2017

# Assessing technical inefficiency in private, not-for-profit, bachelor's and master's universities in the United States using stochastic frontier estimation

James L. Refenes

# Assessing Technical Inefficiency in Private, Not-For-Profit, Bachelor's and Master's Universities in the United States Using Stochastic Frontier Estimation

by

James L. Refenes

Dissertation

Submitted to the Department of Leadership and Counseling

at Eastern Michigan University

in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

of Educational Leadership

Dissertation Committee:

David Anderson, Chair, Ph.D

James Berry, Ph.D.

Murali Nair, Ph.D.

William Price, Ph.D.

February 3, 2017

Ypsilanti, Michigan

# Dedication

To: *Mom*

## Acknowledgments

I would like to thank the following people for their support:

Dr. David Anderson, my advisor and Committee Chair

Pegs, my wife

Chris “Dr.” Jones

## Abstract

This research explored the technical inefficiency of 813 private, not-for-profit, four-year, bachelor's and master's colleges and universities in the U.S. using data from 2006 to 2011. The goal of the study was to describe and explain the level of technical inefficiency in this group of institutions that can be identified using a stochastic frontier estimation (SFE) method and to evaluate the applicability of SFE to higher education. Categories of expenditures were utilized to create a production frontier against which the inefficiency of individual institutions to produce degreed students was measured. The analysis using panel data showed this sector of higher education is operating with a mean technical inefficiency of 21%. Instructional expenditures had a positive effect on inefficiency while institutional support and student services had a slight negative effect on inefficiency. It was concluded that the SFE can be used to provide a reliable relative measure of technical inefficiency in higher education. The SFE can be useful in guiding decision makers by giving them a way to compare themselves with institutions of similar characteristics and competing in the same market.

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# Introduction

This study estimated the technical inefficiency that can be measured in private, not-for-profit bachelor's and master's universities in the United States using stochastic frontier estimation (SFE). While research has been done regarding the efficiency of higher education (HE), much less has been done on this specific sector of HE or utilizing SFE to measure it. Private not-for-profits make up over a third of HE institutions in America and differ in character from public HEs in several ways not the least of which is how they are funded. The empirical estimation of production functions is a standard exercise in econometrics. stochastic frontier estimation is a statistical model that can be used for determining the maximum attainable output given a set of expenditures and then measuring the output of individual institutions against that frontier to determine the degree of inefficiency that exists.

This chapter discusses the background and purpose of the study and how it adds to the growing body of HE efficiency and frontier analysis research. It also puts forth specific research questions surrounding the expenditures and educational productivity of the private, not-for-profit higher education sector. The theoretical foundation and conceptual framework for this research is an econometric approach to estimation of theory-based models of production, cost, or profit. The stochastic frontier model of Aigner, Lovell, and Schmidt (1977) is a standard statistical theory-based model used for this type of analysis. The empirical estimation of production functions is a regular exercise in econometrics (Greene, 2007). The frontier production function is an extension of the regression model based on the theoretical premise that a production function represents the ideal maximum output possible given a set of inputs. Measurement of inefficiency then is the empirical estimation of the extent to which observed agents fail to achieve the theoretical ideal.

**Background**

The focus of this study is the technical inefficiency that can be measured in private non-research universities whose primary focus is undergraduate education. These institutions have a long history in the United States. The first colleges in America were privately operated and this sector comprises 36% of the higher education industry (NAICU, 2014). Today, private universities are at an economic crossroads. Increasing costs and enrollments in higher education institutions have driven the price of attending them beyond what much of the public can afford. Even the relatively lower cost (due to their direct federal and state subsidies) public universities are pricing themselves beyond the reach of many student's ability to pay. As a result, students and their families have been taking on an ever-increasing amount of debt in order to avail themselves of a higher education whether private or public (Pew Research Center, 2012; U.S. Treasury, 2012; Payea, 2013). In response to this pressure, HE has become more sensitive to the financial burden they place on their students and families. They want lower costs, but universities must still collect enough revenue to meet their fiscal needs. In this way, they are finding themselves having to respond to market pressures much like a traditional business, and like a traditional business, they must learn to operate as economically efficiently as possible.

More and more students and their families are being asked to pay a greater share of their higher education expenses (Van DerWerf 2009; Pew Research Center, 2012; Bogaty, 2013). The average posted tuition at four-year, private, non-profit universities rose 57% between 1991 and 2013, from $16,410 to $29,060 (*Trends in College Pricing*, 2013). Traditional undergraduate private universities seem to be at or near the limits of what they can collect from students in tuition. But because they do not receive direct government subsidies to support their budgets (as do their public counter parts), the problem of generating enough revenue via tuition and private donations to support their operations is even more acute in private universities. Government subsidies in the form of grants and low-interest loans that in the past have allowed private universities to charge more than what the majority of their students would have been able to pay also seem to be at or near their limit. Competing public interests like social security and healthcare are demanding ever increasing shares of the federal budget. Each year the federal government faces the problem of limiting the annual deficit and the growth of the national debt. Those in the federal government have to make tough choices.

Students and their families must also balance what they can pay for a higher education against competing interests. The costs of necessary goods and services like food, energy and healthcare have also increased dramatically over the same time period. The vast majority of students and their families simply cannot afford to devote an even greater share of their limited income to higher education. As a result, many are seeking lower cost alternatives like 2-year local community colleges or online education institutions like the University of Phoenix. Private universities now operate in a very competitive higher education market place where institutions are competing for both students and revenues (Bogaty, 2013).

Despite their noble mission statements and perceived public good, universities are still businesses. They have a service to sell, payrolls to meet, and investments to make that ensure their continued existence. Good, sound businesses make a profit, or in the case of not-for-profit institutions, they generate enough revenues to meet expenses and reinvest into the university. Due to the aforementioned pressures, like other types of private businesses, post-secondary institutions of all types must be as efficient as possible in their use of funds in order to survive financially. This need for efficiency in operations is perhaps most acute in private not-for-profit bachelor's and master's institutions that are so tuition and enrollment dependent.

As if the pressures outlined thus far were not enough, in September of 2015 the Obama administration launched a website (collegescorecard.ed.gov) that provides information about the value of a university's education based on average annual cost, graduation rate, and average salary after attending. The purpose of this system is to create a measure of college performance that will give students and families' information that will allow them to select schools that provide the best value. Utilizing these criteria mean that institutions will need to keep their cost low and their graduation rates high. This makes the economic efficiency with which an institution operates of central importance.

In the 1970s, colleges and universities began to be viewed not just as institutions of higher learning but as economic entities. Researchers then brought to bear methods of analyzing the costs associated with the products HE produced. They applied the same types of methodologies that were used to evaluate the economies of other industries. Then, because of the ever increasing costs of higher education, questions arose as to whether or not post-secondary institutions were utilizing public and private dollars as efficiently as possible. Of late, universities have increasingly had to examine their own levels of efficiency because finding the revenue to support their operations is not as easy as it once was. One of the first aspects of its operation any type of firm examines when it is faced with cost and/or pricing pressures is the economic efficiency with which it operates. The problem facing private, not-for-profit colleges and universities is how to identify inefficiency so as to maximize student degree attainment in order to justify the costs students and their families must incur in order to earn an undergraduate or graduate degree.

**Problem Statement**

In recent years private liberal arts institutions–and other sectors of higher education–have been responding to changing market forces. There is heightened competition for students amid a shrinking pool of high school graduates. The parents of the these graduates and the graduates themselves are much more concerned over higher education's cost relative to its value. The perceived prestige of the university is no longer enough to attract students and get them to pay ever-increasing levels of tuition. Combine this with slow economic growth nationally interspersed with periodic downturns and a climate has been created that places a premium on economic efficiency.

Private, not-for-profit bachelor's and master's institutions, especially the small-to medium-sized ones, have unique challenges. These institutions typically have a relatively small endowment, which means they are dependent on enrollment to bring in the tuition revenue they need to continue operations. Because they are private, they receive no public subsidies to augment their budgets. Because their missions are centered on teaching instead of research, they have very little auxiliary income (Desrochers & Hurlburt, 2012). The lack of revenue sources is not the only challenge faced by these institutions, the very nature of how they deliver education exacerbates their costs

Historically, liberal arts colleges are residential–that is, the bulk of their student body lives in campus housing and attends classes in campus buildings. The need to build and maintain brick and mortar buildings for teaching classes and housing students requires a substantial investment of resources. These are costs not faced by 2-year commuter schools and the increasingly popular on-line universities that residential universities are competing with to some degree. A second challenge based on the very nature of these institutions is that they are labor intensive. It is true that all sectors of higher education are labor intensive but this is even more so the case with small-to medium-sized private universities. Most often a primary aspect of their marketing strategy is to sell their small class sizes and easy access to professors and individualized student support services. As a result, they may not benefit from the same economy of scale achieved by larger institutions that routinely place hundreds of students in large lecture halls with one professor or graduate assistant. Because of this, the costs of instruction, academic support, and student services are substantial and unavoidable. Given these challenges, they cannot afford to spend their dollars inefficiently. These institutions must get maximum value from every dollar they spend in order to survive in a very competitive higher education market place.

The problem addressed in this research is identifying the levels of technical inefficiency that exist in private universities in order to provide a resource for these institutions as they work to address the issues of financial stability and viability that they face. In light of the economic pressures being brought to bear in recent decades, more research has been done to examine various aspects of the efficiency of institutions as a way to control their costs. A portion of this research focuses on the production functions describe the relationships between expenditures and products of higher education. Periodically, some have attempted to summarize higher education efficiency research. (Worthington, 2001; Selerno, 2003; Kelly, 2009; Johnes & Johnes, 2013). These studies often attempt to determine what types of expenditures are associated with the highest graduation rates or some other measure of student learning so as to advise higher education decision makers on where they might want to focus their resources. Powell, Gilleland and Pearson (2012) even proposed a benchmark model to advise institutional decision makers on how to evaluate their efficiency so as to be able to identify the minimum amount of expenditure needed to provide an adequate level of effectiveness. The underlying understanding is that HE exist to produce learned graduates under given economic conditions and should do so as efficiently as possible. The results of this research aid private, 4-year, not-for-profit institutions to better understand and explain their levels of technical inefficiency. With the goal being to identify patterns of expenditures that are maximizing the number of graduates being awarded degrees.

**Purpose of the Research**

The purpose of this study was to identify the level of technical inefficiency that exists in private, not-for-profit colleges and universities in the U.S. as determined by their level of spending in key categories measured against the number of undergraduate and graduate degrees they award. This was a quantitative study utilizing an econometric analysis of technical production. The key expenditures identified were the amounts spent on instruction, institutional support, and student services per full-time equivalent (FTE) students. However, because it is widely recognized that a student's ability to earn a college degree is influenced by other factors, the effect of student characteristics of gender, academic ability, and socio-economic level were included in the analysis. Levels of technical inefficiency for each of the subject institutions were obtained using both cross-sectional and panel data for the academic years spanning 2006–2011.

**Research Questions and Hypothesis**

In examining the relationship between the variables hypothesized to effect inefficiency in this sector of higher education, some important questions were addressed.

- The Stochastic frontier estimation
    - Which is the most informative measure, an SFE using cross-sectional data or one using panel data?

  - Does the stochastic frontier estimation explain the relationship between the primary institutional expenditure categories and the number of degreed students produced, controlling for the effects of student gender, academic ability, and economic status?
  - Can the SFE suggest spending levels for instruction, institutional support, and student services that will be the least technically inefficient?
  - Which, if any, of the student characteristics being controlled for will have a significant effect on inefficiency?
- General Patterns
  - What common characteristics of resource allocation exist among these institutions?
  - What pattern of expenditures will be characteristic of the least and most inefficient institutions?

It was hypothesized that in those institutions expenditures on instruction and student services will have a negative effect on inefficiency and expenditures on institutional support will have a positive effect on inefficiency. Expenditures for instruction directly effect the educational experience of students and make up the largest share of university budgets. It only makes sense that this expenditure would have to have a significant effect on the efficiency with which an institution produce degreed students. Similarly, expenditures for student services are specifically aimed at improving retention and the student's experience outside of the classroom. Money spent insuring that students have a positive experience outside of the classroom and are supported in the classroom should lead to greater retention and matriculation.

It was also hypothesized that the SFE will show that the subject institutions show a general pattern of low inefficiency. Institutions that fail to operate efficiently in this regard are likely to be the exception and not the rule. A business of any type cannot long survive if its operation is grossly technically inefficient. The highly competitive market of these tuition-driven institutions should be constantly forcing them to reduce inefficiency.

**Theoretical Foundation**

Two broad theories exist for measuring economic efficiency, one based on a nonparametric, programming approach to analysis of observed outcomes, and one based on an econometric approach to estimation of theory-based models of production, cost, or profit. The theoretical basis for this research employs the latter approach. The stochastic frontier model of Aigner, Lovell, and Schmidt (1977) is now a standard statistical theory-based model used for this type of analysis. The empirical estimation of production functions is a regular exercise in econometrics (Greene, 2007). The frontier production function is an extension of the regression model based on the theoretical premise that a production function represents the ideal maximum output possible given a set of inputs. The estimation of frontier function is based on the theory that no observed agent can exceed the ideal. Measurement of inefficiency then is the empirical estimation of the extent to which observed agents fail to achieve the theoretical ideal. The estimated model of production is the means to the objective of measuring inefficiency. The literature on frontier production function and the calculation of efficiency measures began with Farrell (1957). He suggested that technical efficiency could be understood in terms of realized deviations from an idealized frontier isoquant. In this approach, the inefficiency is identified with disturbances in a regression model. A stochastic frontier function incorporates the error term, which is composed of two parts: a symmetric component that captures the random effects outside the control of the firm and a one-sided error term that reflects the inefficiency in production (Aigner, Lovell, & Schmidt, 1977). This was the approach utilized in this research.

