

On the technical and allocative efficiency of research-intensive higher education institutions¹

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Introduction

In 1980, estimated federal support for higher education in the US totaled approximately \$55-billion.³ By 1999 that figure had swelled to just over \$88-billion even though federal on-budget⁴ support for postsecondary education actually *fell* during this time from \$22.2-billion to \$18.2-billion. What largely stimulated the growth were policy shifts on two different fronts: a significant commitment by the federal government for tuition support and, to a lesser extent, institutional support vis-à-vis research. Indirect support in the form of student aid rose in real terms by \$23.1 billion while appropriations for academic research grew by \$7.6 billion.

In the face of increasing federal support for higher education, public concerns that colleges and universities cared little about containing costs and increasing productivity continued to grow. Institutions were raising tuition while students and their families were shouldering greater portions of financing a collegiate education. At the same time universities embarked on billion dollar capital campaigns and lobbied state governments for greater annual appropriations in the name of maintaining existing levels of quality. In 1997 when the National Commission on the Cost of Higher Education (NCCHE)⁵ released the tentative results of their study into the nature of college costs, much to the dismay of lawmakers and the general public, the panel concluded that for the most part American higher education was actually a bargain. As one panel member noted, “there is a lot wrong with higher education...but the one thing colleges can't be accused of is gouging the public” (Anderson cited in Burd, 1997).

For the most part, public concerns with higher education costs and productivity seem to have been sparked by three converging forces: demand-side cost escalation, a depressed economy, and a shift in the burden of financing a college education toward students and their families. When the public, and eventually legislators, began seriously looking at why it cost so

¹ This paper is an abstract of my recently defended doctoral dissertation in the Higher Education program at the Pennsylvania State University. As I am in the process of writing up my findings and submitting them for publication, what is included here is only a brief overview of the larger study, my results, and several of the more salient findings. Further inquiries may be directed to the address below.

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³ Figures represent the total of on-budget, off-budget, and estimated federal tax expenditures in constant 1999 dollars. Data is from the U.S. Department of Education's National Center for Education Statistics.

⁴ On-budget, as defined by NCES, are funds specifically earmarked for federal programs.

⁵ The NCCHE panel was created in 1997 by Republican lawmakers to study rising college costs.

much to send their children to college their initial perceptions were already tempered by largely negative images of university education. Books like Charles Sykes' *Profscam* (1988) inflamed public opinion with anecdotal stories of professors only teaching late-morning classes and frequently missing office hours. In doing so they (professors) could devote more time to the activities they truly enjoyed: collaborating with their more intellectual graduate students in their departments and focusing on relatively obscure research like "Evolution of the Potholder: From Technology to Popular Art" (p. 102). At the same time, the picture put forth of undergraduate education was of students crammed into 500-person lecture halls being taught by non-native speakers of English. As tuition continued to rise, especially at private institutions, public institutions continued to seek greater levels of state appropriations. It seemed obvious to infer that universities were productively inefficient and cared little about containing costs.

The often complex nature of advancing and transferring knowledge made it difficult for those in the academy to dispel negative perceptions even with studies showing faculty members at public research universities working on average over 55 hours per week (Jordan, 1994). In response, the past decade has borne witness to an outpouring of literature within the academy on cost-containment and increasing productivity in higher education. Guided largely by cost escalation theories with names like "cost disease," the "revenue theory of cost" (Bowen, 1980), and the "administrative lattice and academic ratchet" (Massy and Zemsky, 1994) an underlying tone persists that universities care little, if at all, about issues of efficiency in lieu of direct oversight or externally-imposed incentives.

Yet any approach seeking answers to questions of institutional productivity and costs must eventually address the technical aspects with which universities convert inputs into outputs as well as how the market prices of those inputs influence resource allocation decisions. However, the response to the NCCHE report suggests that to this day the cost structure of American higher education remains something of an enigma to both policymakers and the public. Nor do the images of university behavior put forth by Charles Sykes adequately capture the technical aspects with which universities utilize their academic labor inputs, like faculty and graduate students, to jointly produce undergraduate education and research.

