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Using Data Envelopment Analysis to Transform Data Into Information:

Academic Department Efficiency at a Public University

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Abstract

Institutions of higher education amass incredible amounts of data. Analyzing the data in a way that can improve decision making is an integral part of complex operational and management processes, including resource allocation, programmatic development, and planning. Traditionally, higher education has lagged in its use of the data in operational and management processes (Desouza & Smith, 2016; Siemens & Long, 2011). This study examined the use of the analytical method, data envelopment analysis (DEA), to determine the efficiency of academic departments over the period 2008 to 2014. Data envelopment analysis was a method developed by Charnes, Cooper, and Rhodes (1981) and designed to measure the relative efficiency based on inputs and outputs of decision making units (DMUs).

The purpose of this study was to explore the efficiency of academic departments in a public, Carnegie classified tier one, high research, comprehensive doctoral university with balanced arts and sciences undergraduate instruction. The inputs considered for this study were total research expenditures, state appropriated budgets, and operational budgets. The outputs considered were graduate and undergraduate degrees granted, full time equivalents (FTE) produced, student credit hours generated, scholarly works, and amount of grants awarded. An output-oriented, multi-stage DEA model was used to determine the efficiency scores of 16 academic departments or DMUs. Both constant returns to scale (CRS) and variable returns to scale (VRS) methods were used in DEA calculations. The efficiency results, descriptive data, departmental slacks results, and peer department comparisons were considered in determining the factors contributing to

the efficiency and inefficiency of each DMU. Malmquist indices were used to measure the shifts in efficiency over time.

Seven of the 16 academic departments were identified as efficient throughout the time period, 2008 to 2014. The remaining nine academic departments were identified as inefficient in at least one year throughout the period. The factors contributing to efficiency were undergraduate degree completers and operating budgets. Other factors that contributed to inefficiency of departments were scholarly publications, graduate degree completers, and instructional outputs.

The examination of efficiency scores over time and the respective results generated, such as input and output targets and productivity indices, provide a means for assessing departmental efficiency and determining areas for improvement. Results may be one aspect of institutional decision making and planning about academic direction and resource allocation to ensure ongoing academic excellence.

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Chapter 1

Introduction

In higher education institutions, decision making is an integral part of complex operational and management processes, including resource allocation, programmatic development, and planning. The use of data analytics to inform actions involving these same processes has been a significant component of addressing issues and driving decision making in business; however, higher education is somewhat new to this trend (Desouza & Smith, 2016; Siemens & Long, 2011; Picciano, 2012).

Higher education administrators have access to enormous amounts of data on just about every aspect of operations. The challenge is determining how to transform the data into information that is meaningful for the institution (Desouza & Smith, 2016; Siemens & Long, 2011; Picciano, 2012). While the data statistics demonstrate an understanding of and rationale for the planning and decision making processes, as demanded by accrediting bodies, federal and state agencies, and the general public (Ewell & Jones, 2006; Trow, 1996), there are other factors beyond the demand of data for transparency and accountability that have directed higher education administrators to incorporate data analytics into operational and management process decision making and planning.

During the last decade, the resources of many public universities have been strained by increasing numbers of students and reduced or stagnant state support. Furthermore, increased competition for existing resources and decreased research awards available place additional stresses on academic departments trying to meet enrollment demands and sustain research programs (Alexander, 2000; Doyle & Zumeta, 2014;

McKeown, 1996). Increased efficiency in both teaching and research activities, while making available funds go as far as possible are of critical importance in terms of resource allocation, departmental development and improvement, and institutional accountability.

The allocation of university resources to academic departments is a fundamental role of university administrators. Conventional means of allocating university resources are by using indicators, such as students served by the department, instruction requirements, and research activity (Alexander, 2000; McKeown, 1996). There is also a propensity to maintain similar levels of allocations from one year to the next. Typically, the overall efficiency in the use of those resources has not been a consideration when allocating resources.

A resource distribution model that includes efficiency, takes into consideration quantitative inputs and outputs such as operating budgets, research award amounts, instructional hours, degree completers, and scholarly works, to identify relative optimal targets of those indicators. An appropriate analysis of these data has the potential to incentivize academic departments to reduce costs while increasing positive outcomes, identifying inefficiencies, eliminating wasteful spending, increasing creative instruction and effective research, all the while in tandem with and defined by the institutional and departmental mission and objectives (Massy, 1996). The use of a data analysis model introduces an objective feature to what could be regarded as a political and self-serving process.

Data and data analysis can also provide information for the departmental review process. Departmental efficiency analysis can be used to inform departments and institutions about the size, stability, and vitality of a program, student demand, adequacy of resources, and contributions to the university mission (Barak & Mets, 1995). The goal of the departmental review process is for faculty and administrators to engage in serious periodic self-evaluation, assess program quality and effectiveness, review strategies for development and improvement, and plan for the future (Barak & Mets, 1995). The examination of efficiency scores over time and the respective results generated, such as input and output targets and productivity indices, provide a means for assessing departmental efficiency and determining areas for improvement. Results could be one aspect of institutional decision making and planning about academic direction and resource allocation to ensure ongoing academic excellence.

Background: Data Envelopment Analysis

Efficiency is determined by comparing a measure of how well inputs are used to achieve outputs (Farrell, 1957). Data envelopment analysis (DEA) is a method for evaluating efficiency. The DEA model gives a single measure with respect to multiple inputs and multiple outputs of an organizational unit referred to as a decision making unit (DMU) (Charnes, Cooper, & Rhodes, 1978). Since the development of the DEA model, both public and private agencies have used it for evaluating and improving efficiency (Gattoufi, Oral, & Reisman, 2004). Data envelopment analysis has been used to assess operations of hospitals, airports, police departments, businesses, and public and private education.

There are several types of economic efficiency, including technical and allocative. The DEA model solves for technical efficiency. To achieve technical efficiency, firms structure their output to achieve the lowest possible cost per unit produced (Porcelli, 2009). A measure of technical efficiency shows how much output can be obtained from a given set of inputs. The information obtained from technical efficiency examination pertains to whether or not resources are used efficiently (Porcelli, 2009).

Foundational studies using DEA in higher education have investigated the technical efficiency of education systems contributing to efficiency in teaching and research. However, the systematic focus of these studies vary. One focus is the compared efficiencies of universities (e.g., Abbott & Doucouliagos, 2003; Ahn Charnes, & Cooper, 1988; Ahn, Arnold, Charnes, & Cooper, 1989; Athanassopoulos & Shale, 1997; Avkiran, 2001; Breu & Raab, 1994; Chu Ng & Li, 2000; Facanha, Resende, &, Marinho, 1997; Johnes, G., 1999; Johnes, J., 2006; Lehmann & Warning, 2002; McMillan & Datta, 1998; Rhodes & Southwick, 1993; Thursby & Kemp, 2002; Warning, 2004). An illustration of this focus is Katharaki and Katharakis (2010) efficiency study of 20 public universities in Greece. A second focus is efficiency comparisons of one academic discipline among several universities (e.g., Arcelus & Coleman, 1997; Beasley, 1990, 1995; Colbert, Levary, & Shaner, 2000; Førsund & Kalhagen, 1999; Johnes, 1999; Johnes & Johnes, 1993, 1995; Oleson & Petersen, 1995; Sarrico & Dyson, 2000; Tompkins & Green, 1988; Thursby, 2000). For example, Colbert and coworkers (2000) investigated the efficiency of 24 top ranked Master of Business Administration programs in the United States. A third focus is the evaluation of the efficiency in the academic departments in one university (e.g., Madden, Savage, & Kemp, 1997; Moreno & Tadepalli, 2002; Sellers-Rubio, Mas-Ruiz, & Casado-Diaz, 2010; Sinuany-Stern, Mehrez, & Barboy; 1994).

Purpose of the Study

The purpose of this study was to use the DEA model to transform institutional data to a point that it could become useful in academic department, college, and university decision making processes. In other words, the purpose of the study was to obtain DEA results to explore what the data tells us about the efficiency of academic departments under study.

To accomplish the purpose of this study, two objectives were established. The first objective was to determine the efficiency of selected academic departments at a university over a period of time, from 2008 to 2014. The time period, 2008 to 2014, is interesting because it encompasses the recession beginning December 2008 and ending by October of 2009 (Zumeta, 2010), the subsequent impact of the recession on the state budget for higher education, and the recovery period. The input factors were research expenditures, state appropriated budgets, and operational budgets. The output factors were graduate and undergraduate degree completers, full-time equivalent (FTE) produced, student credit hours generated, number of scholarly works, and the dollar amount of grants awarded. The second objective was to identify the inputs and outputs having the most influence on efficiency.

The following research questions guided the study:

1. What are the relative efficiencies of academic departments?
2. What are the relative inefficiencies in academic departments?
3. What factors contribute to academic department efficiencies?
4. What factors contribute to academic department inefficiencies?

5. What are the trends of academic department efficiency over time?

Theoretical Framework

The overarching framework for this study was based in an economic approach and application to an efficiency study of academic departments at a university. A rational systems perspective was the lens used for this study. This approach assumes organizations as machines that "can or should be rational systems that operate in as efficient a manner as possible" (Morgan, 1997, p. 21).

The approach is economic in nature because it focuses on values, capital, productivity, demand, and financial resources, similar to the economic theory of the firm (Hopkins & Massy, 1981). As applied to higher education, the theory suggests that universities exhibit optimizing behavior; whereby, the university "maximizes a multicriterion value function subject to production, demand-and-supply, and financial contraints" (Hopkins & Massy, 1981, p. 73). Within this framework, decisions about inputs and outputs are based on "subjectively determined utility" maximization (Massy, 1996, p. 67) as defined by the university and departmental officials according to the mission and objectives of the institution.

Efficiency, as understood in this study, is based in a rational approach that is characteristic of the neoclassical economic theory of the firm, whereby the firm makes decisions about inputs and outputs based on objective profit maximization (Coase, 1937). In contrast, there are other management and decision making approaches that are not necessarily based in rationality. Although multiple models of decision making exist, the rational decision making model was especially useful for this study of efficiency among academic departments. The use of data is the foundation of the rational decision making model. The variables examined in this study were objective measures that can be used in decision making processes and planning (Weerts, 2002).

The rational approach allows for decision making that is informed, transparent, based in fact, and reduces the risk of biased, inconsistent judgements. The approach is based on a scientific method of defining a problem, identifying the criteria and measurement, determining and considering solutions, and setting benchmarks for optimal outcomes (March, 1994; Simon, 1959, 1979). The utilization of data analytics may increase the chances that a higher education institution will meet goals and do so in the most efficient manner (Desouza & Smith, 2016).

The objectively straightforward characteristics of the rational approach and decision making model combine to make an analysis of academic department efficiency feasible. The assumptions considered for this study were that the data and results presented were representative of the environment in which decision makers existed, and processes performed. For the purposes of this study, the DEA model and results were considered to be an objective, rational approach for the examination of academic department efficiency. The DEA model takes in to account both inputs and outputs of an academic department.