This econometric measure of production function was first applied to education by Bowles (1970) in his book *Towards an Education Production Function*. In this framework, higher education institutions are seen as being analogous to a manufacturing business that gathers resources or inputs and transforms them through some process into products or outputs. The primary inputs for universities would be students and revenues while the primary outputs would be graduates and research. The production process itself primarily consists of instruction, but administrative (institutional) support and student services academic support are substantial portions of a university's expenditures as well. The reasoning of the theory follows that technical relationships of the production process are of central importance. If such relationships exist and can be quantified, policy can be constructed so as to maximize some preferred educational outputs such as more or better educated graduates (Worthington, 2001). In examining inefficiency in institutions it is assumed that any institution is attempting to operate at optimal efficiency. This is an assumption that may not be true of all institutions. In a seminal study in the field of higher education finance, Howard Bowen (1980) developed what he called the "revenue theory of cost" in regard to higher education economics. This theory described higher education as not being concerned with efficiency or production at all. The driving force behind their operations from an economic point of view was to gather as many resources—revenue—as they could and spend it all on their operations. Under Bowen's revenue theory of cost, universities will spend as much as they can, so as their revenue is increases, their costs will increase as well. This creates a condition wherein their costs are always increasing and those increases may have little or nothing to do with the cost of obtaining the necessary inputs. The inefficiency measures obtained in this research are analyzed in part by how they reflect on the inefficiency of this sector of HE as a whole.

**Nature of the Study**

In conducting research into the inefficiency of a production organization, researchers need to choose between an input or output perspective. An input-oriented efficiency perspective measures how inputs can be reduced while maintaining current output levels. In the output-oriented approach, input levels are maintained and possible means of output expansion are examined. In the literature there seems to be wide consensus to use the input-oriented approach utilizing either prices or expenditures as inputs. In the case of HE, university decision makers can directly influence expenditure levels, and this data is much more readily obtainable than are the input prices universities pay for the technologies necessary to produce graduates. This study employed an input-oriented efficiency perspective utilizing major categories of expenditures as inputs and the number of degree earning graduates as the output. All of this data is readily accessible from publically accessible databases.

Instructional, institutional, and student services expenditures (inputs) served as the independent variables, and the number of degreed students (output) served as the dependent variable. The important covariates hypothesized to play a potential influence on university output included gender, ACT scored and the amount of grant aid awarded per FTE. Stochastic frontier estimation was utilized to determine an estimated level of inefficiency for subject universities during the six academic years from 2006 to 2011.

**Definitions of Key Concepts**

*Production function* is the quantity of output that a firm can produce as a function of the quantity of inputs to production

- *Technical inefficiency* is the degree (measured as a percentage) to which an institution fails to produce the maximal output (graduates) for given inputs (expenditures).
- *Isoquant curve* a line drawn through the set of points at which the same quantity of output is produced while changing the quantities of two or more inputs.
- *Private, not-for-profit institution* is a private institution in which the individual(s) or agency in control receives no compensation, other than wages, rent, or other expenses for the assumption of risk. These include both independent not-for-profit schools and those affiliated with a religious organization. Each operates independently in serving its unique mission as defined by its founders and its present leadership.
- *Higher Education Price Index* (HEPI) is a measure of the inflation rate applicable to higher education in the U.S.; more specifically, the increase in costs for a defined basket of goods and services typically purchased by institutions of higher education. The index is calculated on a fiscal year basis ending each June 30, by the Commonfund Institute.
- *Bachelor's institutions* primarily confer bachelor's degrees represent at least 10 percent of undergraduate degrees; fewer than 50 master's or 20 doctoral degrees are awarded per year.
- *Master's institutions* primarily confer bachelor's degrees and award at least 50 master's degrees and fewer than 20 doctoral degrees per year.

**Assumptions**

The assumptions of the stochastic frontier estimation (SFE) well suit the university decision-making environment. Since its expenditures are endogenous and university output is a fairly fixed product (educated students), the university is motivated to find input combinations that minimize cost of producing graduates. This is a basic assumption of the input-oriented production function. It does not require that the firms being estimated, be attempting to maximize profit. This ability to utilize a production function approach without assuming profit maximization is especially useful in assessing the for not-for-profit institutions. Economic theories of nonprofit behavior have made a strong case that organizations like colleges and universities have little incentive to engage in efficient production practices (James, 1990; James & Rose-Acermann, 1986). These institutions may not be attempting to provide their education services at minimum cost, but by definition, they cannot be engaged in profit maximization. In a seminal study on the costs of higher education, Bowen (1980) put forth the "revenue theory of costs." In Bowen's view, the source of increasing costs in higher education is that institutions continually strive to increase their revenue stream and then spend every dollar they raise. This means that revenue is the only constraint on expenditures. If this is true, then any expenditure effect due to inefficiency will be masked somewhat by an institution's propensity to spend regardless of cost. However, given the pressures being brought to bear on HE over the last decade or so to reduce tuition costs, it is not unreasonable to assume that the majority of private not-for-profit universities in this study are indeed attempting to minimize expenditures or reordering their spending priorities.

In the SFE model, the assumption is made that colleges and universities are operating on a constant returns to scale (CRS). But if the CRS assumption is relaxed, then the SFE may become skewed because any extreme observation makes the results bias. Economic theory suggests that, in the long run, competitive firms will continue adjusting their scale size to the point that they operate at a CRS. This likely holds true even for institutions that do not view enrollment growth as a priority. Indeed, it is highly likely that some universities within this study that want to remain small(er). It is a common selling point among smaller, private liberal arts institutions to market themselves as having higher than average faculty to student ratios. However, this does not necessarily mean that they are operating at decreasing returns to scale. It is probable that these institutions are operating at CRS and simply not moving toward an *increasing* return to scale in order to maintain the present character of the institution.

When comparing a group of firms within a particular industry using SFE, the assumption is made that all of the firms are utilizing similar technologies in the production of their output. If this assumption holds, then some firms will not be more or less efficient because they utilize a more or less efficient technology. In this study, the sample institutions are assumed to be delivering educational services utilizing the common and traditional technologies used in higher education today. It is assumed that the educational technologies characteristic of these universities includes primarily traditional face-to-face instruction with a greater or lesser mix of online instruction that does not vary significantly between institutions. The costs associated with online education are much different than those associated with face-to-face instruction. Along these same lines, it is further assumed that these institutions are all teaching a variety of subjects that incur different costs to produce. Even for a sample of apparently similar schools such as these, each institution comprises many different subjects, and it is likely that there are differences between departments in the production techniques used. Those in higher education understand, and some research has shown, that the cost of delivering science related programs of study are higher than those in the arts or humanities (Johnes & Johnes, 2009). The technologies needed to teach science include laboratories and equipment that drive up the cost of the education. While there most certainly are variations in the ratio of science students to non-science students at the schools in this sample, it is assumed that the variation between this homogenous populations of institutions is not significant. Furthermore, Harter, Wade and Watkins (2005) showed that if the university has a medical school, it cost per FTE will be significantly higher than those without. It was for this reason that private, not-for-profit universities that do have a medical school were omitted from this research.

A final major assumption in this research is that the products being generated by the institutions being compared are similar. Again, here the homogeneity of the selected sample helps to ensure that this assumption holds. Research has shown that there is a difference in the output of research and graduate education that has a significant impact on costs. Universities that are classified as research institutions have been excluded from the sample. The universities in this sample consist of bachelor's and master's institutions that do not engage in any significant research production. However, by definition, they do produce different levels of graduate education.

**Scope and Delimitations**

The scope of this study included the specific sector of U.S. higher education designated as private, not-for-profit, four-year or above bachelor's and master's institutions by the Carnegie Classification System. Higher education is often perceived as a single industry, but that perception is somewhat misleading. There are some significant differences between its major sectors in terms of how they are financed and their educational goals. One of the most significant differences is that the operating budgets of public universities significantly financed by state and federal tax dollars. These funds are given directly to the institution and used to support their operations. Consequently, they are under the supervision of local, state, and federal governing authorities as well. This effects their operational decision-making in that they are less autonomous than their private counter parts. Public universities still collect revenue via tuition, which can vary greatly, but it is substantially lower than that of private institutions. Private universities are primarily tuition driven with regards to their source of revenue, but many can also draw on donated funds in the form of gifts and endowments. Many private colleges are church-affiliated universities receive funding via their church organization. Private colleges do not rely on public funding and are not as closely supervised by any governmental agencies. Consequently, they have much more liberty to run their school as they see fit.

There are also substantive differences in the educational goals of higher education institutions. Large public and private research universities have as a primary goal the generation of new knowledge via original research. They hire faculty who spend the majority of their time engaging in research rather than teaching. This research also generates revenue for the university via patents, the commercial application of developed technologies, and by obtaining grant money, usually from government sources, to fund salaries, facilities, and equipment. Approximately 300 universities in the United States fall into this category (Carnegie, 2014). The remaining 2,000 or so four-year colleges and universities engage in much less, if any, research and instead emphasize vocational or liberal arts education. It is from this population that the sample for this study was drawn.

The most common of these are private liberal arts institutions, which mostly offer undergraduate degrees in various subjects. The majority of private liberal arts universities are between 1,000 and 5,000 students. There are institutions specializing in a particular professional field such as education, music, engineering, agriculture, architecture, law, medicine, etc. But as the name implies, liberal arts colleges predominantly offer classes in the liberal arts and vocational training to a lesser degree. Although some of these institutions engage in research and grant doctoral degrees, the vast majority specialize in undergraduate education or graduate education at the master’s level. The analysis draw, from this research has greater external validity when applied to these institutions as opposed the studies on higher education efficiency, which include more or all sectors of the industry.

**Limitations**

No study of this type can insure 100% comparability between subject institutions. There will always be differences that cannot be controlled for. Even though this research used a subject population that is more homogenous than most, there were differences between these institutions that will affect their costs. The costs for goods, services, real-estate, and the age of its infrastructure vary along with geographic location. This study did not control for differences in the quality of the education being produced or the fields in which degrees are being produced. Kokklenberg, Sinha, Porter and Blose (2008) have shown that estimation of higher educational production functions that do not control for the distribution of degrees granted at an institution across fields yield misleading estimates of the impact of measured instructional expenditures per students on graduation rates, because the cost of educating students varies widely across majors. This may be mitigated somewhat since this research is not using graduation rates but the total number of degrees awarded as a dependent variable. Graduation rates include enrollment and time dependency characteristics that are more likely susceptible to this effect more so than the more straight forward degrees awarded variable. This research also estimated inefficiency from panel data. This estimation compared the performance of an institution with itself over time. This also mitigated the effect of heterogeneity in the sample. However, it is always important to recognize the danger that the measurement of inefficiency may be conflated with the issue of legitimate differences between institutional production structures.

This research used both cross-sectional and panel data. This allowed for both inter-institutional and intra-institutional comparison. Even so, this type of analysis had some drawbacks. Any correlations identified was just that. It was difficult to infer causation from statistical analysis alone. The data also showed that some institutions had higher than optimal expenditures. While the research design tried to account for confounding variables, some of the measured inefficiencies may have been due in part to unmeasurable factors. It was hoped that the longitudinal data may reflect efficiencies and/or inefficiencies in institutions over time thereby limiting the effect of confounders. A more detailed discussion of the research methods and specific research questions is presented in Chapter 3.

Finally, it is important to remember that inefficiency as it was applied in this research is a relative, not an absolute, concept. The inefficiency of any university was evaluated relative to the inefficiency of other universities in the sample. The institutions, in a sense, are graded on a curve. Thus, the university that was found to be the least inefficient need not necessarily be inefficient in absolute terms; its actual inefficiency could be significantly higher.

**Significance of the Research**

This research is important in light of what was stated earlier in describing the public's view of the higher education and its affordability. Students and their families are questioning the value of post-secondary education in part because of its high cost. Given the limited resources available to the vast majority of the American public, and the perceived public good that obtaining a higher education is able to impart, post-secondary institutions have an obligation to provide their service as efficiently as possible. In the current economic climate, taxpayers are not as easily persuaded to support higher education any more than they already do via a variety of taxpayer funded grants and no interest loans. An ever increasing emphasis is being given to issues of accountability and value in higher education. It is more important than ever that institutions of higher education demonstrate that they are being as cost effective as possible. This means being economically efficient.

Even though private, not-for-profit institutions are not in the business of providing dividends for stockholders, they are still very much interested in increasing their value and financial stability. Non-profit universities must maintain a profit margin if they are to survive over the long term. This is accomplished through increasing the revenue they generate via tuition, donations, and investments from their endowments. Administrations make yearly financial reports to their boards of regents (or similar oversight body) and stakeholders. Information such as that produced by this research can give them some measure of how financially successful and efficient they are when compared to similar institutions. This research can give them insight and information for setting priorities and allocating resources for their own institutions.

While there has been research done on the efficiency of higher education, most of the quantitative research has taken one of two approaches. The first is to look at production efficiency along the lines of that being conducted in this research. These studies while useful have had to deal with the difficult problem of measuring student quality, learning, and knowledge production across a wide spectrum of institutional types from 2-year associate’s degree-granting community colleges to 4-year doctoral research universities. The second approach is to compare the different sectors of the industry, like public verses private, to each other. These studies allow us to compare efficiencies between dissimilar types of institutions, but they do not well differentiate between institutions in competition within the same sector. The financial structures and educational goals of the different major sectors of higher education are just too different. It is the proverbial comparison of apples to oranges, which is useful if you are deciding what type of fruit to eat. It is not so useful if you have decided you want an apple but aren't sure which of the many varieties you would like to try. This research compared apples to apples.