In spite of popular perceptions that colleges and universities do not pursue efficient production or cost practices, a review of the literature reveals remarkably little empirical evidence to either support or refute assertions of cost and productive inefficiency at research universities. Two of the most commonly used estimation techniques in the study of higher education institutions, production and cost functions, implicitly *assume* efficient behavior. Of the few studies found that specifically assess efficient production in US higher education institutions, the variety of approaches and differing choices of input and output measures suggests little consensus over how to appropriately and comprehensively capture productive or cost efficiency, much less both.

Coupled with the dearth of empirical studies is little evidence for any theory to guide efforts at measuring efficiency. In terms of the economic literature, theories of nonprofits tend to focus on why these institutions form rather than on behavioral aspects. Hypotheses assert that a lack of market mechanisms and preferences over using particular input combinations prohibit efficient behavior. However, when comparing non-profits' cost functions with similar, for-profit firms, surveys of the literature conclude that the empirical evidence is inconsistent as to whether non-profits are any less allocatively or technically efficient. At the same time, while economic *models* of nonprofit behavior vary in their formulation, the equilibrium conditions derived in these models suggest non-profits can exhibit efficient behavior.

It is this gap between perceptions of productive and cost inefficiency and inconclusive theoretical and empirical research to verify such claims that motivates the research question posed in this study:

In terms of academic labor inputs,⁶ to what extent are research-intensive universities technically and allocatively efficient in the joint production of education and research?

Outline of the study

Chapter 2 is divided into four main sections. The first outlines the economics behind the four types of efficiency measures considered in this study: technical, scale, allocative, and overall efficiency. In addition it pays explicit attention to demonstrating the extent to which each is inter-related to the others. The second section characterizes academic labor inputs and the sometime distinct ways in which research universities allocate those inputs to jointly produce the outputs “education” and “research.” Building on the discussion in section 2, the third section develops a simple prestige-maximizing model of university behavior⁷ by integrating three concepts: a) what the author calls Burton Clark’s (1995) “taxonomy” of education, b) observed academic labor input allocations, and c) the necessary economic conditions for productive and cost efficiency. In doing so the model builds on work by Winston (1997) and Hoxby (1997) and attempts to explain why research universities may choose to engage in efficient behavior as well as where potential inefficiencies may arise. In the last section of chapter 2, data envelopment analysis (DEA) as an empirical approach to testing institutional efficiency is discussed. A linear programming technique that essentially “envelops” the observed data (thereby creating a relatively efficient frontier), DEA is a reasonably restriction-free approach to measuring the efficiency of firms using similar inputs to produce similar outputs. Based on a review of the literature, the author concludes that DEA, in spite of its inherent limitations, possesses several desirable properties that make it suitable not only for studying efficiency, but particularly higher education efficiency. Moreover, it is shown that the input and output weights derived in DEA analyses can be useful for estimating important economic measures such as the marginal productivity of inputs and the marginal transformation between outputs.

Chapter 3 describes the methodological aspects of the study. The population of interest is those institutions defined by the 1994 Carnegie Classification system as Research Universities or Doctoral Universities. Data availability permitted analysis of 183 institutions during the 1993 academic year, or approximately 75% of the population. In an effort to control for differing input and output quality across universities, two “tiers” were created and institutions were only assessed relative to others in their tier.⁸ In addition, the statistical analyses of the findings controlled for both “form of control” and the presence of “medical facilities.”

⁶ The academic human capital universities employ to produce education and research, including faculty members, graduate teaching and research assistants

⁷ Briefly the model posits that universities choose to maximize the production of education and research and that they derive prestige from the outputs directly. See James (1990).

⁸ The two tiers were constructed by first sorting all 183 institutions in descending order based on the National Research Council’s “mean scholarly quality of program faculty” indicator from their 1993 publication Assessment of research-doctorate programs in the United States. From this, the first tier consisted of the top 68 institutions, the

Empirically testing the different notions of efficiency outlined in chapter 2 requires three vectors of data (inputs, relative input prices, and outputs) of which there are a total of 10 variables. Table 1.1 lists the individual components for each of the three vectors.