Limitations

The following limitations were considered in the implementation of this study:

1. This study focused only on academic departments at a single university.
2. The DEA is deterministic in nature. This limitation of the DEA model makes it sensitive to outlying observations.

3. The financial, instructional, and human resources information was limited to data as submitted to the State Appropriated Budgets report published by the University Office of Planning, Budget, and Analysis and the annual reports prepared by the University Office of Sponsored Projects and Office of the Provost.
4. This study examined data collected over the period of 2008 to 2014 and presents a snapshot of data dependent on conditions occurring during that time.

Delimitations

The following delimitations were considered in the implementation of this study:

1. Due to the large number of potential academic departments and programs offered at the institution, this study focused only on academic departments offering bachelors, masters, and doctorate degrees, and were under the supervision of a college within the university. Sixteen academic departments were identified that fit the criteria.
2. The University mission features three core themes: learning, discovery, and engagement. Two of these core themes, learning and discovery, were used as a basis for the data collected and examined. This study focused only on data and statistics that served to describe the teaching and research activities at the university.
3. The objectives of this study were limited to quantitative analysis of efficiency and application of a rational theory approach to evaluation of the results; effectiveness of the department was not considered.

Assumptions

The following assumptions were considered in the implementation of this study:

1. The foundational role of higher education institutions is teaching and scholarship as defined by the State Constitution and encouraged by the legislature, “by all suitable means the promotion of intellectual, literary, scientific, mining, mechanical, agricultural, and moral improvements." (Nv. Const. of 1864, Art. XI, § 1, amended 1956).
2. It was assumed that the data obtained from university reports over the period, 2008 to 2014, was collected consistently and accurately, using similar definitions and methods of data measurements for each academic department considered in this study.

Definitions

Allocative efficiency: the distribution of resources among units (Hoxby, 1996; Lankford, 1985).

Amount of grants awarded: the amount, in dollars, of award for sponsored projects as assigned to a unit.

Constant returns to scale (CRS): a process where the outputs increase proportionally to an increase in inputs (Ramanathan, 2003).

Data Envelopment Analysis (DEA): a method of measuring efficiency that uses optimal efficiency scores to plot a boundary which envelopes the data set (Charnes et al., 1978). For this study, the linear programming measures were solved by using the DEAP Version 2.1 Computer Program, by Coelli (1996).

Decision making units (DMU): the subject of observation in examining the efficiency (Ramanathan, 2003). For this study, each decision making unit was an academic department.

Efficiency: the relation of production of outputs from given inputs (Farrell, 1957).

Faculty salaries: account of the budget appropriation for faculty salaries per unit.

Frontier: the boundary that defines the optimal measurement of outputs given the level of fixed inputs (Charnes et al., 1978).

FTE produced: full time equivalents (FTE), the average number of student credit hours (SCH) taught in undergraduate courses each semester, divided by 15 units per full time undergraduate and the average number of SCH taught in graduate level classes each semester, divided by 9 units per full time graduate student.

Graduate majors: account of the number of graduate students per unit.

Input: an amount or measurement of contribution to a process or production (Cook, Tone, & Zhu, 2014).

Output: an amount or measurement of a product of a process or production (Cook et al., 2014).

Pareto Efficiency: an economic state whereby there is no way to make an improvement in one area without causing a negative impact in another area (Baker, Green, & Richards, 2008).

Productive efficiency: the production of goods and services using minimal costs and effort (Farrell, 1957).

Relative efficiency: the observed performances of units evaluated using the same inputs and outputs (Ramanathan, 2003).

Returns to scale: the rate of output change when inputs are changed by the same factor (Ramanathan, 2003).

Operational budget: account of the budget appropriation for operations per unit.

Research Expenditures: account of funds spent on goods and services as specified in awarded sponsored projects.

Slack: the augmentation needed for an inefficient decision making unit to become efficient (Ramanathan, 2003).

Staff salaries: account of the budget appropriations for the staff salaries per unit.

Student credit hours (SCH) generated: account of the unit value of the course multiplied by the number of students enrolled.

Technical efficiency: the ratio of maximum output with a given input (Porcelli, 2009).

Tobit model: also known as a censored regression model, is designed to estimate linear relationships between variables. The Tobit model is a way to evaluate the determinants of efficiency (Kounetas, Anastasiou, Mitropoulos, & Mitropoulos, 2011).

Undergraduate majors: account of the number of students declared in a major area of study.

Variable returns to scale: a process where the outputs do not change proportionally to an increase in inputs (Ramanathan, 2003).

Summary

Higher education institutions capture data on almost every aspect of their operations. The data have potential to become an integral part of operational and management decision making processes. Transforming data into information that is meaningful to the institutions can guide decision making and improve operational and management processes such as resource allocations and departmental reviews. A study was conducted to determine the use of the DEA model as a tool to transform input and output data for the purposes of determining academic department efficiency.

This study is organized into five chapters. This first chapter provides an introduction to the efficiency studies in higher education. An overview of the research is described in this chapter, followed by an explanation of the theoretical lens used as the framework for this study. Finally, the limitations, delimitations and assumptions of the study are presented.

The following chapter encompasses the review of literature addressing the history of performance and efficiency evaluation of institutions of higher education. The chapter provides background and context regarding the purpose of higher education. This chapter establishes that higher education is accountable to multiple audiences, internal and external to institutions. The accountability aspect is the catalyst used for the introduction of efficiency measures in higher education. Three methods used to evaluate the relationship among inputs and outputs are discussed in terms of their utility in analyzing efficiency of higher education institutions and programs: the production function; Stochastic Frontier Analysis; and, Data Envelopment Analysis. The literature review concludes with an overview of higher education efficiency studies.

The third chapter describes the research design and methodology. The chapter begins with the research questions and study design, given the literature and theory found in the preceding chapters. The sources and collection of data are then outlined, along with the data analysis method.

The fourth chapter presents the efficiency scores of the departments. The descriptive statistics along with the efficiency measures and targets for each department are reviewed. The DEA assignment of inefficient departments to efficient peers are presented and Malmquist index results are reviewed.

In the final chapter, the results are interpreted in order to understand and explain significant findings and implications of the study. The chapter concludes with a summary of the study, a discussion on the findings, conclusions, and suggestions for future research.

Chapter 2

Literature Review

This chapter presents a review of the literature supporting the implementation of efficiency studies in higher education. The organization of this review has three parts. The review begins with a survey of the history of the relationship between higher education and the public sector. The next section examines public finance of higher education and the movement for accountability and transparency. The last section reviews the use of efficiency calculations and studies in higher education in the United States.

Higher Education and the Public Sector

The role of institutions of higher education in society is multidimensional. Traditional roles of higher education consisted of teaching and scholarship. Currently, teaching and scholarship are viewed as instruments for economic growth. In addition to providing educational opportunities for individuals seeking knowledge and endorsement, higher education institutions produce an educated work force (Duderstadt, 2008). In working towards meeting the complementary goals of economic growth and an educated workforce, higher education also prepares students to be active and educated members of society.

At the foundation of the relationship between society and higher education is an implied social contract whereby society subsidizes higher education in order to reduce the costs to the students (Mensah & Werner, 2003). Initially, higher education had limited support from the governing body; rather, support was provided by the denominational organizations, private benefactors, and student tuition (Rudolf, 1962, Brubacher & Rudy, 1997). A relationship between public support and higher education was clearly established through passage of the Morrill Land-Grant Act in 1862 (Rudolf, 1962).

The Morrill Land-Grant Act allowed for the sale of public land to fund the establishment of an institution of higher education (IHE) in that state (Rudolf, 1962). The Morrill Act opened the door of higher education opportunities for farmers and laborers. An implication of the Morrill Act was the emphasis on the state control of higher education, rather than control at a federal level. Shortly thereafter, in 1890, the Second Morrill Act was implemented, which provided annual federal aid to the land grant institutions, with the stipulation of open access regardless of race (Rudolf, 1962). The implications of the relationship between higher education and public governance run deep and hold strong to the ideal that every citizen is able to pursue higher education.

The close of World War II, in the mid-1940s, prompted the next major connection between higher education and public support. The Servicemen's Readjustment Act of 1944, also known as the GI Bill, provided educational assistance for returning veterans. Students received the aid directly, therefore bypassing potential federal and state management and manipulation of higher education. The result of allowing students to use federal aid at public and private institutions was an immense expansion of state IHEs and moderate private IHE growth (Zumeta, 2001).

The enactment of the Higher Education Act of 1965 (HEA) was key in the guarantee of federal and state governments involvement in higher education. The HEA stipulated the support of the federal government in the construction and maintenance of facilities, community service and continuing education programs, library assistance, teacher programs, faculty development, and student financial assistance (United States Office of Education, 1966). Title IV of the HEA provided for grants and long-term, low-interest loans to students enrolled in an IHE. In return, participating public and private institutions were subject to federal conditions for receipt of the funds, such as documentation to demonstrate that the funds would be used appropriately (Zumeta, 2001). In addition, the 1972 Higher Education Act amendments established the State Student Incentive Grant (SIGG) program, whereby states created student aid programs available to public and private IHE students (Zumeta, 2001).

The Morrill Acts, GI Bill, and HEA stimulated federal and state involvement in higher education. The substantial federal and state appropriations to higher education in the areas of facilities support, graduate-level and research education programs, and student financial aid increased access and enrollment. In turn, the appropriations of public funds to higher education prompted mandates for accountability and transparency in the use of public funding in higher education.

Higher Education Accountability

Accountability is the requirement and responsibility of reporting outcomes and consequences (Trow, 1996). The focus on accountability of higher education began in the 1960s and 1970s during the expansion era instigated by the increased public funding of higher education through the HEA (Ewell & Jones, 2006). The federal and state support of higher education resulted in the need to ensure three areas of accountability were addressed. First, public funds were used efficiently and appropriately; second, all people had access and the opportunity to benefit from further education; and finally, the returns to society (Ewell & Jones, 2006; Trow, 1996).

Even prior to the 1960s, higher education was held accountable through the practice of accreditation**.** Accreditation was a tradition founded and continued from pre-colonial times (Brubacher & Rudy, 1997). The accreditation process carried out by accrediting agencies ensures institutions meet a standard level of instructional quality and requirements. In 1952, the Veterans Readjustment Act gave the commissioner of the Office of Education the duty to publish a list of recognized accrediting agencies (United States Office of Education, 1966). The HEA also mandates that IHEs give all students and prospective students information about the academic program and standards that must be met, as well as accreditation information.

Early forms of accountability in higher education consisted of data collection on enrollment, earned degrees conferred, and faculty characteristics (Report of the Commissioner of Education, 1874). A federal Office of Education was established in 1867 to collect institutional data and disseminate the information to the public (An Act to establish a Department of Education, 1867). Later, higher education general information surveys were conducted and included the aforementioned data, along with finance data, faculty salaries, student charges, residence and migration, financial aid data, and specific program enrollments. In 1974 the National Center for Education Statistics was established to manage the data collection and analysis (Education Amendments of 1974, 1974).