In summary, this research addressed a major issue–if not *the* major issue–in higher education today. The increasing cost of higher education must be addressed, and if not slowed, it must be justified. A large part of that justification will involve demonstrating the economic efficiency of its operation. This research provided information on the current state of the technical efficiency of an important sector of higher education. This research also contributed to the growing body of research that seeks to apply efficiency models like stochastic frontier estimation, long used to measure industrial and farm efficiency, to higher education.

# Chapter 2

# Literature Review

## Methods and Variables

Over the last fifty years, different statistical approaches have been used to try and determine efficiency for different sectors of commercial industry and then higher education in a number of western industrialized countries. The first step in these approaches is to select an appropriate input-output combination that can determine efficient behavior or a "best practice" frontier. Then, in the second step, any deviations from the best practice frontier is attributed to inefficiency. However, there are questions that must be considered when employing this approach to efficiency analysis. Firstly, how should researchers derive the best practice frontier from a data set? Secondly, and perhaps most importantly, how should they determine the extent to which deviations from the best practice frontier created in the first step are attributable to inefficiencies and not to other factors? Additionally, two types of deviations from the frontier have been identified–deterministic and stochastic.

The first method to gain wide acceptance was a deterministic one called the data envelopment analysis (DEA). This is a mathematical programming approach that seeks to evaluate the efficiency of an organization relative to other organizations in the same industry. DEA essentially calculates the economic efficiency of a given organization relative to the performance of other organizations producing the same good or service, rather than against an idealized standard of performance. A full blown discussion of this approach is beyond the scope of this paper. There is ample literature explaining DEA and comparing it to the statistical method that will be utilized in this research (Murillo-Zamoroano, 2001; McMillan & Chan, 2006).

In contrast to DEA's mathematical programming approach, the econometric approach of the stochastic frontier estimation utilized in this research attempts to determine the *relative* economic inefficiency of organizations against a benchmark. If input and output data from a set of institutions is obtained, it is possible to compare them to one another and develop a "frontier" to which individual institutions can be compared. This methodology takes a different approach than earlier studies by estimating a frontier production function. Earlier studies utilized regression analysis, which typically focuses on the average producer and can be used to predict the typical producer's cost for a given output. But instead of looking at typical costs, frontier estimation identifies the minimum expenditure for producing a given amount of output, which in the case of universities is most often measured by students educated. Institutions operating behind the frontier are not as efficient as they could be and the degree to which they are inefficient can be estimated based on their distance from the frontier (Kumbhakar & Lovell, 2000).

Stochastic frontier estimation was nearly simultaneously developed by two groups of researchers. Meeusen and Van den Broeck (1977) published in June and the work of Aigner, Lovell, and Schmidt (1977), which was published a month later. This simultaneously developed model was termed "stochasitic" because it accounted for the probability of random error. It can account for things that are not under the control of the institutions decision makers like; regulatory-competitive environments, weather, luck, and socio-economic and demographic factors and therefore should not contribute to operational inefficiency. Although DEA has a longer history of appearing in the literature, and as a result more studies have been done using it, SFE has become increasingly prevalent in the literature since 2000. It has become well accepted econometric method to examine aspects of economic inefficiency.

**Past Approaches Using SFE**

Since the development of SFE, the vast majority of applications have been to industry and agriculture. Fewer studies have applied SFE to education. The majority of educational efficiency studies employing SFE have been done on European educational systems. This review highlights a few of the studies conducted in the last 15 years that employ the SFE model applied in this present research. Robst (2001), Izadi, Oskrochi and Crouchley (2002), Stevens (2005), Kokklenberg et al. (2008) and Webber and Ehrenbert (2010) all utilized SFE in order to determine some measure of the efficiency of higher education. Robst (2001) utilized SFE to determine the effect of various independent variables on the overall efficiency of these institutions. The dependent variables in his model were education and research production. The independent variables he specified included FTE undergraduate and graduate enrollments and research expenditures. He then correlated changes in efficiencies over time with changes in state appropriations. Izadi et al. (2002) applied SFE cost function to estimate the efficiency of HEIs in the UK. The dependent variable in their analysis was total institutional expenditures. The independent variables included undergraduate student load in arts subjects, undergraduate student load in science subjects, postgraduate student load, and the value of research grants and contracts received. Johnes and Johnes (2009) used measures of the average incremental cost of education and returns to scale and scope. Philip Stevens (2005) investigated the costs and efficiency of English and Welsh universities as suppliers of teaching and research using the SFE model. He wanted to determine how the characteristics students and staff affected the efficiency by which universities could produce degreed students and research. Kokklenberg et al. (2008) used SFE in conjunction with ordinary least squares (OLS) methods to estimate the effect that efficiency levels had on the productivity of private higher education in the U.S. as measured by graduation rates. The inputs they considered were total undergraduate expenditure per FTE and the percentage of males at the institutions (Kokklenberg cited prior research that showed males tend to graduate at lower rates and they take longer to graduate than females.). The annual expenditures (adjusted for academic mission) and a variety of student and faculty demographic variables were also used as independent variables. Finally, Weber and Ehrenberg (2010) employed SFE using undergraduate graduation rates as output, and demographic variables, the quality of students, and the annual expenditures as inputs. The author's presented evidence that many institutions were not efficiently allocating resources in the sense that they were not maximizing graduation rates. They concluded that private schools could increase their graduation rates by increasing focused expenditures and through more selective admissions.

**Data Sources**

The studies referenced in this literature review investigated the costs and efficiencies associated with HEIs in the U.S. (Robst, 2001; Izadi et al., 2002; Ryan, 2004; Kokklenberg et al., 2008; Webber and Ehrenberg, 2010) utilize data collected by the National Center for Educational Statistics (NCES) through the Integrated Post-Secondary Education Data System (IPEDS). Data collection by the NCES began in 1993 but was rather sparse and incomplete through the 1990s. Data collection has improved, and over last decade nearly all post-secondary institutions report their cost, enrollment, and graduation data to the agency. This has enabled researchers to conduct more thorough and reliable research into questions regarding the economic efficiency of higher education. The data source used in this study was from the same source but covers the academic years from 2006 to 2011 and only examines a more limited and homogenous sector of HE in the U.S. Comparable lines of study conducted on European higher education utilize data similar to that collected by NCES. Those studies (Izadi et al., 2002; Stevens, 2005; Johnes & Johnes, 2013) rely on data collected by the Higher Education Statistics Agency (HESA). HESA collects a range of data every year UK-wide from universities, higher education colleges, and other differently funded providers of higher education. The HESA data is obtained from student records, university staff and finance records, several surveys of HEIs and institutional profile information.

The types of institutions, the sample size, and the years in which the data was collected vary greatly. There is a mix of cross-sectional and panel data in the studies surveyed here. The determinate of which type of data being used is in part due the nature of the questions being investigated, but it is also a product of the data available. Prior to 2003, data on consecutive academic years is sparse and often incomplete. HEIs in America only gradually (and perhaps grudgingly) began to supply complete data on graduation rates, expenditures, student and staff demographics, etc. All studies have had to narrow their sample because not all institutions were, supply data for all of the variables being investigated. There is no real consistency in the types of institutions examined across studies. Each study uses different combinations of institutions based on mission, Carnegie Classification, or the type of output being considered, usually research, graduate, or undergraduate education. Robst (2001) conducted an institutional cost efficiency study on 440 public colleges and universities in the U.S. between 1991 and 1995. Izadi *et.al.* (2002) estimated the efficiency of 99 universities during 1994–95 in the UK using SFE. Philip Stevens (2005) investigated the costs and efficiency of English and Welsh universities as suppliers of teaching and research using panel data from 80 institutions spanning the years 1995–1999. The data used by Kokklenberg et al. (2008) consisted of 753 private colleges and universities in the U.S. for the period 1997 through 2003. John Ryan (2004) examined similar variables and a similar set of institutions to the study at hand. The data was based on fiscal year 1996 IPEDS expenditure amounts as reported by 363 Carnegie-classified Baccalaureate I and II institutions in the U.S. Webber and Ehrenberg (2010) utilized panel data from a national sample of 1161 four-year American colleges and universities. The data was stratified by bachelors, masters and doctoral Carnegie classifications. Like the present study, Webber and Ehrenberg (2010) used IPEDS data that were compiled and edited by the American Institute for Research. This study utilized data obtained from the same organization but for a different set of years. Webber's data spanned the four academic years from 2002/03 to 2005/06, and also made some comparisons to categories of costs from 1995. This study utilized panel data collected for the academic years from 2005/06 to 2010/11.

**Findings**

The findings of efficiency studies vary of course depending on the variables and types of institutions involved. Some of the efficiency research has segregated expenditures into different functional categories, but few studies have separated out expenditures into the distinct functional categories that were utilized in this research. Research studies investigating questions of HE expenditures and how they might be affecting graduation rates seems a bit mixed, and it is certainly incomplete. There seems to be no universally agreed upon method by which to select and evaluate the variables that might affect the productivity of universities. Simple OLS and multiple regression techniques have been used historically and extensively as means to predict one dependent variable from one or more independent variables. Recent studies that have used these methods in an attempt to determine where a university should invest its resources in order to produce the most products as measured by graduation rate are few. Fewer still are those that have separated out expenditures into functional categories, such as instruction, student services, academic support, and research. Those studies have produced mixed results. Evidence for the conclusion that expenditures for instruction and academic support positively affect graduation rates were found by Ryan (2004) and Gansemer-Topf and Schuh (2006). In the same study, Gansemer-Topf and Schuh (2006) also concluded that student services significantly and negatively contributed to retention rates as did institutional support expenditures. However, Webber and Ehrenberg (2010) ran simulations on their data wherein they decreased instructional expenditures by $100 per FTE and increased student services expenditures by the same amount found that the average institution could increase its graduation rate by 13% in doing so.

Studies utilizing SFE to determine the efficiency of higher education have used graduation rates, research production, or both as dependent variables. The combination of independent variables measured varies. When considering the technical efficiency of universities Robst (2001) found that inefficiencies existed in his sample of U.S. public institutions and that the total education and general expenditures were positively related to undergraduate graduation rates. However, the author was cautious in drawing too strong of a conclusion since the institutions in the sample were producing the multiple outputs of both graduates and research. Without separating the two and determining the expenditure per output graduate, it was not possible to attribute inefficiency directly to expenditures on undergraduates, graduates, or research. In Izadi et al. (2002) study of 99 universities in the UK, their 1991 to 1995 data showed that the average efficiency for institutions producing undergraduate education in England was 87.6%. Forty-five percent (45%) of the sample was shown to be operating at or above 90% efficiency and nearly 88% above 80% efficiency. The authors concluded that the inefficiencies identified in their study are “fairly modest” and “on the margins of statistical significance” (Izadi et.al., 2002, p. 70). In his investigation of costs and efficiency in English and Welsh universities, Philip Stevens (2005) found diseconomies of scope between undergraduate education and research, suggesting that universities would be more efficient if these functions were separated. That is to say, institutions were less efficient at producing graduates if they were trying to output both students and research. However, there was a positive efficiency associated with postgraduate education and research, which was not too surprising given the more overlapping nature of these outputs. Both of these UK studies look at total expenditures only and do not examine individual expense categories.

Another line of research using the SFE model considers the demographic characteristics of the students and/or staff as independent variables. The premise of these studies is that it is the quality of the student and/or faculty that determines how efficiently a university can convert its incoming students into graduates. In his research, Philip Stevens (2005) also looked at the quality of the students as determined by the degree they earned (in the UK degrees are classified into first-class, second-class, and third-class degrees) and the quality of the teaching staff based on experience. Stevens concluded that inefficiency in production did indeed exist and that the efficiency of an institution was the result of the characteristic of their students and teaching staffs. Universities producing students with more third-class degrees were less efficient than those producing more students with first-class degrees. While effecting efficiency to a lesser extent, having older more experienced faculty contributed to greater production efficiency. Research along the same lines in American universities by Kokklenberg et al. (2008) concluded that private institutions can increase their graduation rate efficiency through more selective admission. The authors sighted “maleness” as the single biggest factor contributing to inefficient graduation rates.

A final aspect of efficiency research related to higher education is the attempt to determine if some sectors of the higher education industry are more efficient than others. It would seem that comparing institutions in the U.S. using their Carnegie classification would be useful for this, but it is not that straight forward. The problem with making this comparison is that the different Carnegie classifications are based on the educational mission of the institution; therefore, the products of institutions will differ. Doctoral universities emphasize graduate degrees and research while bachelor's institutions emphasize undergraduate research. Robst (2001) attempted to identify statistically significant relationships between institution types and inefficiency but failed to find any. Though not the primary focus of their study, Hamrick, Shuh, and Shelly (2004) found it puzzling that undergraduates succeeded at higher rates at research-oriented institutions than those whose primary mission was undergraduate education. The explanation proffered was that perhaps academically better-prepared students are more likely to attend research-oriented institutions rather than baccalaureate institutions. This may mean that the only meaningful comparisons of efficiency can be made are between individual institutions with the same educational mission. That will be the operating assumption of this research.

