CA St U-Fullerton	204	170	163	172
201	0.924	Troy U	210	171	164	173
202	0.923	Lock Haven U PA	211	172	165	174
203	0.923	Radford U	196	203	215	85
204	0.922	IN U-Souast	191	210	235	45
205	0.922	Cameron U	213	173	166	175
206	0.922	Austin Peay St U	214	174	167	176
207	0.921	Eastern KY U	215	175	168	177
208	0.921	East Stroudsburg U PA	158	228	237	68
209	0.920	Savannah St U	174	219	213	203
210	0.920	Sul Ross St U	171	222	169	229
211	0.918	Bridgewer St Coll	220	176	170	178
212	0.918	U Central OK	221	177	171	179
213	0.918	Clarion U PA	164	229	239	46
214	0.916	CA St U-East Bay	223	178	172	180
215	0.913	CUNY Hunter Coll	225	179	173	181
216	0.913	Millersville U PA	184	226	223	110
217	0.912	U IL Springfield	13	245	232	245
218	0.910	Western KY U	199	227	174	233
219	0.910	Kean U	228	180	175	182
220	0.909	Weber St U	231	181	176	183
221	0.908	Southwestern OK St U	233	182	177	184
222	0.908	Kutztown U PA	227	195	216	75
223	0.905	CA St U-San Marcos	212	223	178	230
224	0.904	CA St U-Stanislaus	75	243	242	211
225	0.904	U MA-Dartmouth	91	240	233	235
226	0.904	U MI-Flint	81	241	247	3
227	0.904	CUNY Queens Coll	230	199	179	212

228	0.902	U TX Brownsville	235	183	180	185
229	0.901	San Francisco St U	236	184	181	186
230	0.900	Northastern IL U	224	217	182	228
231	0.899	FL A&M U	237	185	183	187
232	0.891	Humboldt St U	205	238	227	225
233	0.889	CA St U-Chico	239	186	184	188
234	0.889	Edinboro U PA	134	242	241	208
235	0.888	CA St U-Sacramento	241	187	185	189
236	0.887	Nicholls St U	218	237	186	242
237	0.885	CA St U-Los Angeles	242	188	187	190
238	0.883	Northern KY U	77	246	229	247
239	0.882	Sonoma St U	229	234	188	241
240	0.881	CA St U-Fresno	238	220	217	191
241	0.879	CUNY City Coll	243	189	189	192
242	0.864	CUNY Brooklyn Coll	244	190	190	193
243	0.863	Northeastern St U	107	247	240	244
244	0.859	CA St U-Dominguez Hills	216	244	245	201
245	0.857	CUNY Bernard M Baruch	245	191	191	194
246	0.839	Lake Superior St U	246	192	192	195
247	0.834	CA Polytech St U-San Luis	247	193	193	196
Note: Abbreviations are used for the U.S. states.						

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