The substance of accountability in higher education has changed over the years. Initial reporting included data on institutional access and efficiency. In the last ten years there has been a shift in reporting to incorporate evidence of student learning outcomes and measures of related economic benefit in the state (Ewell & Jones, 2006).

The current method for obtaining and publishing data on higher education institutions is through the Integrated Postsecondary Education Data System (IPEDS). An amendment of the HEA in 1992 mandated that all institutions accepting student financial aid "complete surveys conducted as part of the Integrated Postsecondary Education Data System (IPEDS) or any other Federal postsecondary institution data collection effort, as designated by the Secretary, in a timely manner and to the satisfaction of the Secretary" (Higher Education Amendments of 1992, 1992, p. 626).

Trow (1996) recognized two major components of accountability in higher education. One area involves a broad view of external and internal accountability. The external and internal accountability denotes the measures demonstrating institutional accountability to society and to those within the institution. The second area entails the distinction between legal, financial, and academic accountability, which includes accounting of resource use and distribution, as well as the outcomes of resource use. Optimal accountability is realized when institutional resources, actions, and outcomes are open to all for review (Ewell & Jones, 2006).

The relationship between accountability and funding of higher education has become evident in recent years (Aldeman & Carey, 2009; Rabovsky, 2012). Public funding of higher education has decreased over 15% in the last five years; with the increased enrollment of 10%, institutions of higher education have increased reliance on tuition and fees by 38% (State Higher Education Executive Officers, 2014). With the reduction in public funding of higher education, the competition for the available public funds has become intense (Doyle & Zumata, 2014). Higher education is one of many efforts seeking support from a limited amount of public funds (Weerts & Ronca, 2012). The culmination of increased tuition rates along with graduation rates of less than 60% (Bowen, Chingos, & McPherson, 2009) has fueled demand for more accountability of IHEs.

Measuring Educational Efficiency

Simply stated, efficiency is determined by comparing a measure of how well inputs are used to achieve outputs (Farrell, 1957). The catalyst that instigated interest in analyzing educational inputs in determining outputs was the study, *Equality of Educational Opportunity*, also known as the Coleman Report (Coleman, Campbell, Hobson, McPartland, Mood, Weinfeld, & York, 1966), released in 1966. The report presented an analysis of the relationship between school, student and community characteristics, and student achievement. The report directed attention to the potential of using input-output statistical analysis in the evaluation of education operations and management (Hanushek, 1979).

Since the release of the Coleman Report, several models using input-output analysis have been developed to estimate efficient educational production. Input-output models used in addressing educational efficiency and production research include production function, stochastic frontier analysis (SFA), and data envelopment analysis (DEA).

Production function. Production is considered the transformation of inputs into outputs (Worthington, 2001). An input is a resource that an organization uses in its production process for the purpose of creating a good or service. A production function describes the maximum output that an organization can produce for every specified combination of inputs, while holding technology constant at some predetermined state (Massy, 1996). An example of the utility of production functions is the ability to predict how much the mean achievement on a standardized exam may vary with an increase in student contact hours. The goal in using production functions is to derive a model that describes the relationship between inputs and outputs (Hedges, Laine, & Greenwald, 1994).

Mathematically represented, the production function is: $Y = f(X)$, where X equals an input, or some vector of inputs and Y equals the maximum output that can be obtained. Similarly, a production function applied to education is represented mathematically as $Y_{IJ} = a + b_1 H_{ij} + b_2 S_j + u_{ij}$, where Y_{IJ} is the known output of student, i, at school, j; H_{ij} and S_j represent the known independent variables of home or external environmental inputs and school inputs, respectively; a, b_1, and b_2 represent coefficients which are calculated, along with the error term, u_{ij}. Although this equation is an extremely simplified version of a production function, it does demonstrate the relationship between educational inputs and outputs (Hopkins & Massy, 1981).

There are several treatments that may be applied to the production function to evaluate different aspects of production; for example, single value-added model, randomized control trial model or regression discontinuity model, difference-in-difference model, fixed effects approach, and Cobb-Douglas model. The simple production function focuses on the relationship between inputs and outputs. A single value-added model evaluates, for example, the influence of the inputs on the improvement, or value added over time, of students from one benchmark to another. The randomized control trial or regression discontinuity model determines the influence of a treatment on an output, such as determining the value-added by the use of a new textbook in a course versus no change in the course textbook. The difference-in-difference model is similar to the randomized control trial, except instead of evaluating a difference in the treated versus non-treated students, the model determines the variance of the treated students versus the variance of the non-treated students. The fixed-effects model controls for differences in students and allows the focus of the analysis to be on the impact of the treatment over a period of time. The Cobb-Douglas model is used to account for a returns to scale application of the inputs (Chambers, 1988; Hopkins & Massy, 1981).

A majority of studies applying the production function methods to describe education production use regression analysis to estimate the relationship between inputs and outputs (Greenwald, Hedges, & Laine, 1996). The basic approach consists of identifying inputs and outputs, processing the function to determine coefficients, and then applying statistical operations on the coefficients. Based on the research questions, statistical operations include descriptive statistics analysis, hypothesis testing, regression analysis, significance testing, and correlational analysis (Chambers, 1988; Greenwald, Hedges, & Laine, 1996). The relationship between inputs and outputs may also be compared as economies of scale or economies of scope in the education production function (Cohn, Rhine, & Santos, 1989; De Groot, McMahon, & Volkwein, 1991; Dundar & Lewis, 1995; Brinkman, 1981; Koshal & Koshal, 1999).

The foundational assumption of production functions is that a relationship between inputs and outputs can be described via mathematical and statistical operations. Other assumptions of production functions include relativity to a period of time, no change in technology, and maximum output is achieved (Chambers, 1988). Production functions application in determining relationships between educational inputs and outputs is not ideal. The educational system is complex, involving multiple processes and programs of production, tangible and intangible variables; it is not clear that educational systems strive to achieve maximum levels of output for a given set of inputs. The inability to accurately estimate coefficients, a lack of understanding about educational technologies, and the difficulty in measuring intangible variables leads to many subjective and different conclusions about the data (Hopkins & Massy, 1981). Regardless of the variability and partiality of the conclusions, production functions have been used to describe the impact of school characteristics on educational achievement.

Key components of production functions are the inputs and the outputs. Higher education is concerned with three major outputs: instruction, research, and service. Common output measures include test scores, degree completions, attendance, the year of education, and research publications. Typical inputs include expenditures per student, student faculty ratios, faculty salaries, class size, and faculty full time equivalent (FTE). The problem exists of separating the inputs according to a category from the output when there is a joint product. For example, a student helping out in a research laboratory is being educated, an output, but also adding to the research input component (Hopkins & Massy, 1981). Hopkins (1990) also has identified a set of tangible and nontangible inputs and outputs of higher education that are not easily characterized in terms of a production function. The tangible inputs and outputs consist of student years, enrollments, library acquisitions, faculty and staff FTE, buildings and equipment, tuition rates, indirect costs, and salaries. The intangible inputs and outputs consider the quality aspect of education, for example, the quality of education obtained, research performed, effort put forth by students, faculty and staff, and the quality of the educational environment (Hopkins, 1990).

The application of production functions to educational systems has been studied for decades (Coleman et al., 1966; Hanushek, 1996). A review of the literature and meta-analysis of the use of production functions in education found in Hanushek (1981, 1986, 1989, 1991) and Hedges, Greenwald, and Laine (1994, 1996) are conflicting. Studies that use production functions to describe the impacts of educational inputs on outputs vary greatly in the categorization of inputs and outputs, production function treatment, and analysis of coefficients. Hanushek's (1986) article, The Economics of Schooling: Production and Efficiency in Public Schools, reviewed 147 regressions from 33 separate studies and compared significance levels of the estimated school input effects on achievement. Hanushek found no compelling evidence of a relationship between school expenditures and student performance. In contrast, Hedges, Greenwald, and Laine (1994, 1996) reviewed the same studies as Hanushek and concluded that there was a relationship between school expenditures and student performance.

There are many ways to characterize the mathematical relationship of inputs and outputs. The cost function, similar to the production function, estimates the relationship between input prices and outputs and is a widely used tool for studying the cost structure of higher education (De Groot, McMahon, & Volkwein, 1991; Robst, 2001). Although the operations of the functions are similar, there is a difference between production functions and cost functions data inputs. Cost functions require data on input prices. In contrast, production functions may involve data for input variables that are not easily defined and more subjective to the study. In cases where the production function is difficult to model, the cost function may be a complementary route for modeling production phenomenon (Robst, 2001).

Many higher education studies have investigated the impact instruction has had on educational outcomes, considering simple unit-cost ratios such as cost of instruction to student credit hours (Wallhaus, 1975; Oliver, Hopkins, & Radner, 1976). A study by Breneman (1976) examined the departmental doctoral production process as impacted by student matriculation, length of time to degree, and time to drop out. Two similar studies used measures of Graduate Record Examination (GRE) scores and institutional cost inputs to determine if there was a relationship between test scores and institutional quality; however, researchers were not able to derive an adequate production function to test the relationship (Astin, 1968; Manahan, 1983). Besides instruction, a focus of production function studies has been on the relationship between student achievement and time invested in education (Becker, 1983; Polachek, Kniesner, & Harwood, 1978). More recent studies have investigated interactions between instruction and research inputs and outcomes (Hasbrouk, 1997; Gander, 1995).

Overall, the findings of research using production functions to describe the relationship between educational inputs and outputs are mixed. The variation is associated with the multiple ways a production function can be applied to a set of inputs and outputs that may or may not be well-defined. Also, the field of education does not necessarily fit the production function assumptions. As such, there are other methods researchers can use to determine the relationship between educational inputs and outputs.

Stochastic Frontier Analysis. Stochastic Frontier Analysis (SFA) is a parametric technique that uses standard regression production function and deterministic production frontiers to determine production efficiency. Much of the work on SFA began in the 1970s and was first proposed by Aigner, Schmidt, and Lovell (1977) and Meeusen and Van den Broeck (1977). Early applications of SFA to education studies sought to evaluate cost function and efficiency (Johnes, 1996). Izadi, Johnes, Oskrochi, and Crouchley (2002) applied SFA to analyze inefficiencies in higher education in Great Britain where they concluded that inefficiencies in higher education were fairly modest and in the margin of statistical significance. Barbetta and Turati (2003) used SFA to evaluate the efficiency of junior high schools in Italy and determined efficiency differences for not-for-profit, for-profit, and public schools. Ruggiero and Vitaliano (1999) used SFA techniques at a more aggregate level to examine the efficiency of New York school districts.