This research differed from previous research based on SFE in a number of ways. Firstly, this research focused in on a more homogeneous sector of American higher education than has been investigated previously. In his synthesis of efficiency research as it stood in 2003, Carl Selerno advised that the more similar the inputs and outputs of the institutions being compared, the more meaningful the results obtained from econometric analysis will be. This speaks in support of the study at hand in that the institutions being compared were found within the same sector of higher education. The most similar study found was conducted by Ryan (2004) whose subject population included Carnegie-classified Baccalaureate I and II institutions, but he used OLS to identify relationships. The importance of this aspect to the research at hand cannot be underestimated. Whenever seeking to make conclusions based on inductive logic from data, it essential that potential confounding variables are limited. In an attempt to make broader and potentially more publishable conclusions or conclusions that have a wider implications, studies too often compare broadly similar groups. While this may accomplish those goals, it weakens the strength of the conclusions, rendering them at times to the realm of sheer speculation. This research, based on a more homogenous sector of HE, limited its conclusions broader applicability but has more importantly increased its internal validity.

Secondly, when compared to research into other aspects of higher education economics, none have used the combination of independent and dependent variables that were considered here. Several have used combinations of variables describing the characteristics of the institution and evaluated them against its education and research output. Fewer have examined the relationship between various expenditure categories and educational production alone. The data set used in this research was one of the primary characteristics that set it apart from anything else in the field. Oftentimes, when using doing secondary analysis, one finds when doing the literature review that the data has already been “mined” for significant correlations and inferentially based conclusions. Not so with this data set released in August of 2012. In the search through the literature, no studies could be located that were utilizing this data to perform any type of production inefficiency related research. The Delta Cost Project provides nearly complete panel data from 2006 to 2011. No econometric studies that utilize this data could be found. The primary line of econometric research used cross-sectional or panel data from an earlier time period or from post-secondary education outside of the U.S.

# Chapter 3

## Research Method

This study examined key variables that can reflect the technical efficiency of 4-year, private, not-for-profit, non-research universities in the U.S. whose primary focus is undergraduate education. Technical efficiency is a measure of the extent to which an institution efficiently allocates the inputs it has to produce a given level of output. In the case of HEs the inputs would be assets such as faculty, administration, computers, laboratory equipment, etc. How an institution allocates its resources is reflected in the relative amount it spends in different expenditures categories. This chapter includes a description of the research design, the methodological approach, the population and the justification for using them. It explains stochastic frontier estimation in greater detail, the data that were utilized, and how the data was analyzed. It also gives a description of the statistical models that were applied, the assumptions of the models, and it addresses the strengths and weaknesses of the approach that was used in this research.

### Research Design and Rationale

The technical efficiency of the subject institutions is measured using the number of degreed students produced each year—both bachelor's and master's degrees. This is the most appropriate dependent variable to use since producing graduates is the primary "product" of a higher education institution. It is common in a limited number of empirical studies of higher education production or costs that the educational output is represented by FTE enrollments or the number of degrees awarded (Solerno, 2003; Johnes & Johnes, 2013). It is also common practice among educational researchers to utilize graduation rates as a measure of the success of HEs (Ryan, 2004; Johnes, 2005; Stevens, 2005; Athanassopoulos & Shale 2006; Webber &

Ehrenberg 2010; Kokklenberg et al., 2008). Since the Federal Student Right-to-Know and Campus Security Act of 1991 was passed into law, all post-secondary institutions have had to report data on graduation rates. This measure is famously utilized by *U.S. News and World Reports* annual rankings, which include graduation rates as one of the metrics for determining quality institutions. Despite their widespread use, graduation rates have drawbacks as a means to measure a universities production and were not be used in this study. Porter (2000) critiques the use of predicted graduation rates as the basis for ranking institutions. One problem with this measure is that the law defined the rate as the percentage of full-time, first-time students who enrolled in the fall and completed their degree within 150% of normal time or six years for students seeking a bachelor's degree. This measure therefore excludes those who transfer in and eventually graduate from an institution and those who transfer out but go on to graduate from another institution. In order to avoid the problems associated with this indicator of university production, this study used the total number of bachelor's and master's degrees awarded per year as the dependent variable. This measure is irrespective of when the student initially enrolled in that institution (i.e., as a freshman or a junior) and without regard to the number of years the student was enrolled before attaining the completion. The total number of degrees awarded is a measure more reflective of what the university is producing as a result of their expenditures.

The independent variables used included expenditure categories defined by the American Institute for Research (2014) based on institutional self-reported data for IPEDS. The expenditure categories included instruction, institutional support, and student services. Similar expenditures have been utilized by others to measure the inputs via costs to an HEI. (Izadi et al., 2002; Hamrick, Shuh, & Shelly 2004; Ryan, 2004). One approach to analyzing the separate allocative effects of expenditures is to express categorical expenditures as percentages of a budget. However, for the purposes of this study, the expenditure variables were expressed in dollars per FTE student before being transformed. This method allowed for a relative comparison between expenditure categories and a way to fairly compare expenditures between institutions of different sizes. This approach was utilized by Ryan (2004) in his examination of the relationship between university expenditures and degree attainment using regression analysis.

**Stochastic Frontier Production Function**

In his seminal paper, Michael J. Farrell (1957) introduced a method to break down the overall efficiency of a production unit into its technical and allocative component. Farrell characterized the different ways in which a productive unit can be inefficient. A production unit can be technically inefficient if it is obtaining less than the maximum output given the inputs it has available. Building on the pioneering work of Farrell, the stochastic frontier production function was independently proposed by Aigner, Lovell, and Schmidt (1977) and Meeusen and Van den Broeck (1977). Stochastic frontier analysis is a parametric technique that uses standard production function methodology. The various derivatives of the basic stochastic production function model are referred to as stochastic frontier estimators. They are described as being stochastic because the models they contain a stochastic, or random chance factors like dramatic changes in the local economy, acts of nature, unpredictable market force, etc., that could affect the production process. The random chance factors are not directly attributable to the entities being analyzed or their underlying technology. Whatever these stochastic effects may be, it is assumed they are random and can be described by a common distribution e.g., exponential, half-normal, gamma). The standard production model and the one being used in this research is based on a Cobb-Douglas translog. The Cobb-Douglas and translog models overwhelmingly dominate the applications literature in stochastic frontier and econometric inefficiency estimation

(Greene, 2007). This is a relatively flexible functional form, as it does not impose assumptions about constant elasticities of production nor elasticities of substitution between inputs. It thus allows the data to indicate the actual curvature of the function, rather than imposing *a priori* assumptions.

The essential form is,

$$\log y = \beta' x + v - u,$$

where *log y* is the observed outcome, (product goal), the components of **x** are logs of inputs for a production model $\beta' x + v$ is the optimal, frontier goal (e.g., maximal production output) pursued by the individual units of production, $\beta' x$ is the deterministic part of the frontier, and *v* is the stochastic part. The two parts together constitute the "stochastic frontier." Then *u* represents the proportion by which *y* falls short of the goal, and has a natural interpretation as proportional or percentage inefficiency. This is the half-normal model, which forms the basic form of the stochastic frontier model. Several varieties of the stochastic frontier model appear in the literature. Presenting them all is beyond the scope of this research, but a catalog of many of these formulations can be found in Kumbhakar and Lovell (2000) and Greene (2008).

It is perhaps easiest to understand the model by viewing it graphically. The stochastic frontier approach involves fitting a curve through data on costs and a variety of explanatory variables. This is not, however, a line of best fit; rather, it is an envelope that defines an efficiency frontier—a curve that shows the lowest possible costs at which a given set of outputs can be produced. The position of this curve can then be used as a benchmark against which the efficiency with which each institution produces its output can be determined (Johnes & Johnes, 2013). The result of the analysis can give indication of what the "best-practice" in the industry might be. These frontier techniques are generally recognized as having a closer correspondence with the theoretical framework underlying production economics than do regression analysis, and are therefore more consistent with the overall education production function approach (Worthington, 2001).

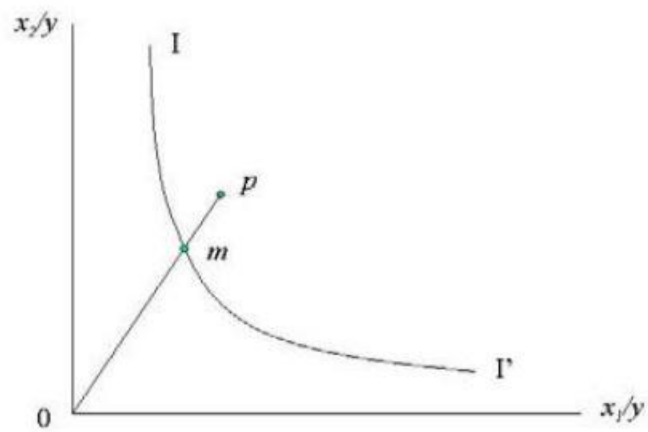


*Figure 1*. Technical efficiency measures

The analysis of efficiency as based on the SFE as constructed by Farrell (1957) can be illustrated in Figure 1. The technological efficiency frontier is described by the unit-output isoquant I-I' is the set of input-output combinations characterized by the highest level of technical efficiency. In this study, any university with (x1/y, x2/y) above the I-I' curve, are technically inefficient. For example an institution at point ***p***, may have relatively high instructional and institutional expenditures to produce a degreed graduate compared to the university at point ***m*** on the efficient frontier. University ***p*** is therefore technically inefficient relative to university ***m***. The index of technical efficiency is defined at the ratio between the distance from the origin of the unit-output isoquant and the distance from the origin of the given DMU's normalized input combination.

Because it explicitly allows for the presence of noisy data, SFE can effectively deal with random error through statistical inference on the estimated parameters. In terms of relative versus absolute efficiency, since SFE characterizes the behavior of the "average firm" after taking into account the distribution of efficiency scores estimates are much less sensitive to changes in a single data point. As the frontier reflects the average firm *after* efficiency is taken into account, what is left is a hypothetically absolutely efficient frontier. The statistical method then estimates a production frontier for each case, thereby allowing each institution's efficiency to be assessed relative to other institutions of the same type.

**Population**

The subject institutions for this research were private, not-for-profit, four-year bachelor's and master's universities in the U.S. These institutions engage primarily in traditional undergraduate liberal arts education with some degree of emphasis on graduate education. Master's universities are more involved in the production of graduate degrees, including doctoral degrees, than are bachelor's institutions. Even so, both types of institutions obtain revenue by tuition and gifts/endowments, utilize similar technologies in their production of students, and their efficiencies can be fairly compared since their one single dominant output is educated students. Another important identifying characteristic of these institutions is that the vast majority of them are affiliated with a church body or denomination. Some place more emphasis on the spiritual aspect of their mission more so than others, but many require biblical or religious course work and hold regular formal or informal religious services and activities. Whether or not this characteristic has an effect on the inefficiency levels of these institutions is not a consideration in this research, but it is a distinctive characteristic and worth noting. The institutions included ranged in enrollment from 200–4,000 FTE for bachelor's universities and from 200–15,000 FTE for master's universities. Institutions included in the research also had to produce at least 50 degreed graduates per year. The research sample did not include specialty schools like medical schools, theological seminaries, or tribal schools. There are significantly different costs or technologies associated with these types of institutions. Data from the private, not-for-profit institution that engage in a significant amount of research were excluded because research is another type of production output. Research institutions can also differ significantly in the inputs they receive in that research grants can make up a sizable portion of their revenue diminishing the effect of tuition revenue. It is possible for SFE to accommodate multiple outputs, the goal of this research was to analyze a more homogeneous sector of HE for the reasons already stated. While this approach limited the ability of the conclusions of this study to apply to the entirety of the higher education industry, it increased the validity of the conclusions as they are applied to these institutions. Considering the aforementioned criteria the study sample included 422 private, four-year, not-for-profit bachelor's institutions and 326 private, four-year not-for-profit master's institutions.

## Data Sets and Variables

The data used for this study was originally collected as part of the Integrated Postsecondary Education Data System (IPEDS). Data for all of the variables used in this research were taken from six academic years spanning 2005-06 through 2010-11. The data from these national databases have been widely used by higher education researchers. The independent variables of expenditures per FTE (instruction, institutional support, and student services) and the dependent variable (total number of BA and MA degrees awarded) were downloaded from the Delta Cost Project. These data have been compiled from IPEDS, edited for consistency, and then made available to researchers. (American Institute for Research, 2014).

Each variable is clearly defined by Delta Cost Project. Instructional expenditures includes expenses of the colleges, schools, departments, and any other instructional divisions of the institution directly responsible for the academic instruction of students. Institutional support consists of the expenses for the day-to-day operational support of the institution, such as expenses for general administrative services, central executive-level activities concerned with management and long range planning, legal and fiscal operations, space management, employee personnel and records, logistical services such as purchasing and printing, and public relations and development. Student services expenditures includes expenses for admissions, registrar activities, and activities whose primary purpose is to contribute to students emotional and physical well-being and to their intellectual, cultural, and social development outside the context of the formal instructional program. Examples include student activities, cultural events, intramural athletics, student organizations, and student records. The dependent variable of total degrees awarded includes the number of bachelor's and master's degrees earned by students in a given academic year, regardless of how many years it took the student to earn the degree or when the student first enrolled at the institution.

The dollar amounts for all of the independent variables were adjusted using the Higher Education Price Index (HEPI). This is an inflation index designed specifically to track the main cost drivers in higher education. HEPI is a more accurate indicator of changes in costs for colleges and universities than the more familiar Consumer Price Index (CPI), which is better used to measure the purchasing power of university personnel. HEPI measures the average relative level in the prices of a fixed market basket of goods and services purchased by colleges and universities through current-fund educational and general expenditures. Educational and general expenditures include the functions of instruction, student services, general expenses, and operation and maintenance of the physical plant. HEPI has been calculated every year since 1983, and in 2005, Commonfund Institute assumed responsibility for maintaining HEPI and calculating its annual rate of change (Commonfund, 2014).