Table 1.1 – Input/Output Vectors and Associated Variables

Outputs:	<ol style="list-style-type: none"> 1. Undergraduate Education <ol style="list-style-type: none"> a. Lower-level b. Upper-level 2. Graduate Education 3. Research
Inputs:	<ol style="list-style-type: none"> 1. Faculty 2. Graduate Teaching Assistants 3. Graduate Research Assistants
Input Prices:	<ol style="list-style-type: none"> 1. Faculty Wages 2. Graduate Assistantship Wages <ol style="list-style-type: none"> a. Teaching Assistants b. Research Assistants

Data for the input and output measures was obtained from multiple sources including the National Center for Education Statistics' *IPEDS database*, the National Science Foundation's *Survey of Graduate Students and Postdoctorates in Science and Engineering*, the Institute for Scientific Information's *Citation Indexes*, the National Research Council's *Assessment of research-doctorate programs in the United States*, and the University of Nebraska at Lincoln's *National survey of graduate stipends, graduate fellowships, and postdoctoral fellowships*. From the various data sources, input and output measures were computed and derived for analysis.

Data limitations restricted the ability to jointly analyze technical and allocative efficiency to only 35 public institutions that were almost exclusively from Tier 2. As such, a second analysis was conducted on all institutions in both tiers that focused only on technical and scale efficiency.

The remainder of chapter 3 is devoted to the methodological aspects of DEA and presents a brief mathematical treatment of the different efficiency measures computed as well as a discussion of the analytical techniques employed in the study. Based loosely on Byrnes and Valdmanis' (1994) study of non-profit hospitals, the DEA approach used in the study derives the radial efficiency measures listed in Table 1.2:⁹

"prestigious" universities, and the second tier consisted of the remaining 115. Throughout the paper these Tier 1 is referred to as "high quality institutions" and Tier 2 as "other institutions."

⁹ It is important to note that the derived efficiency measures are relative, and not absolute, measures of efficiency.

Table 1.2 – Various efficiency measures calculated in DEA analyses¹⁰

- Overall inefficiency:
1. Technical inefficiency
 - a. Variable returns to scale (VRS)
 - b. Constant returns to scale (CRS)
 2. Scale inefficiency
 - a. Increasing returns to scale (IRS)
 - b. Decreasing returns to scale (DRS)
 3. Allocative inefficiency

The analysis in Chapter 4 is disaggregated into two parts. The first presents the calculated technical and scale efficiency scores for the two tiers and proceeds to test whether any statistically significant differences exist between the distributions of, and the mean efficiency scores for, the two tiers. The analysis then proceeds to test whether the confounding variables (i.e. form of control and the presence of medical facilities) are likely to affect the efficiency scores. As noted earlier, because certain data was not available for all institutions the second analysis involved developing measures of overall, technical, and allocative efficiency for 35 public institutions.

Results

The results of the variable returns to scale technical efficiency analyses indicate that, on average, Tier 1 (Tier 2) institutions are approximately 93% (86%) efficient at allocating their academic labor compared to the “best practice” institutions in the respective tier groups.

As institutions are grouped to account for variations in output and input quality, the statistically different mean efficiency scores between the groups suggest that “high-quality” institutions, on average, are likely to be operating closer to best practice universities in their tier than the other institutions. When the distributions of efficiency scores for the two tiers are

¹⁰ Overall efficiency is calculated as the product of technical and allocative efficiency. Scale efficiency can be regarded as a form, or specific type, of technical efficiency. The VRS (variable returns to scale) and CRS (constant returns to scale) distinction under the technical efficiency heading represents the scale assumption invoked in that particular model. For example, assuming CRS (VRS) means that the researcher assumes the absence (presence) of scale inefficiencies. Both models were run in order to estimate whether scale inefficient institutions were operating at increasing or decreasing returns to scale.

compared to each other, the difference between tiers is shown to be statistically different. Tier 1 institutions are more likely to be classified as technically efficient or clustered near the constructed efficient frontier. Two out of every three institutions in the higher quality tier are at least 90% technically efficient compared to just less than half of Tier 2 institutions and more than 4 of every 5 Tier 1 institutions is at least 80% efficient compared to 2 of every 3 institutions in Tier 2.