Similar to the production function, SFA uses mathematical operations to determine the relationship between inputs and outputs. In addition to production function similarities, features of SFA include an alternative treatment of the error term and the application of a frontier estimator that is inclusive of the error. The SFA approach uses the production function methodology and considers an error term composed of statistical noise and inefficiency. The error term includes all events outside the control of the study, such as differences in organization operating environments, measurement errors, and or misspecification or bias in the functional form used. The SFA takes into account these external factors when estimating the efficiency of organizations. A simplified version of the stochastic frontier model consists of three components: the deterministic production function, the symmetric error, and the asymmetric error term representing inefficiency. Simply, the SFA model is represented as $y_i = f(x_i; \beta)\ exp\ (v_i)\ exp\ (-u_i)$, where y_i is the output vector of unit *i*, x_i is the input vector of unit *i*, β is the vector of technology parameters, $exp\ (v_i)$ is the statistical noise, and $exp\ (-u_i)$ is the inefficiency component (Coelli, 1996; Kumbhakar & Lovell, 2003).

The SFA frontier estimators are similar to traditional parametric regressions. The difference between traditional regressions and frontier estimators is due to the inclusion of the error term. The objective of a typical regression analysis, such as ordinary least squares, is to fit a line through the data that minimizes the sum of the squared deviations from the line. The objective of a frontier is to estimate a line that corresponds to the distance between the average and the estimate of the theoretical ideal (Porcelli, 2009).

In using SFA, the level of maximum output for any given set of inputs is calculated as the production frontier. The performance measure or technical efficiency is a function of the distance between a unit's actual output level and the production frontier. The unit that is producing less than the maximum for their level of inputs is considered less efficient and falls below the production frontier. The best performing units in the data set have an output level directly on the production frontier, as estimated by the model. In SFA, the error term relates to the distance from the production frontier to the unit's actual outcome measure (Kumbhakar & Lovell, 2003).

The primary advantage of using SFA in explaining the relationship between inputs and outputs is the inclusion of a term representing noise, measurement error, and factors beyond the control of the production unit. The deviation from the production frontier can be explained by these components of inefficiency and noise. Assumptions of the model involve the distribution of the noise and inefficiency error term. For example, homoscedasticity of the noise, meaning the noise or unexplained variance of the sample is similar over the units and the inefficiency, is assumed to be identically and independently distributed random variables. The disadvantage of SFA is the significant structure imposed upon the data from the firm parametric form and distributional assumptions (Porcelli, 2009).

In summary, the SFA approach for measuring production efficiency attempts to distinguish between the effects of noise and the effects of inefficiency. The SFA is parametric and as a result is not immune to functional form misspecification. The model provides a means of comparing individual units to an ideal production frontier and also provides estimates of uncontrolled variable effects on the efficiency of units.

Data Envelopment Analysis. Data Envelopment Analysis is a method for evaluating efficiency (Farrell, 1957). The DEA gives a single measure with respect to multiple inputs and multiple outputs of an organizational unit referred to as a decision-making unit (DMU) (Charnes et al., 1978). The use of DEA models in early analysis of public education investigated the effectiveness and management of an educational program (Bessent, Bessent, Charnes, Cooper, & Thorogood, 1983; Charnes et al., 1981). The DEA model has since been extended and applied to a wide variety of educational systems, institutions, and programs in many different contexts.

The DEA model is a non-parametric approach for the estimation of efficiency and depends on linear mathematical programming to describe a set of DMUs to determine estimates of efficiency. The analysis starts with determining measures of production functions and then systematically ranking DMUs. The best performing DMUs are used to construct the frontier. The estimates of efficiency for inefficient DMUs are based on how far the inefficient DMUs deviate from the most efficient DMUs (Charnes et al., 1978). The DEA is also non-stochastic and deterministic in that all deviations from the production frontier are due to inefficiency and treated as if there is no noise or measurement error.

The fundamental conceptual DEA model compares the measured outputs of a DMU relative to the inputs. The values of the inputs and outputs are identified and weighted so each unit is compared to all of the other units and controlled to be no larger than the best input/output ratio. The weights are calculated to give the largest possible ratio value for the DMU within the control limitation. The motive for the weight conditions is to determine an objective measure of efficiency based on optimal relations rather than the means (Bessent & Bessent, 1980). The objective of DEA is to obtain efficiency measures based on the combined inputs and outputs of DMUs and for each DMU *j*, the objective is to:

(1) Determine weights to maximize the efficiency of DMU *j*:

Maximize $h_j = (\sum_{r=1}^{s} u_{rj}\, y_{rj} / \sum_{i=1}^{m} v_{ij} x_{ij})$

(2) Maximized h_j, subject to the best DMU input/output ratio:

$(\sum_{r=1}^{s} u_{r}\, y_{rj} / \sum_{i=1}^{m} v_{i} x_{ij}) \leq 1$ for $j = 1, \ldots, n$ and $u_r, v_i, y_{rj}, x_{ij} > 0$

Where there are *s* inputs x_i ($i = 1, \ldots, s$) and *m* outputs y_r ($r = 1, \ldots, m$),

y_{rj} is the measurement of *r*th valued output for DMU *j*,

x_{ij} is the measurement of *i*th input for DMU *j*,

u_r is the weight for output *r* to be calculated from the analysis, and

v_i is the weight for input *i* to be calculated from the analysis (Bessent & Bessent, 1980).

Bessent and Bessent (1980) explained that the value, h_j, increases as the weighted set of outputs increases relative to the weighted set of inputs. Solutions are sought to maximize the ratio of weighted output to weighted input for each DMU. The same weights that maximize h_j for DMU_j are applied to the inputs and outputs of all DMUs. This process is repeated for each DMU in the set and ultimately the weights determined are the most favorable to each DMU. The efficiency scores calculated for each DMU reflects these optimal weights (Bessent & Bessent, 1980).

The conceptual representations (1) and (2) are not linear and thus cannot be solved by linear optimization methods. Charnes, Cooper, and Rhodes (1978) demonstrated that this non-linear problem can be changed to linearity by algebraic manipulation. This modification allows the DEA to be solved using linear methods. A linear version of DEA is:

(3) Determine weight to maximize the efficiency of DMU j:

Maximize $h_j = (\sum_{r=1}^{s} u_{rj}\, y_{rj} - \sum_{i=1}^{m} v_{ij} x_{ij})$

(4) Maximized h_j, subject to the best DMU input/output ratio

$- \sum_{i=1}^{m} v_i x_{ij} \leq -1$, $(\sum_{r=1}^{s} u_r\, y_{rj} - \sum_{i=1}^{m} v_i x_{ij}) \leq 0$ for $j = 1, .., n$ and u_r, v_i, y_{rj}, $x_{ij} > 0$ (Bessent & Bessent, 1980).

The linear programming model is solved for each DMU and a measure of efficiency is obtained for all units. The units with the best combination of inputs and outputs have an efficiency of 100%.

There are some details to consider before using DEA to estimate efficiencies of DMUs. The DMUs should use the same set of inputs in producing the same set of outputs. Ideally, all important inputs are used and outputs are produced by all DMUs.

However, sometimes this is not the case and in DEA there are relatively simple methods by which allowable weights can be limited to account for input and output differences. Another detail to consider is that for a measure to be an appropriate input it should be something that, all else being equal, the DMUs strive to minimize. Additionally, each input and output should measure something that is distinct from all of the other inputs and outputs or confounding effects may make the interpretation of results very difficult (Dyson, Allen, Camanho, Podinovski, Sarrico, & Shale, 2001).

In order to determine the DEA model to use in a study, it is necessary to consider the sources of variation in the model. The approach, input oriented or output oriented, must be determined. An input approach seeks to minimize the inputs keeping the outputs fixed, whereas, an output approach seeks to maximize the outputs keeping the inputs fixed (Porecelli, 2009). The DEA model may include terms and conditions that account for constant return to scale (CRS) (Charnes et al., 1978) or variable returns to scale (VRS) (Banker, Charnes, & Cooper, 1984). Once the data for the DEA are collected, it should be determined whether the data exhibits constant or variable returns to scale. If a process exhibits constant returns to scale, then doubling all inputs should allow all outputs to be doubled. If a process exhibits constant returns to scale, then multiplying all inputs by any positive number should impact all outputs linearly based on that number. If on the other hand a process exhibits variable returns to scale then this relationship is not necessarily linear (Banker et al., 1984). The VRS model is essentially the CRS with an additional convexity constraint added to the linear programming conditions.

The most basic DEA case is of a single input and singe output model. Figure 1 is a graphical representation of the performance of the various DMUs where the horizontal axis is input units and the vertical axis is output units. The segmented line that passes through DMUs A, B, C, D, and E represents the efficient frontier inferred by the data. This means that any data points between the frontier and the origin, such as DMUs F, G, and H are inefficient. Any data point that falls on the efficient frontier between DMU A and DMU D is relatively efficient and Pareto optimal. Any data point that falls on the vertical or horizontal sections of the efficient frontier are relatively efficient but not Pareto optimal. For example, a DMU is Pareto optimal if improvement in performance along one axis can only be accomplished by degrading performance along another axis. The distinction between Pareto optimal and relatively efficient but not Pareto optimal can be explained by considering DMUs D, and E. DMU D is Pareto optimal because no other DMU produces more of output per unit input. DMU E is not Pareto optimal because DMU D is better with respect to output while holding the same input as DMU E. Despite this, DMU E is relatively efficient (Porcelli, 2009; Charnes, Cooper, Golany, Seiford, & Stutz, 1985; Bessent et al., 1983).