Studies have shown that whether or not a student graduates is also a result of factors not associated with university expenditures or even practices. The characteristics of the students like; academic ability, gender, ethnicity, and socioeconomic status have all be shown to have some effect on whether or not students successfully complete their degree program Stevens, 2005; Kokklenberg et al., 2008; Webber, 2010). The characteristic of the institution with regards to its selectivity, degree programs offered, and the characteristics of its faculty, can also have an effect on graduation rates. (Hammrick, 2004; Ehrenberg, 2004; Stevens, 2005; Gansemer-Topf and Shuh, 2006; Kirjavainen, 2012). In order to account for this effect, the SFE used in this study incorporated covariates that functioned as a type of "correction factor" to account for differences in the characteristics of the student bodies that may impact whether or not students obtain a degree. Data for the covariates of student gender, ACT scores, federal and state grant aid, and total enrollment were directly obtained from IPEDS. The characteristic of the gender was recorded a percentage of the of the student body. In 2014, the President's Council of Academic Advisors released a report that showed that postsecondary attainment for women has risen in recent decades. Women are more likely to go to college and graduate. In 2013, 25–34-year-old women were 21 percent more likely than men to be college graduates and 48 percent more likely to have completed graduate school. A second covariate used was the ACT score for the 75$^{th}$ percentile of students enrolled in the university. The ACT has long been recognized as a predictor of student success in higher education. The third covariate included was the amount of federal and state grant aid awarded per FTE student. This covariate served as a proxy for the socio-economic status of students. Since federal grants like PELL and similar state "gift aid" grants are awarded on a needs basis, they are an indicator of the number of students from low-income backgrounds. There is a substantial body of research that indicates that students of low socioeconomic status (SES) are less likely to earn a degree from a four-year institution. (Terenzini, Cabrera, & Bernal, 2001; Walpole, 2003; Titus, 2006).

Once it could be determined that inefficiency indeed varied across institutions using cross-sectional data or through time using panel data, researchers of course sought to identify the possible causes of the inefficiency variation. As just described, that was the case with this research. To accomplish this, early studies would utilize a two stage approach. In first the stage, efficiencies would be estimated using SFE. In the second stage, the estimated inefficiencies would be regressed against possible explanatory institution specific variables such as the characteristics of the students, the faculty, or the institution itself. This method was flawed however (Kukumbar et. al., 2000). The issues with it were eventually addressed by Kumbhakar, Ghosh, and McGukin (1991) and Reifschneider and Stevenson (1991) who propose stochastic frontier models in which the inefficiency effects ($u_i$) are expressed as an explicit function of a vector of firm-specific variables and a random error. The models used in the research incorporated this one-step approach.

**STATA for Statistical Analysis**

There are relatively few software packages available that are capable of running a SFE. This type of analysis is well beyond the capabilities of Excel or SPSS. STATA is a complete, integrated statistical software package capable of running several variations of the basic stochastic estimation production function model. It has commands for running SFE on both cross-sectional and panel data, the ability to run the model under different distributional assumptions, and post-estimation commands. The help menus, and forums were of inestimable assistance in completing the analysis for this research.

**Synopsis of Methodology**

The SFE was performed using cross-sectional (each individual academic year from 2006 thru 2011) and panel data (the entire six year period from 2006—2011). Cross-sectional data provide a snapshot of producers and their efficiency at set point in time, one academic year. It creates an efficiency frontier based on the characteristics of the most efficient institutions for a specific academic year. Which institutions are functioning most efficiently in any given year will vary as will the position of the frontier. An SFE of panel data allows for an examination of changes in expenditures and efficiency over time. The panel data allows comparisons of intra-institutional efficiency so that increases or decreases in a universities inefficiency over time can be measured. It essentially determines an institutions relationship to the frontier in a given year and then compares that to the institution's relationship to the frontier in subsequent years. In other words, and SFE of panel data can measure both year-to-year changes in the position of the frontier for the subject universities as a whole and how an individual institution is changing in relation to that dynamic frontier. Panel data allows for the control of variables that cannot or are not controlled like institutional cultural differences or difference in business practices; or variables that change over time but not across entities like local economies and government policies. If a variable unique to some institution existed, the panel data provided a way to eliminate any bias it may have produced because it is likely that whatever variable or characteristic an institution may have had that made it different from other institutions, and therefore respond differently to the independent variable(s), is fixed over time. Any such variable that is fixed to an institution will take on the same value each time it is observed.

In order to perform the SFE in STATA, all variable data was first transformed into natural logs using Excel and then imported. The SFE was then run for each individual year. The cross-sectional model was executed using the *sfcross* command based on the formulae designed by Belotti et. al. (2012).

Their SFE cross-sectional model is as follows:

$$y_i = \alpha + x'_i \beta + \varepsilon_{i,} \qquad i = 1, \ldots, N,$$

$$\varepsilon_{i,} = v_i - u_i$$

$$v_i \sim N(0, \sigma_V^2)$$

$$u_i \sim F,$$

where $y_i$ represents the logarithm of the output of the *i*-th productive unit, $x'_i$ is a vector of inputs and β is the vector of technology parameters. The composed error term $\varepsilon_i$ is the sum of a normally distributed disturbance, $v_i$, represents stochastic error, and a one-side disturbance, $u_i$, represents inefficiency. Moreover, $v_i$ and $u_i$ are assumed to be independent of each other and independent and identically distributed across observations. The distribution of the inefficiency term is assumed to be exponential as per Meeusen and Van den Broeck (1977). This assumption has the advantage of robustness, but comes at the cost of downward bias (Kim and Schmidt, 2000).

The panel data model was executed using the *sfpanel* command based on the formulae derived by Pitt and Lee (1981) and later refined by Battese and Coelli (1995). That SFE panel model is as follows:

$$y_{it} = \alpha + x'_i \beta + \varepsilon_{i,} \qquad i = 1, \ldots, N, \quad , \qquad t = 2, \ldots, T,$$

$$\varepsilon_{it,} = v_i - u_i$$

$$v_{it} \sim N(0, \sigma_V^2)$$

$$u_{it} \sim N(0, \sigma_u^2)$$

The distribution of the inefficiency term in this variation of the model is assumed to be half normal. A recent comprehensive review of the econometric literature on the estimation of stochastic frontiers and technical efficiency by Parmeter and Kumbhakar (2014) found that the half-normal assumption for the one-sided inefficiency term was undoubtedly the most commonly used in empirical studies of inefficiency. So that is the assumption used in this research.

The stochastic panel model with time invariant inefficiency can be estimated under either the fixed effects or random effects framework (Wooldridge, 2010). Both the cross-sectional and panel data SFE models were run as true random effects models. As a check, both random effects and fixed effects were run and very similar results were obtained. Because only the fixed effects model controls for unobserved heterogeneity that could have been correlated with the independent variables, the similarity between the two estimates suggests that unobserved heterogeneity is not creating a large bias in this data set. The random effects model is preferred since it has a tighter parameterization, than the alternative fixed-effects model. This allowed for direct individual specific estimates of the inefficiency term in the model, and it overcame the problem of serial correlation of the panel data if it existed.

**Model Output**

When performing the analysis on cross-sectional data using the SFE model, inefficiency levels for bachelor's and master's institutions were produced separately for each academic year from 2006 through 2011. However, an inefficiency measure could not be calculated for any institutions that lacked information for any of the independent variables or covariates. The data from these institutions for all of the variables that it did report was used by the model to help create the frontier, but if an institution did not provide its student services expenditures or the amount of grant aid awarded per FTE for example, its inefficiency measure could not be generated by the model. For the cross-sectional data, there were between 73 and 93 schools out of 422 bachelor's institutions in any given year for which an inefficiency measure could not be obtained. For the master's institutions, anywhere from 62 to 125 out 326 schools in a given year did not receive inefficiency scores. In both cases, the sample size is more than adequate for the SFE model to produce reliable estimations.

The SFE model was applied to the panel data for both bachelor's and master's institutions spanning six academic years from 2006 to 2011. Again, an inefficiency measure could not be calculated for any year in which the institution that lacked information for any of the independent variables or covariates. This created an unbalanced panel, which the SFE model could accommodate. As was the case with the cross-sectional data, the model would still utilize all of the available data to create the frontier, but some institutions did not receive and inefficiency score for some years. In the bachelor's panel, there were 509 missing variables out of a possible 14,856, and in the master's panel, there were 418 missing variables out of a possible 11,610. Again, for both panels the sample size was more than adequate for the SFE to produce reliable estimations.

In reporting an inefficiency estimate for each institution, the term $u_i$ is the log difference between the maximum and the actual output (total degrees awarded). Therefore, $u_i$ x l00% is the percentage by which the actual output could be increased using the same level of inputs (expenditures) if production were fully efficient. In other words, $u_i$ x l00% give the percentage of output that is lost due to technical inefficiency. So, in the stochastic frontier framework, "inefficiency" scores can range from zero to infinity. A value close to zero implies that the institution is close to being fully efficient.

# Chapter 4

# Findings

## Characteristics of the Data

All data were obtained from IPEDS and DELTA Cost Project for the six academic years (AY) spanning 2006 through 2011. The study sample included 422 private, not-for-profit bachelor's institutions and 326 private, not-for-profit, master's institutions. Institutions excluded from the study included specialty schools (medical schools, seminaries, tribal schools, etc.), universities that engage in a significant amount primary research, and those that did not award at least 50 degrees in a year. Any institutions missing data for more than two of the variables in a given year were excluded for that year but not all years. Descriptive statistics for untransformed data from the sample year 2010 are displayed in Tables 1 and 2. Enrollment data were included to show the size range of institutions in the study and are graphically displayed in Figures 2 and 3. While master's universities are generally larger than bachelor's universities, well over half of the institutions included in the study have an FTE enrollment between 1,000 and 5,000 students.

Table 1
*Bachelor's Universities Study Variables*

| | Mean | Minimum | Maximum |
|---|---|---|---|
| FTE Enrollment | 1464 | 210 | 3955 |
| ***Degrees Awarded*** | | | |
| BA's | 286 | 36 | 919 |
| MA's | 23 | 0 | 477 |
| Total Degrees | 309 | 50 | 933 |
| ***Expenditures per FTE*** | | | |
| Instruction | $8,975 | $2,002 | $35,793 |
| Institutional | $5,464 | $155 | $71,000 |
| Student Services | $4,096 | $112 | $11,780 |
| ***Student Characteristics*** | | | |
| ACT 75$^{th}$ Percentile | 26 | 13 | 35 |
| Grant Aid | $7,582 | $707 | $23,202 |
| Female | 58% | 0% | 100% |

*Note.* Data from AY 2010 only.

Table 2

*Master's Universities Study Variables*

| | Mean | Minimum | Maximum |
|---|---|---|---|
| FTE Enrollment | 3306 | 249 | 14,921 |
| ***Degrees Awarded*** | | | |
| BA's | 549 | 2 | 2662 |
| MA's | 460 | 11 | 5427 |
| Total Degrees | 924 | 74 | 6660 |
| ***Expenditures per FTE*** | | | |
| Instruction | $7475 | $1476 | $36457 |
| Institutional | $3984 | $703 | $23425 |
| Student Services | $2880 | $293 | $9457 |
| ***Student Characteristics*** | | | |
| ACT 75th Percentile | 25 | 17 | 31 |
| Grant Aid | $7077 | $439 | $33,751 |
| % Female | 63 | 16 | 100 |

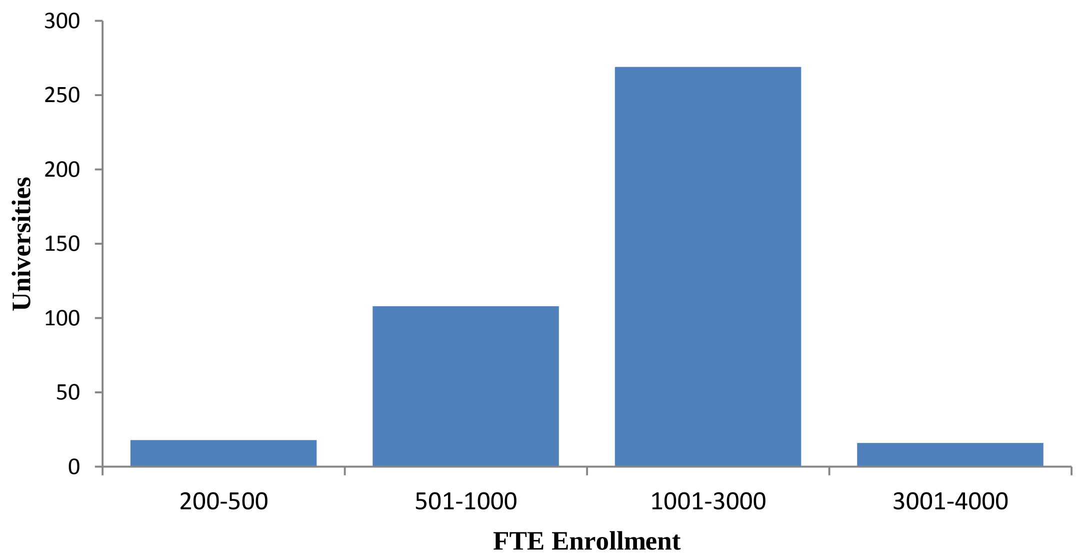


*Figure 2*. In bachelor's level institutions over half of the universities have FTE enrollments between 1,000 and 3,000.
*Note*. Based on 2010 enrollment data.