Form of institutional control (public or private) is shown to not affect technical efficiency scores. For both groups, public institutions are just as likely to be situated on the efficient frontier as privates. However, when the presence of medical facilities is considered, technical efficiency scores are shown to differ for Tier 1. Institutions without medical facilities are almost twice as likely to be considered technically efficient than those with.

In terms of scale efficiencies, institutions in Tier 1 (Tier 2) are shown to be, on average, 95% (91%) efficient at operating on a scale consistent with long-term equilibrium (the case of constant returns to scale – CRS). The difference between the mean scale efficiency scores for the two tiers is also shown to be statistically significant. Compared to the most scale efficient institutions in each quality group, high quality institutions are more likely to operating at a level consistent with constant returns to scale than other institutions. Considering the nature of scale inefficiencies, there are no statistically significant differences between tiers and in both groups more institutions are likely to be operating at increasing returns to scale than decreasing.

When form of institutional control is accounted for, the results suggest that publics are just as likely to be regarded as scale efficient as privates in both tiers. However, when the presence of medical facilities is considered, scale efficiency scores are shown to differ for Tier 2. Only one medical institution in Tier 2 was classified as scale efficient (3% of all medical institutions in Tier 2) versus 16 without (20% of all nonmedical institutions). Moreover, institutions with medical facilities are shown to be more likely than those without to be the *least* scale efficient.

Considering efficiency as the joint product of technical and allocative components for a sample of public institutions, the results show public institutions to be 77% efficient overall. When this score is decomposed into technical and allocative efficiencies, approximately half of the overall inefficiency is attributable to each component under the assumption of constant returns to scale. The institutions in the sample are shown to be, on average, 89% efficient in choosing an input-minimizing mix of academic labor, and 87% efficient at choosing an input bundle that is cost minimizing. When individual institutions' scores are examined, 9 institutions were shown to be using a technically efficient input-mix but of these, only four picked a bundle that also minimized academic labor costs.

Select Discussion

Overall, the results from this study are consistent with the model of university behavior outlined in the framework for analysis section of chapter 2. There it was argued that competition in the input markets for high quality students should act as an incentive to universities employing those inputs to engage in more efficient production behavior. With regards to technical efficiency, Tier 1 institutions are shown to be, on average, just under 93% efficient and Tier 2 institutions approximately 86%. The statistically significant difference between the mean

technical efficiency scores supports that claim and finds further support in the distributions of scores, which were also shown to be statistically different between tiers. Whereas 67% of Tier 1 efficiency scores fell between 90% and 100%, over half (56%) of the efficiency scores for Tier 2 were below 80%. Less variability and a higher mean efficiency score for Tier 1 both support the notion that competition for high quality inputs acts as an incentive to use those inputs more efficiently in the face of scarce resources.

Additional evidence can be found by looking only at those institutions the DEA analysis identified as being technically efficient. If there is a greater degree of substitutability between high quality graduate students and faculty members, it would be evident in lower marginal rates of technical substitution (RTS) between inputs relative to those computed for Tier 2. An RTS value of -1 between inputs indicates they are perfect substitutes at that point on the isoquant. The further the RTS deviates from this (either positively or negatively) implies more (less) of one input would have to be added if the amount of the other input were reduced by one unit.