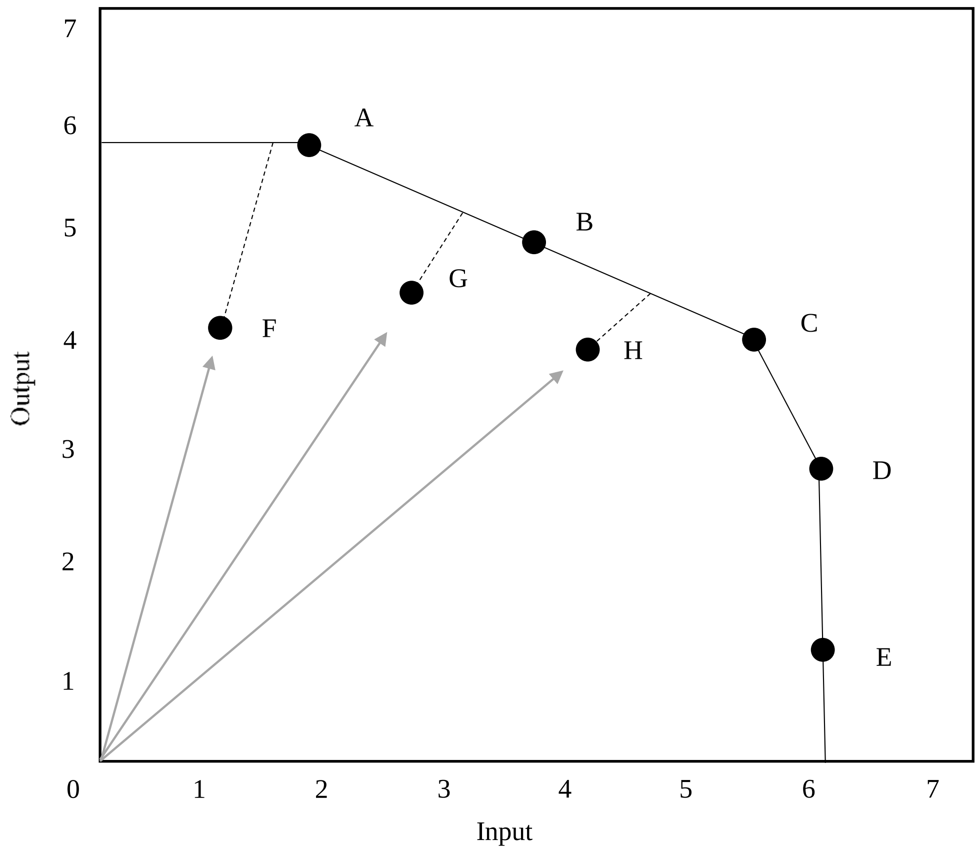

Figure 1. *Data Envelopment Analysis Single Output and Input Model.*

Relatively efficient DMUs exist on the frontier; however, Figure 1 can be used to determine the efficiency of relatively inefficient DMUs as well. This is done by taking the ratio of the lengths of two partially overlapping line segments (Porcelli, 2009). For example, a ratio to determine relative efficiency can be done using the line segment that connects the origin with DMU F and second line segment passes through DMU F while connecting the origin and the efficient frontier. The line segment passing through DMU F intersects the efficient frontier between the y-axis and DMU A, therefore DMU A is the reference for optimal efficiency for DMU F. Similarly, if a line passed from the origin, through DMU G, to the efficient frontier, the DMUs of reference for DMU G would be DMU A and DMU B (Porcelli, 2009).

With four or more inputs and outputs combined, it is not possible to generate a graphical representation; therefore, it is necessary to consider the analysis of raw DEA results. Results obtained from DEA are the optimal weights and relative efficiency scores. In order to distinguish between the efficient DMUs that are Pareto optimal and those that are not, the inputs and outputs of efficient DMUs need to be reviewed for differences (Bessent & Bessent, 1980). An index of inefficiency can be determined from the model, which shows the deviation between inefficient and efficient DMUs. Slack values and opportunity costs also may be calculated to determine the extent inputs are underutilized by DMUs and determine the opportunity for gaining efficiency by increasing resources fully utilized (Porcelli, 2009). Once the DEA results are computed, second stage regression analysis, for example Tobit model, can be done to test hypotheses on the effect of specific variables. The use of Tobit model can treat the characteristics of the distribution of efficiency measures and provide results that can guide policies to improve performance (Ruggiero & Vitaliano, 1999).

The DEA model is a useful tool for determining relative efficiency of DMUs. One advantage of using DEA is that production functions can vary amongst DMUs because of the nonparametric, linear programming solution. The DEA efficient frontier is produced piece-wise using the most efficient DMUs in the set, thereby providing a comparison of DMU efficiency relativity. This feature affords the ability to make comparisons with actual efficiency leaders instead of an average or hypothetical ideal. In contrast, using the most efficient DMUs in constructing the frontier does not take into account performance anomalies like SFA, a model that estimates an average. Table 1 presents a comparison of Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) models (Hjalmarsson, Kumbhakar, & Heshmati, 1996).

Table 1. *Comparison of DEA and SFA models.*

DEA	SFA
Nonparametric method	Parametric method
Uses linear mathematical programming	Uses maximum probability econometric estimation
Does not distinguish noise from the efficiency score	Specifies noise
Accommodates multiple outputs and multiple inputs	In general, only accommodates a single output with multiple inputs
Functional form need not to be specified	Functional form needs to be specified
Frontier is based on most efficient DMUs	Frontier is based on the average efficiency

The DEA model is an appealing tool utilizing multiple inputs and outputs to measure the efficiency of higher education systems, institutions, and academic departments (Salerno, 2003) and provides insight into the performance of higher education. The inputs and outputs, while unique to each DEA study, are deterministic and may not capture the quality or effectiveness of the teaching and/or research performed in higher education. However, the inputs and outputs specified can provide a basis for discussion of improvements in the efficiency of higher education.

Inputs and outputs. Higher education efficiency studies provide insight into the effectiveness of teaching, research, or overall productivity based on the inputs and the outputs utilized. As discussed next, the inputs for DEA studies of higher education institutions are similar and may be categorized as labor, capital, and environmental

(Lindsay, 1982). The inputs often include expenses such as operating, research, equipment, faculty and staff labor (Ahn et al., 1988; Athanassopoulos & Shale, 1997; Breu & Raab, 2004; Warning, 2004). Honing in on measurable outputs is more difficult since capturing a value on knowledge or benefit to society is not easily measured directly (Lindsay, 1982). As a result, many teaching efficiency studies focus on outputs, such as the number of graduates receiving a degree, the retention rate of students, and/or the graduation rate (Breu & Raab, 1994; Lehmann & Warning, 2002; Warning, 2004). Research efficiency studies often focus on publications, articles, and books (Lehman & Warning, 2002; Thursby & Kemp, 2002; Warning, 2004).

Inputs factors for most efficiency studies in higher education include labor and operational costs. Some studies include resource expenditures such as libraries, technology, and infrastructure (Arcelus & Coleman, 1997; Lehmann & Warning, 2002; Rhodes & Southwick, 1993; Thursby, 2000). Students' academic achievements, such as grade point average, and student enrollment numbers are also used as input factors (Athanassopoulos & Shale, 1997; Breu & Raab, 1994; Colbert et al., 2000; Facanha et al., 1997; Førsund & Kalhagen, 1999; Johnes, 2006; Kuah & Wong, 2011). Facility space is another factor considered (Facanha et al., 1997; Førsund & Kalhagen, 1999; Johnes & Johnes, 1995; Kao & Hung, 2008; Moreno & Tadepalli, 2002).

Instructional and research staff make up most of the labor input. Salary for staff describes the labor input of a university for all staff, which may also be divided into teaching staff (Abbott & Doucouliagos, 2003; Arcelus & Coleman, 1997; Avkiran, 2001; Johnes, 1995; Moreno & Tadepalli, 2002, Warning, 2004), research staff (Chu Ng & Li, 2000; Johnes & Johnes, 1995; Kuah & Wong, 2011; Lehmann & Warning, 2002) and administrative staff (Arcelus & Coleman, 1997; Casu & Thanassoulis, 2006; Førsund & Kalhagen, 1999). Further distinctions are faculty level of degree obtainment (Facanha et al., 1997), full-time and temporary faculty (Giménez & Martínez, 2006) and non-academic staff (Katharaki & Katharakis, 2010; Tyagi, Yadav & Singh, 2009). Simple ratios, such as number of faculty to students, also work as input factors (Kuah & Wong, 2011).

Operational costs consist of facility maintenance and instructional and research supplies. As input factors, operational costs may be considered as office supplies, copies, and instructional supplies (Ahn et al., 1988; Arcelus & Coleman, 1997; Giménez & Martínez, 2006; Kao & Hung, 2008; Katharaki & Katharakis, 2010; Thanassoulis, Kortelainen, Johnes, & Johnes, 2011). Beasley (1990, 1995), Moreno and Tadepalli (2002), and Post and Spronk (1999) emphasized equipment expenditures as important input factors. Facility space is an input factor that Facanha and coworkers (1997), Førsund and Kalhagen (1999), Kao and Hung (2008), Moreno and Tadepalli (2002) considered in their studies of efficiency. Other related input factors are the value of non-current assets (Abbott & Doucouliagos, 2003) and research income (Athanassopoulos & Shale, 1997; Beasley, 1995; Johnes, 2006; Kuah & Wong, 2011; Lehmann & Warning, 2002; McMillan & Datta, 1998).

Resource inputs include mainly investments in library and technology. Library expenditures may be viewed as a characteristic of quality research and instruction. Arcelus and Coleman (1997), Johnes (2006), Lehmann and Warning (2002), Rhodes and Southwick (1993), and Thursby (2000) considered the availability of recently published journals and textbooks, and overall library expenditures as a predictor for the infrastructure quality of a university or department. Taking into account the expenditures on computing and/or library resources may serve as an additional means to gauge and validate the institutional commitment to teaching and research (Johnes, 2006).

Analogous to inputs, common outputs used in DEA studies of higher education are teaching and research oriented. Teaching outputs may have a student-focus, examining student counts, retention rates, degree completions, and data on alumni (Abbott & Doucouliagos, 2003; Ahn et al., 1988; Arcelus & Coleman, 1997; Athanassopoulos & Shale, 1997; Avkiran, 2001; Beasley, 1995; Breu & Raab, 1994; Colbert et al., 2000; Johnes, 2006; Katharaki & Katharakis, 2010; Kuah & Wong, 2011; Moreno & Tadepalli, 2002; Tauer, Fried, & Fry, 2007; Thanassoulis et al., 2011; Tyagi et al., 2009). Teaching outputs may have an instructor-focus, examining teacher loads and course evaluations (Colbert et al., 2000; Facanha et al., 1997; Giménez & Martínez, 2006). Research outputs consist of publications, research income, patents and invention disclosures (Abbott & Doucouliagos, 2003; Beasley, 1995; Chu Ng & Li, 2000; Førsund & Kalhagen, 1999; Johnes & Johnes, 1995; Johnes, 2006; Kao & Hung, 2008; Katharaki & Katharakis, 2010; Kuah & Wong, 2011; McMillian & Datta, 1998; Oleson & Petersen, 1995; Thursby & Kemp, 2002; Warning, 2004).

Efficiency studies in higher education have been conducted world-wide, mostly outside the United States. The efficiency studies conducted to compare higher education institutions reveal characteristics of efficiency by adjusting, disaggregating, or aggregating inputs and outputs (Salerno, 2003). A few studies postulate reasons for efficiency differences between institutions (Salerno, 2003), but more often efficiency scores are ranked and input and output factors are compared to determine the differences in efficiency scores.

Data envelopment analysis studies in the United States. In the United States, DEA studies have investigated relative efficiencies of institutions, academic programs between institutions, or academic departments within institutions (Ahn et al., 1988; Breu & Raab, 1994; Colbert et al., 2000; Moreno & Tadepalli, 2002; Rhodes & Southwick, 1993; Tauer et al., 2007; Thursby, 2000; Thursby & Kemp, 2002). The studies differ slightly based on the focus of inputs and outputs used in the DEA model. Also, the DMUs, such as public and private institutions, institutional departments, or internal department comparisons, are specified in the studies.

A comprehensive list of higher education efficiency studies around the world using DEA can be found in Appendix A. In the United States, Ahn, Charnes, and Cooper (1988) were among the first to study institutions of higher education using DEA. They found public institutions were more efficient than equivalent private schools. Similarly, Rhodes and Southwick (1993) studied public and private institutions in the United States and found that increased competition, as measured by number of institutions in the state and institutional size, increased efficiency.