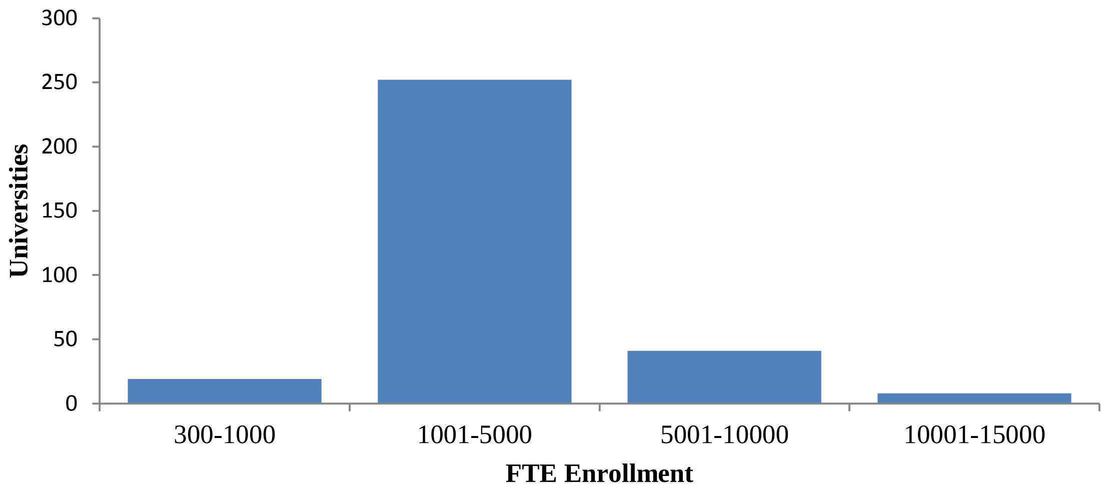


*Figure 3.* In master's level institutions over half of the universities have FTE enrollments between 1,000 - 5,000.
*Note.* Based on 2010 enrollment data.

**SFE Panel Data**

When the SFE measures inefficiency using panel data, it compares the performance of each institution to itself over time as well as to all of the other institutions in the sample. Using this model, the mean inefficiency of both bachelor's and master's universities was estimated at 21%. The impact of each of the independent variables and covariates for bachelor's universities is shown in Table 3 and for masters' universities in Table 4. In both classes of university, the effect of institutional support and student services expenditures was significant, $p < 0.000$. For the covariates, mean ACT score and the amount of grant aid per FTE were both significant with $p < 0.000$. The results from the panel data show that increasing the share of expenditures for institutional support and student services had a significant negative effect on inefficiency.

Table 3

*Stochastic frontier estimation for Bachelor's Institutions from Panel Data 2006–2011*

| Predictor Variables | Frontier Coefficients | p > \| t \| |
|---|---|---|
| Instruction | -0.006 | 0.833 |
| **Institutional** | **-0.126** | **0.000** |
| **Student Services** | **-0.117** | **0.000** |
| Covariates | | |
| **ACT** | **-5.11** | **0.000** |
| % Female | 0.233 | 0.208 |
| **Grant Aid** | **-0.768** | **0.000** |

Note. *Variables with significant levels p < .05 [CI95%] are shown in boldface.*

Table 4

*Stochastic frontier estimation for Master's Institutions from Panel Data 2006–2011*

| Predictor Variables | Frontier Coefficients | p > \| t \| |
|---|---|---|
| Instruction | 0.056 | 0.231 |
| **Institutional** | **-0.107** | **0.000** |
| **Student Services** | **-0.068** | **0.022** |
| Covariates | | |
| **ACT** | **-4.071** | **0.000** |
| % Female | 0.229 | 0.388 |
| **Grant Aid** | **-0.907** | **0.000** |

Note. *Variables with significant levels p < .05 [CI95%] are shown in boldface.*

For bachelor's institutions the coefficient for institutional support was -.1265, $p = 0.00$, and for student services it, was -.1173, $p = 0.00$. For master's universities the coefficient for institutional support was -.1072, $p = 0.00$, and for student services, it was -.0687, $p = 0.02$.

The possibility of interaction effects between the independent variables for both the cross-sectional and panel data was also explored. An interaction occurs when an independent variable has a different effect on the outcome depending on the values of another independent variable. This analysis discovered no interaction effects between the independent variables of instruction, institutional support, and student services and the number of degrees awarded.

**SFE Cross-Sectional Data**

The SFE model was applied to data from six different academic years and is displayed in Table 5. The mean inefficiency of master's universities during the years investigated ranged from 14% to 20%, and for bachelor's universities, it varied between 30% and 39%.

Table 5

*Institution Inefficiency by Sector*

| Academic Year | Bachelor's Universities | Master's Universities |
|---|---|---|
| | Mean Inefficiency | |
| 2006 | 39% | 14% |
| 2007 | 30% | 18% |
| 2008 | 35% | 16% |
| 2009 | 37% | 20% |
| 2010 | 33% | 17% |
| 2011 | 38% | 19% |

Approximately 85% of master's institutions were less than 20% inefficient (Figure 3). For bachelor's institutions only a fourth of them were less than 20% inefficient (Figure 4). The most common inefficiency range for bachelor's institutions was between 21% and 40% inefficiency, where nearly half of the schools fell. A small portion of Bachelor's universities, a group of about 20 schools, had inefficiencies in excess of 90 to-100%. Very few master's universities were more than 40% inefficient, and inefficiencies over 80% were almost non-existent. The distribution of inefficiency scores for three of the years covered in the study, the first (2006), middle (2009), and last (2011) are illustrated in Figures 4 and 5.

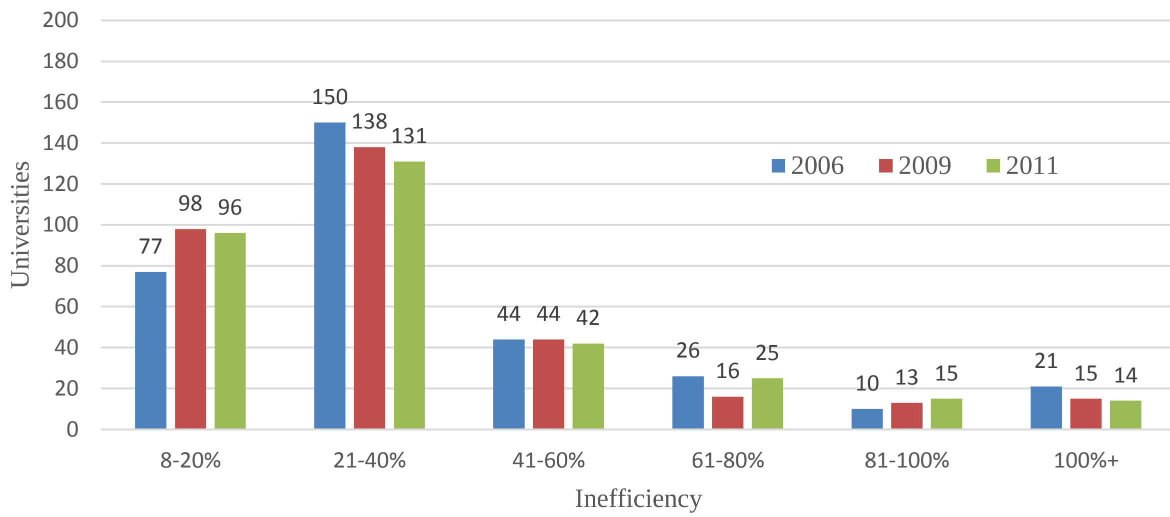


*Figure 4*. The distribution if institutional inefficiency among bachelor's universities was consistant throughout the study years. The majority of instutions had technical inefficiencies of less than 40%.

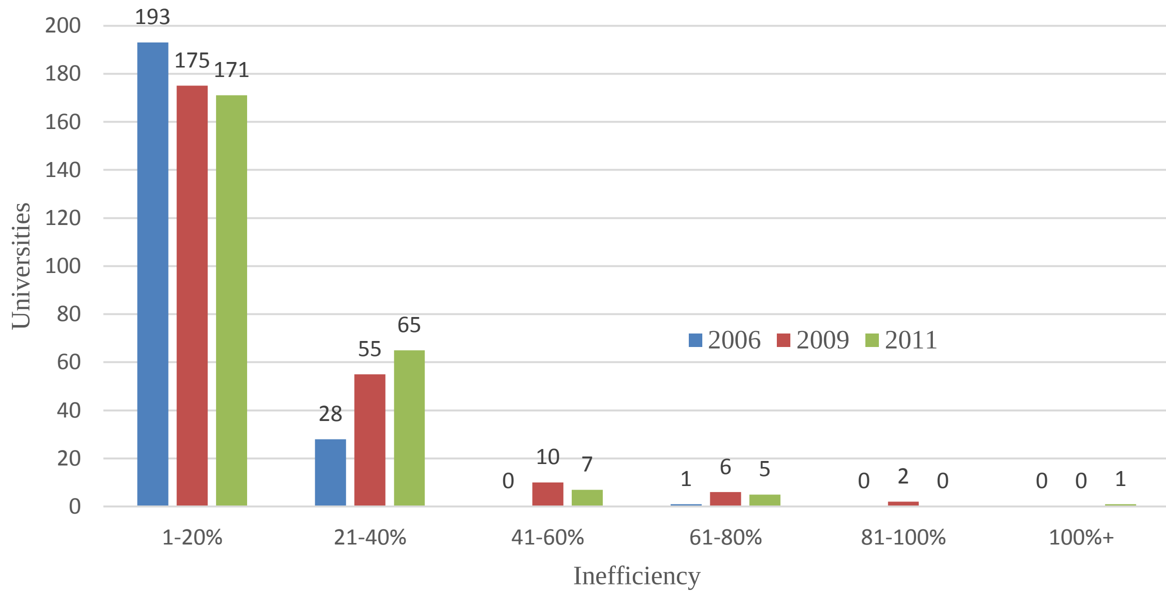


*Figure 5*. The distribution of institutional inefficiency among master's universities was consistant throughout the study years. The majority of instutions had technical inefficiencies of less than 20%.

The primary output of the SFE is shown in Tables 6 and 7. Instructional expenditures had the greatest influence on inefficiency with a frontier coefficient ranging from of 0.492 to 0.717 for master's institutions and from 0.777 to 0.932 for bachelor's schools. The effect was significant with $p = 0.000$ for all years. Institutional expenditures have a negative effect on inefficiency. The frontier coefficients ranged from -0.325 to -0.473 in bachelor's institutions and from -0.361 to -0.691 in master's schools (with one aberrant year [2007] where the coefficient was calculated at 0.616). The significance level for all years was $p = 0.000$. Student services expenditures have a negative effect on inefficiency as well. The frontier coefficient was -0.182 to -0.266 for bachelor's schools and was significant for all years with $p = 0.05$ or less. For master's schools, the coefficient for the independent variable of student services ranged from -.141 to -0.326 and was significant for four of the six years at $p = 0.05$ or less. For the years 2010 and 2011 the affect did not reach significance with $p > .15$ and .14, respectively.

In examining the influence of the covariates considered, student ability as indicated by ACT score had a strong negative effect on inefficiency. For bachelor's schools, the frontier coefficient ranged from -2.913 to -0.8249 reaching the significance level of $p < .05$ or less for three of the years and just outside the level of significance for the other three years. For master's universities, the coefficient had an even greater effect for the two years in which it reached the level of significance. In 2011 it was -7.263 with $p < 0.03$, and in 2010 it was -4.876 with $p < 0.00$. The amount of grant aid received per FTE, was significant for just two of the six years at each institutional level. At the bachelor's level in 2007, the coefficient was 0.8023 with a $p > 0.05$ and in 2011 the coefficient was .8475 with a $p < 0.02$. At the masters level, coefficient was positive for 2011 and 2010 at 2.24 ($p < .04$) and 1.47 ($p < 0.00$), respectively. For all other years the coefficient was consistently positive at both types of institutions. P values were just outside the significance levels for all other years.

Table 6

*Bachelor's Universities SFE coefficients for All Variables in All Years Included in Study*

| Year | Predictor Variables | | | Covariates | | |
|---|---|---|---|---|---|---|
| | Instruction | Institutional | Student Services | ACT | Percent Female | Grant Aid |
| 2006 | 0.894*** | -0.324*** | -0.266* | -0.824 | 0.008 | 0.092 |
| 2007 | 0.932*** | -0.455*** | -0.225* | -2.913** | 0.107 | 0.802* |
| 2008 | 0.868*** | -0.351*** | -0.182* | -1.759 | 0.130 | 0.418 |
| 2009 | 0.865*** | -0.473*** | -0.191* | -2.751** | 0.020 | 0.775* |
| 2010 | 0.811*** | -0.393*** | -0.212** | -1.899 | -0.297 | 0.417 |
| 2011 | 0.777*** | -0.418*** | -0.204** | -2.904* | 0.279 | 0.847* |

*Note. (*** - <.001, ** - <.01, * - <.05).*

Table 7

*Master's Universities SFE coefficients for All Variables in All Years Included in Study*

| | Predictor Variables | | | Covariates | | |
|---|---|---|---|---|---|---|
| | Instruction | Institutional | Student Services | ACT | Percent Female | Grant Aid |
| 2006 | 0.717*** | -0.691*** | -0.279 | 2.528 | 4.031 | -1.185 |
| 2007 | 0.616*** | -0.4920*** | -0.326** | 0.522 | 3.653 | -0.4** |
| 2008 | 0.693*** | -0.528*** | -0.273* | -5.532 | 2.838 | 1.645 |
| 2009 | 0.631*** | -0.359*** | -0.313** | -4.396 | 3.71 | 1.33 |
| 2010 | 0.821*** | -0.55*** | -0.141 | -4.876* | 2.851 | 1.478* |
| 2011 | 0.603*** | -0.361*** | -0.147 | -7.263* | 2.795 | 2.24* |

*Note. (*** - <.001, ** - <.01, * - <.05).*

In order to a better idea of the expenditure patterns and student characteristics of the most and least inefficient universities, a comparison was made between the upper and lower quartiles of schools. The data from a representative year (2010) is shown in Tables 8 and 9. In bachelor's universities, the major differences are found in the number of degrees awarded and the amount spent on instruction per FTE. It is significantly higher in the less inefficient schools. There was a 3 point difference in the mean ACT score but little difference in student socioeconomic status as indicated by the amount of grant aid awarded per FTE. In master's institutions the least inefficient schools are larger, and spend more on instruction. The amount of grant aid per FTE at the most inefficient institutions was more than twice that of the least inefficient universities.