If one assumes, at the margin, that the production of education is additively separable¹¹ then summing the marginal productivities of faculty in the production of all three education outputs provides some measure of the marginal productivity of faculty to the production of the more general output education. These summary RTS measures were calculated in chapter 4. For Tier 1, the mean RTS between faculty and research assistants was -1.50 and between faculty and teaching assistants it was -1.37 . For tier 2, the values were -2.0 and -1.8 respectively. In both cases, the mean RTS measures for Tier 1 are closer to -1 than that for Tier 2, indicating both teaching and research assistants at institutions using higher quality inputs are more likely to be regarded as substitutes for faculty labor relative to other institutions. This result however, has to be considered in light of the fact that DEA does not permit statistical testing of the results, hence it is not possible to say with any statistical certainty that the differences between the RTS values are different than zero. Moreover, this relationship is dependent on whether the additive separability assumption holds. Nonetheless, the general finding regarding quality differences and efficiency is important because it offers empirical support linking the two ideas. This relationship has not been addressed or estimated in prior studies of higher education efficiency and thus represents an important result.

A final observation that can be drawn from the technical efficiency results concerns the extent to which institutions are efficient in the *joint* production of education and research. In the discussion from chapter 2 on the economics of technical efficiency, it was shown that technical efficiency in a two-output case requires the RTS values between inputs be the same in the production of all outputs. There is partial evidence to support this based on the calculated RTS values for the institutions found to be relatively efficient in each tier. For both tiers the calculated RTS values are reasonably close to each other (-1.50 and -1.37 for Tier 1; -2.00 and -1.8 for Tier 2). However, in the absence of statistical tests to determine whether the difference is significant, it is not possible to draw further conclusions.

The findings from the scale efficiency analyses provide additional evidence to support other researchers' findings with regard to how competitive forces shape higher education institutions. Geiger and Feller (1995) for example show that the historically pre-eminent research universities were not able to maintain their share of total academic research

¹¹ Additive separability implies that the marginal productivity in producing one of the outputs does not change when increasing or decreasing the amount produced of another output. A case can be made that adding a single student to an undergraduate course is not likely to influence the marginal productivity of faculty to the production of other education outputs.

expenditures during the 1980s. One reason they suggest is that the characteristics making them prestigious¹² limited their ability to expand during a decade marked by increased overall funding for research. These institutions had already maximized much of their productive capacity. As evidence, they present figures showing that institutions experiencing the greatest gains in research share were those which expanded their number of full professors by more than the average while those experiencing the greatest loss expanded by less.

This pattern is also evident in the results presented here. Institutions that have already maximized their productive capacity should, at the least, not be operating at increasing returns to scale. Of the 14 institutions in Tier 1 that were also among the greatest losers of research share in the Geiger and Feller study, only two are shown to be operating at increasing returns. In contrast institutions that have room to grow should either be operating at increasing returns or be at constant returns, given that there is a three-year gap between the last year in their data and that used here. Only two of the institutions among those exhibiting the greatest gains in research share are shown to be operating at decreasing returns.¹³

In terms of overall and allocative efficiencies, the results show a sample of Tier 2 public institutions operating at 77% and 87% respectively. The usefulness of these figures are limited though as data limitations did not permit comparisons between groups and the number of institutions analyzed was small, which increases the likelihood that the frontier would be altered significantly by including more institutions. However, presenting the results does highlight how useful this type of analysis can be for testing assertions regarding non-profit behavior. Disaggregating inputs into their physical and cost components allows researchers to consider whether institutions may be efficient at allocating physical inputs even if cost efficiency is not sought or achieved. Higher education is an industry whose institutions' goals differ considerably from the cost-conscious, profit-maximizing firms guiding economic notions of efficiency. If universities are going to be productively efficient, it will more likely emerge then in the allocation of their physical inputs and not costs. To not consider this in an empirical analysis is a serious omission, yet the literature review conducted for this study revealed no instances where efficiency was considered or tested in such a manner. In this respect, the results from the analysis show how disaggregating inputs into physical and cost components makes it possible to evaluate whether physical input allocations stemming from non-cost-related objectives may conflict with cost-minimizing objectives.