Alternatively, Breu and Raab (1994) examined the relationship between efficiency and perceived quality of the top 25 universities, as ranked by the U. S. News and World Report (1992). Their findings suggested that the best universities expended resources to enhance reputation and prestige, however this did not automatically result in student satisfaction. Breu and Raab (1994) offered a course of action for universities, suggesting that the leadership consider increasing demonstrated factors of efficiency rather than focusing on increasing the perceived quality and efficiency factors, as demonstrated by modeling of a mock university.

Instead of examining the whole institution, DEA studies have also explored programs and departments. Thursby (2000) used DEA to determine a rank of efficiencies of 104 economic departments. Specifically, he calculated efficiency ratios based on inputs and outputs related to department research and compared those results to other departments and to rankings reported by the National Research Council (NRC) quality survey of economics departments in the United States. He found the rankings of the NRC quality survey and research efficiency were in alignment. In a similar study, Colbert, Levary and Shaner (2000), compared the top 24 Master of Business Administration (MBA) programs, as ranked by Business Week magazine (Byrne, 1997), using DEA. They concluded that using DEA provided a more complete and accurate picture of MBA program inputs and outputs relative to each other. The authors also stressed the importance of the inputs and outputs selected as they can affect the calculated efficiency scores.

Thursby and Kemp (2002) conducted a study to examine the overall efficiency of 57 universities over six years and focused on inputs and outputs related to licensing activities. The analysis of university efficiencies over a period of time provided for identification of trends. This study established the use of DEA measurements over time to show the mission and direction of an institution.

Two studies concentrated on the efficiency in teaching and research at the academic departmental level in a university (Moreno & Tadepalli, 2002; Tauer et al., 2007). The studies both used DEA to evaluate the efficiencies of departmental teaching and research; however, Tauer and colleagues (2007) also included extension activities in their analysis, including the number of hours faculty spent performing community outreach activities. The results of both studies identified areas of inefficiency in individual departments. The benefits of using DEA to evaluate the efficiency at the departmental level are the inputs and outputs may correspond to the university mission and the comparisons of departments using the same set of criteria decreases bias (Moreno & Tadepalli, 2002). Likewise, DEA is useful in identifying sources of efficiency and inefficiency and may lead to strategies to increase efficiency and quality of the institution (Tauer et al., 2007).

Summary

The role of higher education is complex. Higher education institutions are responsible for providing educational and scholarship opportunities, while also meeting the economic and workforce needs of the state and community (Ehrenberg, 2007). In addition to collecting tuition and fees, higher education systems are subsidized by taxpayers. There has been a growing demand for demonstrated accountability from higher education systems that are seeking funding and status in a highly competitive environment with other public programs, agencies, and institutions (Weerts & Ronca, 2012).

Among the techniques used for production efficiency analysis are production functions, SFA, and DEA. The production functions estimate an average of all observations and may use a regression framework to model the relationship between inputs and outputs. The SFA and DEA models use a frontier, or maximum, which is fit over the data points and represents a maximum output for corresponding levels of input.

The SFA model uses a parametric approach, accounting for statistical noise and measurement error, to compute an estimated maximum relationship between inputs and outputs. The DEA model uses a nonparametric approach, linear programming approach to compute exact values for output performance. The advantages of one approach are the disadvantages of the other. The primary reasons for using SFA over DEA are DEA only assesses relative efficiency and can be sensitive to data errors. Whereas, the primary reasons for using DEA over SFA are due to the ability to assess multiple inputs and outputs and the functional forms do not need to be specified. The use of these approaches is dependent on the goals and specific questions investigated.

Data envelopment analysis is an appealing tool utilizing multiple inputs and outputs to measure the efficiency of higher education systems, institutions, and academic departments (Salerno, 2003) and provides insight into the performance of higher education systems, institutions, and departments. The inputs and outputs, while unique to each DEA study, are deterministic and may not capture the quality of the teaching and research performed in higher education. However, the inputs and outputs specified can provide a basis for discussion on improvements to efficiency in higher education.

Chapter 3

Methodology

The purpose of this study was to explore the efficiency of academic departments in a public, Carnegie classified tier one, high research, comprehensive doctoral university with balanced arts and sciences undergraduate instruction. The research design was a quantitative descriptive study using data envelopment analysis (DEA). This chapter has six parts. After a brief introduction to the use of DEA in higher education, the purpose of the study and research questions are presented. The next sections present: the research design; the decision making units (DMUs) which were the focus of the study; data sources and collection; and data analysis. This chapter concludes with a summary.

The DEA model is a mathematical application used to measure the relative efficiencies of similar units, known as decision making units or DMUs (Charnes et al., 1978). The DMUs studied in higher education include universities, academic programs among universities, and departments within a single university. The value of merit used in DEA is the ratio between total inputs and total outputs (Ramanathan, 2003). The use of DEA models in early analysis of public education investigated the relative efficiencies of educational programs (Bessent et al., 1983; Charnes et al., 1981).

In general, DEA is an expansion of conventional ratio analysis:

$$\text{Efficiency} = \frac{\text{Outputs}}{\text{Inputs}}$$

The DEA model is nonparametric and relies on linear programming to differentiate the set of efficient DMUs from inefficient DMUs. Relative efficiency measures are derived estimates of efficiency for inefficient DMUs based on how far their values deviate from the most efficient scores. Therefore, the DEA technique compares individual DMUs against the performance of the collective. Graphical analysis is a tool used for enveloping all the DMU efficiency score into a frontier. Given the ratios of inputs to outputs, a line joining the more efficient DMUs can be drawn and indicate the efficiency frontier. The DMUs not on the frontier are considered less efficient (Ramanathan, 2003).

Purpose of the Study

The purpose of this study was to use the DEA model to transform the data to a point that they could be useful in academic departments, colleges, and university decision making processes, as well as explore what the data tells us about the efficiency of academic departments. The objectives of this study were twofold. The first objective was to determine the efficiency of academic departments at a university over a period of time, from 2008 to 2014. This timeframe encompasses the recession beginning December 2008 and ending by October of 2009 (Zumeta, 2010), the subsequent reduction in the state budgets, and the recovery period. The input factors were research expenditures, state appropriated budgets, and operational budgets. The output factors were graduate and undergraduate degree completers, full-time equivalent (FTE) produced, student credit hours (SCH) generated, number of scholarly works, and the amount of grants awarded. The second objective was to identify the inputs and outputs having the most influence on efficiency.

The following research questions guided the study:

1. What are the relative efficiencies of academic departments?
2. What are the relative inefficiencies in academic departments?
3. What factors contribute to academic department efficiencies?

4. What factors contribute to academic department inefficiencies?
5. What are the trends of academic department efficiency over time?

Research Design

The focus of this study was to determine the relative efficiencies of academic departments at a National Tier One university in the western United States. This study mirrors several other studies that have examined the efficiency in the academic departments at a single university using DEA (Madden et al., 1997; Moreno & Tadepalli, 2002; Sellers-Rubio et al., 2010; Sinuany-Stern et al., 1994). The DEA model is an objective tool which determines the input and output weights for each DMU under examination and eliminates any researcher bias in weighting (Charnes et al., 1978). Through the use of a linear equation, the DEA model estimates a production frontier, the graphical line upon which all DMUs would lie if they were efficient. The efficiency measurement of each DMU are based on other DMU's in the population. Thus, calculating an efficiency rating is based on best practice DMUs within the population and not on statistical averages of a population (Charnes et al., 1978).

The first production frontier type model was developed by Farrell (1957) to evaluate the efficiency of manufacturing operations. Farrell's model consisted of multiple input measures to produce a single output and was input-oriented. Charnes et al. (1978) determined that Farrell's model was limited when there were multiple inputs and outputs used as measures. The model was expanded to include multiple outputs and efficiency was calculated as the maximum ratio of weighted inputs to outputs. Data envelopment analysis has become the principal technique for measuring the relative efficiency of a set of DMUs that utilize multiple inputs to produce multiple outputs (Zhu, 2014). Since the development of the DEA method, both public and private entities have used it for evaluating and improving efficiency (Gattoufi et al., 2004). The

DEA model has been used to assess operations of hospitals, airports, police departments, businesses, and public and private education.

Data envelopment analysis takes into account inputs and outputs to determine an efficiency score for each DMU. The optimal efficiency score of a DMU is valued at one (1). Efficiency scores of one for any given DMU indicates that no other DMU produced more outputs using relatively the same or less inputs. For this study, the DMU with the a relative efficiency value of one indicated that for a DMU's input level of research expenditures, state appropriated budget, and operating budget, no other DMU achieved a better output of undergraduate and graduate degrees granted, FTE produced, student credit hours generated, scholarly works, and amount of grants awarded. The DMUs with relative efficiency scores less than one had associated slack input and output values. The slack values were used to identify the modifications in inputs and outputs that must occur in order for a DMU to reach a relative efficiency of one.

There are two orientations to consider for DEA efficiency measures, input-oriented and output-oriented measures. Input-oriented measures seek to answer the question, "By how much can input quantities be proportionally reduced without changing the output quantities produced?" (Coelli, 1996, p. 6). Output-oriented measures seek to answer the question, "By how much can output quantities be proportionally expanded without altering the input quantities used?" (Coelli, 1996, p. 6). The input- and output-oriented measures produce the same efficiency scores under constant returns to scale; however, the slacks may be different depending on which orientation is used. To calculate slacks that best represented the measure from optimal efficiency, a multi-stage DEA model was conducted for an output-orientation of both the constant return to scale and variable return to scale method. The multi-stage DEA model, recommended by Coelli

(1996, p. 14), "identifies efficient projected points which have input and output mixes which are as similar as possible to those of the inefficient points, and that it is also invariant to units of measurement."

Decision Making Units

This study examined the efficiency of selected academic departments at a National Tier One university in the western United States. The university studied has over 150 academic degree granting programs. For the purpose of this study, academic departments offering bachelors, masters, and doctorate degrees were considered as decision making units (DMUs). There were sixteen academic departments that fit the criteria. The departments examined for this study are listed in Table 2. It is assumed that both teaching and research is the primary role of these departments.

Table 2. *List of departments examined in this study and their respective colleges and degrees offered.*

College	Department	Degrees Offered
College of Agriculture, Biochemistry, and Natural Resources	Biochemistry	BS, MS, PhD
College of Engineering	Chemical Engineering Materials Science Engineering	BS, MS, PhD
	Civil Engineering	BS, MS, PhD
	Computer Science and Engineering	BS, MS, PhD
	Electrical Engineering	BS, MS, PhD
	Mechanical Engineering	BS, MS, PhD
College of Business	Economics	BA/BS, MA/MS, PhD
College of Liberal Arts	Anthropology	BA, MA, PhD
	English	BA, MA, PhD
	History	BA, MA, PhD
	Political Science	BA, MA, PhD
	Psychology	BA, MA, PhD
College of Science	Chemistry	BS, MS, PhD
	Geography	BA/BS, MS, PhD
	Geological Sciences	BS, MS, PhD
	Physics	BS, MS, PhD

The size of departments may have significant variation due to the number of degree-seeking students in that area of study. Also, the amount and type of coursework offered by the department has an impact on the teaching load requirements. Hence, the FTE produced and credit hours generated should capture the department teaching contribution, along with the number of degrees granted. Similarly, operating budgets may vary due to the type of research conducted. For example, science verses social science research require different instrumentation and resource requirements. The differences in research activity were considered as part of the operating budget, scholarly works, and the grants awarded.