Table 8

*Comparison of Mean Expenditures and Student Characteristics in Lower and Upper Quartiles of Bachelor's Institutions for 2010*

| | | Degrees | | Expenditures [a] | | | Student Characteristics | | |
|---|---|---|---|---|---|---|---|---|---|
| Quartile | INF | BA | MA | Instruction | Institutional Support | Student Services | ACT | %F | Grant Aid [a] |
| Lower | 16% | 475 | 51 | $9,905 | $5,310 | $4,222 | 27 | 59% | $8,619 |
| Upper | 64% | 130 | 8 | $7,874 | $5,604 | $3,924 | 24 | 57% | $8,163 |

*Note.* INF = Inefficiency
[a]All expenditures and Grant Aid expressed as per FTE

Table 9.

*Comparison of Mean Expenditures and Student Characteristics in Lower and Upper Quartiles of Master's Institutions for 2010*

| | | Degrees | | Expenditures [a] | | | Student Characteristics | | |
|---|---|---|---|---|---|---|---|---|---|
| Quartile | INF | BA | MA | Instruction | Institutional Support | Student Services | ACT | %F | Grant Aid [a] |
| Lower | 8% | 449 | 841 | $8731 | $4372 | $3283 | 27 | 59% | $5740 |
| Upper | 35% | 170 | 307 | $7309 | $3976 | $3225 | 24 | 69% | $12539 |

*Note.* INF = Inefficiency
[a]All expenditures and Grant Aid expressed as per FTE

# Chapter 5

# Conclusions

## Estimating Overall Inefficiency

Central to any study of efficiency via statistical analysis is the model being utilized. In this research, one of the two primary research questions sought to address the internal validity of the SFE method for obtaining a measure of inefficiency. The other primary questions addressed the inferences that could be made about the inefficiency of the subject institutions. That is a question of external validity, which will be addressed subsequently. First, the question of whether the SFE model applied using cross-sectional or panel data produced the most informative measure of inefficiency is discussed.

An analysis based on cross-sectional data measures inefficiency at a single point in time. This approach provides a rather limited view of how universities are operating. Universities are both unique and dynamic institutions. While the universities selected for this research share important characteristics, they are not identical. They share similar instructional technologies, infrastructure, student populations, and the like. However, they have unique priorities and emphasis in their culture and curriculum. These differences influence their financial priorities, which in turn affects their level of inefficiency when compared to other institutions. They are dynamic in that they respond to changes in their external and internal environment. For these reasons, panel data may be a more realistic estimation of inefficiency. Because in addition to estimating the efficiency frontier based on the performance of similar competing institutions, panel data allows the inefficiency of an institution to be measured against its own performance over time.

By comparing the performance of an institution to itself over time, the SFE is in effect accounting for the unique features of each institution. If an institution adjusts operations to improve its efficiency from one year to the next, it will positively effect its position relative to the SFE frontier even if it is still less efficient than other institutions. This ability makes it possible to account for the phenomena of unobserved heterogeneity. Unobserved heterogeneity is something different (heterogeneous) about the institution itself or how it responds to a predictor variable or covariate but is not directly measured or controlled for in the model (unobserved). For example, a school may eliminate an unprofitable line of study or add a more successful one without significantly altering its expenditures or student demographic. The net effect in the SFE of any change that has a negative effect on inefficiency will be to ‘drive down’ the inefficiency term ($u_{it}$). In this research, the inefficiency measured using the panel data from bachelor’s institutions produced a dramatically lower inefficiency score of 21% over a six year period. The SFE using cross-sectional data produced inefficiency scores ranging between 30% and 39% for any individual year during the same period of time. There was a much less marked difference in the inefficiency of master’s universities. Using panel data the average inefficiency score of these institutions was also 21%, but this is a slight increase in inefficiency compared to the range of 14%–20% produced using data from a single year. The reason for this is uncertain. To be consistent with how the SFE of the bachelor’s universities was interpreted, it would seem that when compared to their own performance over time they were becoming slightly more inefficient. Even so, the difference between inefficiency scores calculated under each type of analysis is only 1 or 2 percent for three of the six years studied. In any event, both methods show that master’s universities are operating with low levels of inefficiency.

The most likely reason for the SFE of panel data to show lower levels of inefficiency than did the cross-sectional data is that individual institutions are likely moving closer the frontier in response to market pressures like those described in chapter 1.   Demands for lower cost/slower growth in college costs from potential students, state and federal governments, and competition with similar institutions is likely driving technical progress at these institutions.  Over the last decade, universities are reducing instructional expenditures by hiring more adjunct/non-tenure track professors.  A 2013 article published by the Association of Governing Boards (ABG) of Universities and Colleges reported that percentage of non-tenure track faculty accounts for two thirds of the instructional faculty at non-profit colleges and universities in the U.S.  Although the research is not definitive, and outside the scope of this study, institutions may be decreasing inefficiency by increasing their use of online and computer assisted instruction.

**Analysis of Expenditures**

When the SFE is applied using panel data, the expenditure categories significantly affecting efficiency are slightly different than under the cross-sectional model.  The panel data analysis shows that the inefficiency measure is significantly negatively affected by institutional support and student services expenditures, and instructional expenditures do not significantly effect the dependent variable. This was not the case when measuring inefficiency using the cross-sectional model where in any single year instructional expenditures had the greatest effect on inefficiency.  This is likely do to instructional expenditures being fairly consistent across time within individual institutions.  A review of the raw data revealed that for nearly every institution changes in instructional expenditures were relatively small and incremental.  It may increase (usually) or decrease (rarely) each year but not substantially enough to have an effect on decreasing inefficiency over the time.  Instructional expenditure is far and away the largest expenditure category for any institution. Because of this, it is unlikely to change much from year to year, making little impact on inefficiency over time. If the institutions instructional expenditures makes them inefficient they are likely to remain inefficient and vise-versa. On the other hand, institutional and student services expenditures are much more likely to vary and have an effect on inefficiency over time. Over the past decade or so, the trend for many schools in higher education has been to increase expenditures in the supporting areas of institutional and students services. This effect is supported by other studies which have shown that increases in non-instructional expenditures can improve student engagement, retention and graduation rates (Ryan, 2004; Gansemer-Topf & Schuh, 2006).

**Relationships Between Variables**

Another questions posed in this research was to ascertain whether or not the SFE could explain the relationship between the primary institutional expenditure categories and the efficiency of degreed students produced, controlling for the effects of student gender, academic ability, and economic status. The SFE could not identify a particular level of expenditure or combination of expenditures that clearly distinguished between efficient and inefficient institutions. While conclusions could be drawn based on average expenditures, applying those expenditure patterns to individual institutions would be no guarantor of efficiency. Much like the conclusions drawn by epidemiologists and medical researchers about what might be healthful or unhealthful based on data obtain from large populations, applying those conclusions to an individual's unique biology is fraught with peril. In the same way, using average expenditure levels to dictate a specific university's budget will not necessarily account for the unique curriculum and priorities of a specific institution. Still, it was hoped that a consistent pattern of expenditures would emerge that could help individual institutions set spending levels that would help them reduce inefficiency. But no definitive correlation between expenditure levels in the categories considered and degrees granted could be identified. Even so, the SFE using the cross-sectional model did show that spending on instruction had the most consistent positive effect on degree granting inefficiency. The SFE was not capable of determining that an increase of "x" dollars in any of the expenditure categories could produce a greater efficiency of degreed students. When examining the expenditure levels of the least inefficient institutions, some spent more than twice as much on instruction as on institutional or student support. Others allocated less on instruction, more on institutional support, and less on student services. The combination of expenditures levels in each of the key categories varied widely. Testing for interaction effects between variables proved negative. No definitive interaction effect between variables was identified.

Since no consistent correlation between the independent and dependent variables could be identified, the results of the SFE cannot suggest specific spending levels for universities. However, the results obtained from the SFE using cross-sectional data may be used to suggest a possible guideline, or "rule of thumb" when making budgetary decisions. The mean ratio between the three primary expenditure categories considered in this research may be a helpful starting point for setting expenditure levels. The mean expenditures of the least inefficient quartile (lower) for each year revealed that institutions expended about twice as much per FTE on instruction than they did for institutional support and student services. The ratio of FTE expenditures for these three categories then was about 2:1:1. However, because of the nature of a stochastic frontier, this by no means is a ratio that an institution *must* achieve in order reduce inefficiency. Indeed, there were institutions with low inefficiency scores that had an expenditure ratio that was different. Still, for institutions suffering from very high technical inefficiency, reorganizing so as to bring expenditures closer to this 2:1:1 ratio could be a good starting target.

**General Patterns**

The previous discussion of expenditures and inefficiency notwithstanding, some common characteristics of resource allocation were found to exist within this sector of higher education. First, most of the least inefficient institutions spent the highest amounts in instruction per FTE. The least inefficient quartile of bachelor's institutions averaged nearly $2,000 more dollars in instructional expenditures per FTE than did the most inefficient quartile. Expenditures for instruction are typically a little more than double those for institutional support and student services, especially in the least inefficient schools. Investing in quality instruction whether that be faculty or instructional technologies seems a wise use of a university funds since the goal of instruction is to produce degreed students. The bulk of this expenditure is for faculty. It is common for these private liberal arts-centered schools to promote their low faculty to student ratio as a way of making themselves attractive to potential students and their families. The thought of easier access to faculty because they are dealing with fewer students is appealing for potential students but costly for the university. Instructional expenditures could be reduced, and the delivery of faculty services to students could be made more cost efficient from the universities prospective by having larger class sizes. This would however change the nature of the many small-to mid-sized schools. Indeed, it would seem that because of this, the four-year not-for-profits have a built in inefficiency that they may not necessarily want to eliminate. This inefficiency is a major part of what differentiates them from larger, and less expensive, public institutions. It would be of interest to run the same analysis used in this research to schools with larger faculty to student ratios in order to test this hypothesis.

Second, universities that award a substantial number of graduate degrees are less inefficient. The SFE clearly shows that it is more efficient to produce doctoral and master's degrees than bachelor's degrees. The mean expenditures for instruction, institutional support and student services were all roughly $2,000 less per FTE in master's institutions than they were in bachelor's schools. It is also likely that graduate students as a group are more motivated to complete their degree than are undergraduates. Graduate education can be provided more efficiently than undergraduate education and/or increasing graduate school enrollment can reduce the overall inefficiency of a university. This indicates that schools striving to become more technically efficient would do well to grow their graduate schools.

In order to get an idea of what the most and least inefficient schools may be doing differently with regards to the variables examined, the upper and lower quartiles from 2010 were compared (Tables 6 and 7). It appears that institutions with larger enrollments benefit from scaling effects. This scaling effect was found in studies that have examined graduation rates (Koshal & Koshal, 1999; Solerno, 2002; Laband and Lentz, 2003) although these studies did not use the number of degrees produced as the dependent variable, it is not beyond reason to assume degree production also benefits from increasing returns to scale. In bachelor's institutions, there is a substantial difference in the instructional expenditures per FTE. As stated previously, the least inefficient schools spend an average of nearly $2,000 more per FTE on instruction. What specific form that spending is taking can only be inferred, but it seems reasonable to suggest that the more inefficient universities may have lower faculty/student ratios or have more experienced faculty with requisite higher costs to employ. Little difference was found in institutional and student expenditures between the most and least inefficient schools. The biggest difference in expenditures between the upper and lower quartiles in master's institutions are the institutional expenditures which differed by $1,900 per FTE. For master's schools it appears that institutional expenditures improve productivity.

Some patterns related to the effect of student characteristics and inefficiency were present. In the SFE of cross-sectional data the effect that student characteristics had on the inefficiency term was not as evident as anticipated. Most years the effect of any of the student characteristics failed to reach the level of significance. When it did, it was either the ACT score or the amount of grant aid awarded per FTE that were the significant covariates. The SFE using panel data showed that student ability as indicated by ACT score had a strong negative effect on inefficiency. These results are not surprising in that it has long been understood that ACT score is a strong indicator of post-secondary success and degree attainment. The purpose of including this covariate was not to provide further support for this fact but to reduce the impact on inefficiency that accepting students with lower ACT scores would have on institutions that do so. Although the overwhelming number of BA and MA institutions in the lower quartile of inefficiency percentages had incoming first-time students with a $75^{th}$ percentile ACT score of 25 or higher, there were a handful of schools in the lower quartile with a $75^{th}$ percentile ACT score of 20 to 23. The influence of the amount of grant aid received per FTE was significant in just two of the six years covered in the study. In those years, the most inefficient quartile of schools had students with lower ACT scores and the average amount of grant aid was nearly $7,000 greater per FTE. This seems to indicate, though not strongly, that schools with students receiving more need-based aid had their inefficiency score increased. It was an assumption of this research that the level of grant aid would serve as a proxy for students from a lower socio-economic background and that those students, because of their background, would have a more difficult time earning a degree. This assumption was only weakly supported by the SFE. In a study examining variables similar to this one, Webber (2010) found that universities with students receiving more grant aid per FTE had higher instructional expenditures. He concluded that universities with students receiving high amounts of grant aid per FTE could increase their graduation rates by increasing instructional expenditures. It may be that we are seeing this effect here in that the most efficient institutions have higher instructional expenditures per FTE and having higher amounts of grant aid per FTE has no effect or in rare instances a slightly negative effect on inefficiency.