An example of this can be found in the discussion of the non-profit literature from chapter 1. One of the three assertions put forth about non-profit behavior was that non-profits might possess preferences over using particular input combinations that would result in higher cost curves. To empirically test an assertion such as this first requires separating physical input usage from costs and evaluating whether technical efficiency is being achieved but not cost efficiency. Focusing exclusively on only one type of efficiency (e.g. technical) does not permit one to test this type of hypothesis, nor does using cost-based input measures.

In this study the findings indicate only about half of the overall inefficiency is actually cost-related. These results are far from conclusive but suggest, at least for these institutions, that cost-containment may not be a primary goal. Moreover, if it was the case that institutions were driven to efficiently minimize physical input usage instead, then disaggregating overall

¹² The authors define the most prestigious institutions as being "characterized by low turnover, a relatively large number of senior faculty, and a high percentage of full professors" (p. 22).

¹³ Assuming institutions with scale efficiency scores above 99% are also operating at constant returns to scale. If not the numbers change to 3 and 4 institutions respectively.

efficiency should reveal cost inefficiency to be the main source of overall inefficiency, which it does not.

There are several compelling reasons to cast doubt over the validity of these results or whether they can be generalized beyond the group being evaluated. The number of institutions analyzed is comparably small (35) and are mostly doctoral-granting universities operating in what can be called regional markets. Had the data been available, it would have been preferable to analyze cost behavior from institutions in Tier 1 instead. Those institutions are not only more likely to operate in competitive input and output markets, but because they also tend to attract resources from a larger geographic pool, regional differences would not factor as heavily into the analysis. From the technical efficiency analysis comparing Tiers 1 and 2, it was shown how the distribution of efficiency scores in the latter was likely to be more dispersed. Moreover, because the group consisted only of public institutions from a variety of different states, no accounting is made for the effects of different state regulations such as the performance-based funding mechanisms in Tennessee and South Carolina. James (1990), for example, notes that one of the main distinctions between public and private institutions is the decrease in institutional autonomy publics face as a tradeoff to the stability of annual state appropriations. Because state legislators have what James calls “monopsonistic power [to] specify certain inputs and outputs that must be met” (p. 89) it could be that the efficiency scores here reflect inefficient physical or cost-based allocations stemming from state regulations.

While the actual results are severely limited in their descriptive ability, the analysis itself demonstrates another instance where DEA has value as an analytical tool. Specifically, the designs of prior higher education efficiency studies were not capable of jointly estimating overall, technical, and allocative efficiency. In this respect, what was done here represents a significant departure from past approaches and reveals how DEA may be used for testing hypotheses regarding non-profit behavior.

Conclusion

This study provides a much needed empirical perspective on productive and cost efficiency in higher education institutions. At the same time, what has been done here only scratches the surface of a topic that has historically been neglected yet is critically important to gaining a stronger theoretical understanding of production and cost behavior in higher education institutions in general. While much research still needs to be done, this study represents a solid step in the right direction.

The reason for this can be found in the development of an economic rationale for why universities may strive to be efficient and how inefficiencies may arise in the process. It is not enough to incorporate traditional measures of higher education inputs and outputs into a DEA analysis and simply interpret the results. Understanding whether efficiency is even a rational expectation of university production, much less what factors may give rise to it, requires forethought about the underlying production process. By taking such an approach in this study and outlining a plausible framework for analysis, it was possible to do more than just identify relevant input and output measures and to generate relative efficiency scores. Being able to corroborate the results with more general observations on higher education production provides

evidence that there is more to gain by attempting to understand why inefficiency occurs rather than just measuring it.

In chapter 1, a gap was identified between perceptions of university efficiency and empirical evidence to support such claims. What has been done here “closes” that gap to some extent by providing empirical results that reveal how concepts like quality, competition, form of control, and the presence of medical schools are associated or influence efficient behavior in research universities. To that end, though absolute measures of higher education efficiency continue to elude, this study does succeed in shedding new light on important relationships that arise and should be taken into account when evaluating higher education efficiency.

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