Data Sources and Collection

Applying DEA methods by obtaining the maximum ratio of weighted outputs to weighted inputs is a way to assess the relative efficiency of the departments or DMUs. A list of inputs and outputs used in efficiency studies of higher education academic departments was compiled and reviewed to determine the variables that best represented the efficiency of the DMUs. The inputs selected for this study were research expenditures, state appropriated budgets, and operating budgets for each department. Research expenditures consisted of the costs associated with operations of sponsored research programs in departments awarded those funds. State appropriated budgets consist of monies from the state general fund dedicated to the University's instructional budget and included salaries, fringe, travel, and operating expenses. The funds were distributed by the administration of the University to the academic division or college and then apportioned to the academic departments. The operating budgets consisted of the expenses, other than salaries and fringe benefits, of the academic departments. These expenses may include instructional and research supplies depending on the operational needs of the department. These input variables were recorded annually per fiscal year (July 1 through June 30).

The outputs selected were undergraduate and graduate degrees granted, student credit hours generated, FTE produced, scholarly works, and amount of grants awarded. Undergraduate degrees consisted of bachelors and graduate degrees consisted of masters and doctoral degrees completed and reported annually by the academic department. To determine the FTE produced and the student credit hours, the credit hours for each departmental course was identified. A credit hour is equivalent to "One hour of classroom or direct faculty instruction (defined as a nominal 50 minute classroom hour) and a minimum of two hours of out-of-class student work each week for approximately fifteen weeks for one semester hour of credit or the equivalent amount of work over a different amount of time" (University of Nevada, Reno, 2013). Student credit hours is the result from multiplying course credits taught by the specific department by the number of enrolled students in those courses. The student credit hours calculated shows the department contribution to the overall instruction. The FTE produced is a value used to measure student and faculty activity at the undergraduate and graduate levels. The FTE produced is calculated from the addition of multiplying the student credit hours obtained from undergraduate coursework in a semester by 15, and by multiplying the student credit hours obtained from master's coursework in a semester by 12, and by multiplying the student credit hours obtained from doctoral coursework in a semester by 9. Scholarly works are reported by each department annually and include external publications originated in the department. Finally, the amount of grants awarded includes funds from government agencies, foundations and other organizations primarily for the development and/or continuation of research. Grant awards are reported in the fiscal year.

The data for this study were collected from publically available reports. Data were collected for the period beginning with the fiscal start of 2008 through the end of fiscal year 2014. The research expenditures and grants awarded data were available from the university Office of Sponsored Projects, fiscal data were available from the university Planning, Budget and Analysis Office and the teaching data were available from the Office of the Provost. Table 3 provides a description of the data and source.

Table 3. *Input and output variables, data sources, and reporting timeframes used in this study.*

Input Data	Source	Reporting Timeframe
Research Expenditures	Office of Sponsored Projects	Fiscal Year, Annually
Operational Budget	Planning, Budget & Analysis	Fiscal Year, Annually
State Appropriated Budget	Planning, Budget & Analysis	Fiscal Year, Annually
Output Data	**Source**	**Reporting Timeframe**
Graduate Degree Completers	Office of the Provost	Academic Year, Annually
Undergraduate Degree Completers	Office of the Provost	Academic Year, Annually
FTE produced	Office of the Provost	Academic Year, Fall Semester
Student credit hours generated	Office of the Provost	Academic Year, Fall Semester
Grants awarded	Office of Sponsored Projects	Fiscal Year, Annually
Scholarly Works	Office of the Provost	Academic Year, Annually

Data Analysis

The inputs and outputs data, as described in the previous section, were compiled into spreadsheets using Microsoft Excel (2013). Individual spreadsheets for each academic department were created along with a master spreadsheet containing all of the departmental data. The data were examined for completeness and cross-checked by reviewing annual departmental reports submitted to Office of the Provost.

Descriptive statistics, such as mean, range, and standard deviation were calculated for each input and output category of academic departments for each year's data, 2008 to 2014.

Using a Microsoft Excel add-in, MegaStat, the descriptive statistics were calculated for each variable, for each department. Additionally, the descriptive statistics were calculated for the total dataset using all of the departmental data for each year.

Data envelopment analysis was used to determine the efficiencies of academic departments. Specifically, the DEAP Version 2.1 software (Coelli, 1996) was used to compare the efficiencies of academic departments. The data from the spreadsheets were transferred and formatted to meet the DEAP specifications. Coelli's (1996) step-by-step instructions for data formatting and program operations were followed to obtain DEA results.

The relative efficiencies of the departments were calculated using output maximization and both a variable returns to scale (VRS) and constant returns to scale (CRS) method. The output maximization considered the optimal outputs given the inputs. The constant returns to scale model assumed that all units were operating optimally and an increase in inputs should produce a proportionate increase in the outputs. The variable returns to scale model accounted for variation in units size and referenced against units of similar size (Coelli, Rao, O'Donnell & Battese, 2005). The efficiency results, descriptive data, departmental slacks results, and peer department comparisons were considered in determining the factors contributing to the efficiency and inefficiency of each DMU.

Malmquist DEA (Coelli, 1996) was used to determine the change in efficiency over the period 2008 to 2014. The Malmquist indices measurement procedures developed by Caves, Christensen, and Diewert (1982) and expanded on by Färe, Grosskopf, Norris, and Zhang (1994) were used in this study to assess the change in total output relative to the change in the usage of all inputs by DMUs. The Malmquist DEA provided a useful way to differentiate between changes in efficiency and shifts in the efficiency frontier over the time period 2008 to 2014 (Flegg, Allen, Field & Thurlow, 2004).

Summary

This study compared the efficiency of academic departments at a National Tier One university in the western United States using date envelopment analysis (DEA). The efficiency model was based on multiple input and output variables collected during the time period 2008 to 2014. Data envelopment analysis was used to determine the relative efficiency of the departments over the study period. The data was also analyzed using Malmquist DEA to measure productivity change over the time period.

Chapter 4

Results

The purpose of this study was to use the data envelopment analysis (DEA) model to transform institutional data to a point that it could become useful in academic department, college, and university decision making processes. In other words, the purpose of the study was to obtain DEA results to explore what the data tells us about the efficiency of academic departments under study.

To accomplish the purpose of this study, two objectives were established. The first objective was to determine the efficiency of academic departments at a university over a period of time, from 2008 to 2014. The time period, 2008 to 2014, is an interesting stretch because it encompasses the recession beginning December 2008 and ending by October of 2009 (Zumeta, 2010), the subsequent impact of the recession on the state budget for higher education, and the recovery period. Throughout the 2008 to 2014 academic years, sixteen departments were selected for this study. These sixteen departments offered bachelors, masters, and doctoral degree programs and operated under a college within the university. The input factors were research expenditures, state appropriated budgets, and operational budgets. The output factors were graduate and undergraduate degree completers, full-time equivalent (FTE) produced, student credit hours generated, number of scholarly works, and the amount of grants awarded. The second objective was to identify the inputs and outputs having the most influence on efficiency.

The following research questions guided this study:

1. What are the relative efficiencies of academic departments?
2. What are the relative inefficiencies of academic departments?

3. What factors contribute to academic department efficiencies?

4. What factors contribute to academic department inefficiencies?

5. What are the trends of academic department efficiency over time?

The DEA model was generated using DEAP Version 2.1 software (Coelli, 1996). The data for the sixteen departments were publically available and were obtained for each department. The relative efficiencies of the departments were calculated using output maximization and both constant returns to scale and variable returns to scale models. The output maximization considers the optimal outputs given the selected inputs. The constant returns to scale (CRS) model assumes that an increase in inputs should produce a proportionate increase in the outputs. The variable returns to scale (VRS) model accounts for variations of department size and modifies the efficiency frontier trajectory so that inefficient departments are referenced against departments of similar size (Coelli et al., 2005). The DEA model also calculates the scale efficiencies and the Malmquist index (Coelli, 1996).

This chapter presents the results and is organized into four sections. First, efficiency scores of the sixteen departments for the 2008 – 2014 academic years are reported. The second section reports descriptive statistics and is separated into three parts. The first part presents an overall summary of statistics for the inputs and outputs used in the efficiency model and the pair-wise correlations between the variables. The second part presents overall departmental descriptive statistics. The third part is divided into sixteen subsections; each presents summary statistics for individual department data, including information about the undergraduate and graduate programs, faculty and staff composition, budgets, and efficiency measurements. The Malmquist index results are reported in the third section. Finally, the findings are summarized in section four.

Efficiency Scores

Data envelopment analysis takes into account inputs and outputs to determine an efficiency score for each decision making unit (DMU). For the purpose of this study, an academic department was considered a DMU. The optimal efficiency score for a DMU is a value of one (1). The DMU with a relative efficiency value of one indicates that for the DMU's level of inputs (i.e., research expenditures, state appropriated budget and operating budget), no other DMU achieved a better output of undergraduate and graduate degrees granted, full time equivalent (FTE) produced, student credit hours (SCH) generated, scholarly works, and amount of grants awarded. The efficiency frontier is defined by those departments with a relative efficiency of one. The DMU with a relative efficiency value of less than one indicates that the department is operating below the efficiency frontier.

The academic department efficiency scores calculated using the CRS model are presented in Table 4. The average efficiency score for the period 2008 – 2014 was .91 (*SD* = .16, *CV* = .18).

Table 4. *Academic department efficiency scores using the CRS model, 2008 to 2014.*

Department	2008	2009	2010	2011	2012	2013	2014	Department Average
Biochemistry	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Chemical and Materials Engineering	0.92	1.00	0.72	0.77	0.30	0.55	0.49	0.68
Civil Engineering	1.00	1.00	1.00	1.00	1.00	0.79	1.00	0.97
Computer Science and Engineering	0.50	0.89	0.73	1.00	0.60	0.91	1.00	0.81
Electrical Engineering	0.41	0.43	0.51	0.76	0.77	1.00	1.00	0.70
Mechanical Engineering	1.00	1.00	0.77	0.83	0.63	0.71	0.86	0.83
Economics	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Anthropology	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
English	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
History	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Political Science	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Psychology	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Chemistry	0.66	0.67	0.70	0.62	0.65	0.99	1.00	0.75
Geography	1.00	1.00	0.87	0.91	0.80	1.00	0.82	0.92
Geological Sciences	0.82	1.00	0.98	0.87	1.00	1.00	1.00	0.95
Physics	1.00	1.00	1.00	1.00	1.00	0.68	0.95	0.95
Year Average	0.89	0.94	0.89	0.92	0.86	0.91	0.95	0.91

Seven departments, Biochemistry, Economics, Anthropology, English, History, Political Science, and Psychology were identified as efficient throughout the time period, 2008 – 2014; each had an efficiency score of one for all years, 2008 to 2014. The 2012 academic year had the lowest efficiency score average (*M* = .86, *SD* = .21, *CV* = .24) and ten efficient departments. The 2014 academic year had the highest efficiency score average (*M* = .95, *SD* = .13, *CV* = .14) and twelve efficient departments.