Like the ACT scores of incoming students, it is widely understood that female undergraduate and graduate students graduate at a higher rate than their male counterparts. This was the basis for including the percentage of female students as a correction factor. It was assumed that schools with a higher percentage of female students would be more likely to produce degreed graduates. However, the SFE model indicates that the influence of females in the student body was insignificant for all schools in all years. After closer examination, this may be because the difference in the percentage of females between institutions did not vary significantly enough. The schools at the extremes were the exception and not the rule. The vast majority of the study population has a female student body comprised of between 40 and 70 percent female. Since the vast majority of subject schools were very similar in this regard, it is understandable that this characteristic would not contribute significantly to differences in inefficiency.

**Hypothesis**

It was hypothesized that the SFE would show that the subject institutions show a general pattern of low inefficiency. It was believed that the highly competitive market of these tuition driven institutions should be forcing them to reduce inefficiencies. The SFE based on panel data and to a lesser degree from yearly data both revealed that the majority of institutions in both sectors, bachelor's and master's, were in the lower ranges of inefficiency scores for any given year (Figures 4 and 5). These results indicate that on the whole, the private, not-for-profit sector of higher education is not terribly inefficient. Based on the panel data the SFE mean inefficiency for private, four-year, not-for-profit universities was only 21%. It is likely that market forces and competition in higher education is requiring that these institutions operate as efficiently as possible. This is not to say that higher education isn't too costly or that there is no room for reducing costs. The SFE tells us only that when analyzed as a market sector most institutions are not operating with detrimentally high levels of inefficiency.

It was also hypothesized that expenditures on instruction and student services would have a negative effect on inefficiency and expenditures on institutional support would have a positive effect on inefficiency. The later portion of the hypothesis was clearly refuted. A result that is perhaps surprising to those often critical of the ever growing costs of a college education is the finding that institutional expenditures had a negative effect on inefficiency (Tables 4, 5, and 9). In other words, increasing expenditures for institutional support that includes things like administrators, the financial aid office, and the registrar can actually reduce inefficiency! It is a common criticism of HE that bloated administrative costs is a primary driver of the increasing cost of post-secondary education. However, counterintuitive this finding may be, based on the results of this study it looks as though there is evidence supporting the value of institutional support services. This result is in agreement with the findings of Ryan (2004), which showed a positive relationship with institutional support and graduation rates. Since the production frontier is constructed by finding the right combination of inputs, there must be an ideal range and/or ratio of institutional support needed to create the optimal level of efficiency. The idea that any expenditure not directly related to instruction if reduced would create greater efficiency is not supported by the results presented here. It is clear that some degree of institutional support, for the time period examined in this research about $5,000 per FTE on average, must be provided in order to maximize an institutions ability to produced degreed students. The hypothesis was supported in that student services expenditures did have a negative effect on inefficiency. This result is in agreement with a body of related research compiled over the last decade showing that increasing student services has a positive effect on student retention which in turn is thought to directly contribute to matriculation. These services are mostly targeted toward undergraduate students. This effect may be mitigated somewhat in master's universities which have a larger graduate student is population.

**Implications/Recommendations for Practice**

The recommendations made here are based on the priority of making these four-year, not-for-profit colleges and universities as economically efficient as possible. To that end, this research showed the level of technical inefficiencies that existed from 2006 to 2011 in the subject institutions. Since SFE is by its nature an estimate, recommendations for *exact* expenditure levels cannot be reliably determined. However, it is reasonable to rely on the SFE model used here to provide guideline parameters, which can aid university decision makers in their strategic fiscal planning. This research can also give decision makers an idea of how they compare to similar institutions in the higher education market place. This research is especially helpful in that regard since it was designed to compare universities in a specific sector of higher education rather than a more expansive and heterogeneous range of institutions. Students and families that have decided to attend private (often religion affiliated), four-year not-for-profits will be comparing them to each other and not with the local or large research oriented public university. Knowing how your institution measures up against the immediate competition is valuable information. Functioning in a more technically efficient manner can help a university succeed in outperforming the competition in what has become a more competitive higher education market place.

Bachelor's colleges and universities should look to increase their graduate school enrollment and the number of graduate degrees they could award. This research has shown that master's level intuitions operate less inefficiently than bachelor's institutions. Though the specific reasons for this will need to be the subject of future studies, it is reasonable to conclude that in addition to improving the economy of scale by increasing enrollment, it takes fewer university resources to provide a graduate degree than an undergraduate one. The data showed that master's institutions spent about $1,000 less per FTE on student support services than bachelor's universities. That is approximately 25% less per FTE while producing more degree-earning students.

The SFE did not consistently show that the student characteristics included as covariates in this research were significant contributors to technical inefficiency. The female percentage of the student body never reached significance, and the ACT and grant aid per FTE were significant less than half of the years examined. But by again examining the student characteristics of the least inefficient quartile, it reinforces the well-established principle in higher education that if you want to produce degreed students, start with those that are best prepared to succeed. Applying the same analysis to the amount of grant aid it appears as though the range of $5,000 to $9,000 per FTE is common among those schools nearest the efficient frontier.

Keep in mind that these recommendations apply only to improving technical efficiency as measured by the number of degreed graduates produced. Technical efficiency is important to any group of institutions striving for optimal production but it may not be the *most* important objective. This may be especially true of this sector of higher education. Private, not-for-profit liberal arts institutions have a long history of striving to achieve lofty goals described in mission statements that make no mention whatsoever about being technically efficient. Producing a certain type of graduate regardless of time and expense has been the history of their practice (Bowen, 1980). Whether or not these institutions can maintain that priority at the expense of sacrificing technical efficiency remains to be seen. It would be irresponsible for decision makers to disregard efficiency research believing that nothing can be gained from it. At the very least, SFE demonstrates that inefficiency improvements by can be made by emulating those institutions closest to the frontier.

**Implications/Recommendations for Theory**

The SFE model used in this research based on a production function assuming exponential or half-normal distribution for the error term and true random effects is a valid model for identifying sources of expenditure inefficiency and for comparing inefficiency level within the private, not-for-profit sector of bachelors and masters universities in the U.S. The conclusions arrived at in this research are in line with what has been found in similar research. A 2006 study of efficiency in Canadian universities (McMillan and Chan) used both DEA and SFE models to rank the efficiency of institutions based on a number of different parameters and obtained consistent results with average inefficiencies of 11.6% and 10.2% Tanja Kirjavainen (2007) performed an analysis of Finnish schools using different model variations of SFE on panel data. The effects of key expenditure categories and student characteristics on matriculation efficiency was analyzed. While the inefficiency scores of institutions were different based upon the model variation being used, the relative rankings of schools was fairly consistent. Averages inefficiencies ranged from 29% to 8%. As was the case with this research, the difference between the most efficient and least efficient schools could be quite large, as much as a 60% difference in efficiency depending upon the model used. While this research did not determine the superiority of one model over the other, it did conclude that the true random effects model, like that used in the research, did allow for time constant effects and time varying inefficiency. The results obtained using SFE here are also not inconsistent with other research using a similar model. Kokklenber et. al. (2008) using an SFE and OLS models on a sample of 753 private colleges and universities in the U.S. for the period 1997 through 2003 reported that private schools can increase their graduation rates by increasing some categories of expenditures and through more selective admissions.

**An Example Institution**

Concordia University Ann Arbor (CUAA) is a small liberal arts university that was struggling to be successful at the turn of this century. Taking a closer look at the output for this institution is useful for verifying the application of SFE to higher education and for pointing out an important point to keep in mind when interpreting SFE output. In the years prior to 2007, CUAA was on the verge of financial ruin. The SFE cross-sectional analysis showed this institution to be operating at 76 percent and 73 percent inefficiency in 2006 and 200, and the panel data analysis revealed even worse inefficiencies of 100 percent and 101 percent inefficiency, respectively (Table 10). Inefficiency was markedly improved in 2008 and in subsequent years. In reading this output, one must keep in mind that the changes put in place by the leadership of an institution which lead to reduced inefficiency were enacted in AY2007. The SFE shows the results of those changes in the following academic year when graduate output is measured. This means that when year-by-year inefficiency is measured using SFE, as it was in this research, any changes in expenditures that produce a change in the level of technical inefficiency will not have revealed itself until the following year. In other words, there is a one year lag time from when expenditure changes are implemented and the resulting effect on production are realized. The improvement in the inefficiency of CUAA continued throughout the length of the panel data. In 2008 administrative operation of CUAA began to be taken over by a sister institution Concordia University Wisconsin (CUW) with an eye to a future merger. CUW is a successful master's institution and based on the SFE performed in this research, operating with a low level of inefficiency of between 10 and 20 percent. While totally independent institutions, both are part of the Luther Church Missouri Synod (LCMS) and function in harmony with LCMS church doctrine. In 2009, CUW took full control of CUAA and in 2011 the merger of the two campuses was officially sanctioned and approved by the Higher Learning Commission (HLC). In 2008 the inefficiency of CUAA dropped to 43 percent and by 2011, the last year included in the panel, its inefficiency was reduced to 24 percent. CUAA is now financially healthy and has more than doubled its enrollment since the merger. So in this specific case, it can be seen that the SFE accurately reflected significant inefficiency changes.

Table 10

*An Example Institution: Concordia University Ann Arbor*

| Cross-sectional Analysis | | Panel Data Analysis | |
|---|---|---|---|
| Year | Inefficiency | Year | Inefficiency |
| 2006 | 76% | 2006 | 100% |
| 2007 | 73% | 2007 | 101% |
| 2008 | 46% | 2008 | 75% |
| 2009 | 26% | 2009 | 3% |
| 2010 | 22% | 2010 | 5% |
| 2011 | 24% | 2011 | 6% |

**Implications/Recommendations for Further Research**

The initial plan for this research was to expand the list of independent variables to include operations and academic support additional expenditure categories. However, at the time this study was written, there were still too many universities that did not report that data to IPEDS. Operations include expenses associated with the university's physical plant and its maintenance. Academic support included any expenditures that supported but instruction, it include things library databases and technological support. These are recently developed categories and historically universities have been slow to comply with new federal requests for information. The expenditure data used in this study for example, was very incomplete prior to 2005. Adding these inputs would likely create an altered inefficiency frontier.

Along those same lines, including other student characteristics as covariates may be insightful. It is well understood that the type of degree a student pursues requires different financial investments by the university. Students pursuing a degree in the fields of science or health require the university to increase resource expenditure for the laboratories and specialized equipment needed for these fields. By comparison, degrees in English or history require very few resources. The percentage of student athletes would be another characteristic worth incorporating in the SFE. The student-athlete can often be different from the rest of the student body with regard to their incoming academic skills and the amount of time they have to devote to pursuing their degree.

When the necessary data becomes available it would be beneficial to perform an analysis to assess allocative and overall economic efficiency. The technical inefficiency assessed in this research captured the extent to which expenditure inputs were efficiently apportioned. These other two measure of efficiency consider how efficient institutions are based on costs. This requires input cost data which is not as yet readily available. Allocative or price efficiency can measure the extent to which inefficiency occurs because an institution is not using the “best” combination of inputs given what they cost to purchase. Once the data for measuring allocative efficiency becomes available, a third measure of efficiency - the overall economic efficiency – could be determined. The overall economic efficiency considers both technical and allocative efficiencies. These additional efficiency measures could be very helpful for both advising decision makers and evaluating the higher education market.

Finally, this research should be applied to other types of higher education institutions such as public, 4-year bachelor’s and master’s schools, large research institutions, and community colleges. The research should seek to compare these very different types of institutions separately since their educational characteristics and expenditures are likely to be very different. As this research has contended, applying SFE to a homogenous group of institutions is much more likely to produce measures of inefficiency which will give a more realistic pictured of on a universities performance.

**Summary**

The SFE inefficiency measure for private, four-year, not-for-profit universities shows that most institutions in this sector of higher education are operating with acceptable levels of inefficiency. Inefficiency may be created by over spending, but determining the right balance of expenditures in key categories is vitally important for reducing inefficiency in producing degree earning students. The SFE is likely a fair estimate for identifying sources of inefficiency in higher education. The best use of a frontier analysis would be for university decision makers to gauge their inefficiency relative to comparable institutions and to itself over time. It is likely not an accurate measure of the absolute inefficiency of an institution. More research needs to be done in order to determine which variables are most appropriate to use for measuring inefficiency and which assumptions of the available SFE models are most suitable for the analysis.

Finally, studies of efficiency are interesting and can be a source of information and possibly guidance for higher education decision makers. At the very least, efficiency research generates thought provoking questions for decision makers to address regarding how limited resources are utilized and how effective they are at producing graduates. It should be remembered, however, that possible answers to these questions are being generated from a statistical exercise in which a line created from data is hypothesized to show optimal efficiency. It is at best an *estimate* of efficiency, and, like any other statistical estimates, are measured with error. Moreover, there is no consensus about the precise value an efficiency score should have in order for the entities under study to be deemed efficient or inefficient.

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