The academic department efficiency scores calculated using the VRS model are presented in Table 5. The average efficiency score for the period 2008 – 2014 was .94 (*SD* = .13, *CV* = .14). Similar to the CRS model, the VRS model showed that the 2014 academic year had the highest average efficiency score of .97 (*SD* = .09, *CV* = .09) and thirteen of the sixteen departments were efficient. Also similar to the CRS model, the lowest average efficiency score calculated for the VRS model was for academic year 2012 at .89 (*SD* = .18, *CV* = .20) with ten efficient departments. Both of the VRS and CRS models identified almost the same number of efficient departments per year (M_{VRS} = 5.06, M_{CRS} = 4.69). Nine of the departments in VRS model were found to be efficient throughout the 2008 – 2014 period. However, two departments (Civil Engineering and Physics) were classified as efficient in the VRS model, but not efficient via the CRS model, throughout the 2008 to 2014 period.

Table 5. *Academic department efficiency scores[a] using the VRS model, 2008 to 2014.*

Department	2008	2009	2010	2011	2012	2013	2014	Department Average
Biochemistry	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Chemical and Materials Engineering	0.94	1.00	0.91	0.79	0.39	0.55	0.64	0.74
Civil Engineering	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Computer Science and Engineering	0.51	0.89	0.80	1.00	0.86	0.98	1.00	0.86
Electrical Engineering	0.51	0.51	0.52	0.79	0.78	1.00	1.00	0.73
Mechanical Engineering	1.00	1.00	0.83	0.88	0.63	0.85	0.86	0.86
Economics	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Anthropology	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
English	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
History	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Political Science	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Psychology	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Chemistry	0.81	0.81	0.75	0.75	0.79	1.00	1.00	0.84
Geography	1.00	1.00	0.94	0.96	0.80	1.00	0.99	0.96
Geological Sciences	0.82	1.00	1.00	1.00	1.00	1.00	1.00	0.97
Physics	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Year Average	0.91	0.95	0.92	0.95	0.89	0.96	0.97	0.94

[a] Range of scores is 0 to 1.

The differences in the CRS and VRS efficiency scores for the departments indicate the influence of scale efficiency. The scale efficiency is a measurement of the operating size of a DMU. For example, a DMU that is scale efficient is operating at an optimal size and at a constant returns to scale. A DMU that is scale inefficient may be too large to take full of advantage of the size, or may be too small to operate at optimal scale efficiency (Bogetoft & Otto, 2010). The complete table of scale efficiency for all departments, 2008 to 2014, is presented in Appendix B. Due to the minimal differences in results between the CRS and VRS models, the CRS model results will be used for the presentation of the results.

Descriptive Statistics

This section describes the data in three parts. The first part presents an overall summary of statistics for the inputs and outputs used in the efficiency model and the correlations among the variables. The second part presents overall departmental descriptive statistics. The final part is divided into sixteen subsections, each which presents summary statistics for individual department data, including information about the undergraduate and graduate programs, faculty and staff composition, budgets, and efficiency measurements.

Inputs and outputs. The inputs considered for this study were total research expenditures, state appropriated budgets, and operational budgets. The outputs considered were graduate and undergraduate degrees granted, FTE's produced, student credit hours generated, scholarly works, and amount of grants awarded. Table 6 presents a summary of the descriptive statistics for department inputs and outputs for the period 2008 to 2014. The inputs and outputs varied considerably across the years, meaning that although departments were charged with instruction and scholarship activities, there were large fluctuations among individual department inputs and outputs. The largest variance among department inputs and outputs was the awards category. The least variance among department inputs and outputs was the graduate degree completers.

Table 6. *Summary descriptive statistics by departments for inputs and outputs, 2008 to 201 (N = 112).*

	Mean[a]	Standard Deviation	Variance	Minimum[b]	Maximum[c]	Range	Coefficient of Variation
Awards	$1,818,974.18	$2,589,542.49	6.71E+12	$0.00	$19,737,688.00	$19,737,688.00	1.42
Scholarly Publications	22.26	17.52	3.07E+02	0.00	106.00	106.00	0.79
Fall Semester Total SCH	4,405.71	3,061.52	9.37E+06	975.00	13,988.00	13,013.00	0.69
Fall Semester Total FTE	307.12	208.68	4.35E+04	71.20	947.60	876.40	0.68
Completers Undergrad	48.29	37.51	1.41E+03	3.00	218.00	215.00	0.78
Completers Grad	14.68	9.02	8.13E+01	2.00	57.00	55.00	0.61
Operating	$45,288.61	$31,841.05	1.01E+09	$12,259.00	$175,953.00	$163,694.00	0.70
Total State Appropriated	$2,162,836.55	$924,745.38	8.55E+11	$747,930.00	$4,973,112.00	$4,225,182.00	0.43
Total Research Expenditures	$1,584,391.65	$1,851,262.75	3.43E+12	$0.00	$8,583,410.39	$8,583,410.39	1.17

[a] Calculated by dividing the aggregate variable value of the sixteen departments for the period, 2008-2014, by the number of variable observations (N = 112).
[b] The minimum observation reported by departments for the period, 2008-2014.
[c] The maximum observation reported by departments for the period, 2008-2014.

The statistics in Table 6 were calculated using all of the departmental data for the total seven years of the period, 2008 to 2014. The individual input and output data for each department, each year, were merged to determine the description statistical summary results. The input variables represent the total amounts of operating, state appropriated, and research expenditures, as recorded on a fiscal year basis. The output variables for instruction, FTE and SCH, represent the total amounts of FTE and SCH, as recorded for the fall semester of each year. The FTE and SCH amounts, for this study, only include the data obtained in the fall semester, not the entire academic year. Awards data represents amounts that were recorded on a fiscal year basis. The scholarly publications, undergraduate and graduate degree completers were counts reported for academic years.

Correlation. In this study, five pairs of variables were correlated higher than 0.70, indicating there was a strong relationship among the pairs of variables. The highest correlation (0.998) was between SCH and FTE which was expected because the student credit hours were used to calculate the full time equivalents; that is, FTE is a linear function of student credit hours. Awards and research expenditures were correlated at 0.856 which indicated a strong relationship between obtaining awards and the support to maintain research programs. The instructional variables of SCH and FTE and the total state appropriated funds were strongly correlated at 0.820 and 0.821, respectively. The strong correlations do not cause concern in this study, as the strong relationships identified made sense and were anticipated. Correlations among all output and input variables are displayed in Table 7.

Table 7. *Correlation matrix[a] for inputs and outputs (N = 112).*

Correlation Matrix	Awards	Scholar. Pubs.	SCH	FTE	Undergrad Degrees	Graduate Degrees	Oper. Budget	State Approp.	Res. Exp.
Awards	1.000								
Scholarly Publications	.391	1.000							
Fall Semester Total SCH	-.110	.241	1.000						
Fall Semester Total FTE	-.095	.271	.998	1.000					
Undergraduate Degrees	.014	.064	.402	.410	1.000				
Graduate Degrees	.304	.268	.174	.198	.350	1.000			
Operating Budget	.056	.209	.440	.447	-.149	.133	1.000		
Total State Appropriated	.031	.197	.820	.821	.185	.286	.583	1.000	
Total Research Expenditures	.856	.545	-.172	-.152	-.093	.269	.082	-.000	1.000

[a] Correlations were calculated using aggregate variable data for the sixteen departments for the period, 2008-2014.

Decision Making Units

For the 2008 to 2014 academic years, the sixteen departments or DMUs identified for this study offered bachelors, masters, and doctoral degree programs and operated under a college within the university. Table 8 presents a summary of departmental statistics recorded for the period 2008 to 2014. The data includes undergraduate student information, graduate student information, and faculty and staff information.

Table 8. *Summary of departmental statistics for the period 2008 to 2014.*

	mean	standard deviation	variance	minimum	maximum	Range
Undergraduate Student Data – Majors (Fall Semester Student Count)						
Majors	259	184	34024	45	826	781
Degrees Granted	48	38	1407	3	218	215
Time to Degree	5.2	0.6	0.4	2.2	7.4	5.2
Graduate Student Data – Master's and Doctoral (Fall Semester Student Count)						
Master's	24	11	122	5	56	51
Doctoral	31	22	476	5	109	104
Degrees Granted	15	9	81	2	57	55
Time to Degree (MS)	3.1	0.8	0.7	1.4	5.8	4.4
Time to Degree (PhD)	6.1	2.2	4.8	2.0	18.0	16.0
Faculty and Staff Data						
Academic Faculty (Instructional)	13	4	18	7	24	17
Full Professor	6	3	7	1	12	11
Associate Professor	4	3	7	0	12	12
Assistant Professor	3	2	4	0	8	8
Continuing Lecturers	3	5	22	0	24	24
Academic Faculty (Research)	1	2	6	0	11	11
Postdoctoral Fellows	2	2	6	0	11	11
Administrative Faculty	1	2	2	0	6	6
Classified Staff	4	4	13	1	17	16
Letter of Appointment	5	7	45	0	35	35
Graduate Teaching Assistants	15	12	148	0	56	56
Graduate Research Assistants	19	15	238	0	56	56
Total Faculty and Staff	62	31	952	23	117	94
Budget and Expenditure Data ($)						
Operating	45,289	31,841	1.01E+09	12,259	175,953	163,694
Total State Appropriated	2,162,837	924,745	8.55E+11	747,930	4,973,112	4,225,182
Total Research Expenditures	1,584,392	1,851,263	3.43E+12	0	8,583,410	8,583,410
Awards	1,818,974	2,589,542	6.71E+12	0	19,737,688	19,737,688
Instruction and Scholarship Data – FTE (Fall Semester), SCH (Fall Semester), Annual Scholarly Publications						
Undergraduate FTE	267.6	197.9	39160.6	49.1	900.3	851.2
Graduate FTE	39.4	21.4	458.2	12.7	111.3	98.6
Total SCH	4405.7	3061.5	9370000	975	13988	13013
Scholarly Publications	22	18	307	0	106	106

Overall, student full time equivalents for the departments studied were 13% graduate and 87% undergraduate. For the data set, the average percent of student population consisted of 83% undergraduate majors, followed by doctoral students at 10% and master's students at 7%. The student credit hours varied over the 2008 to 2014 period, ranging from a low of 975 to a high of 13,988 (*M* = 4,406, *SD* = 3,062). The percent of degrees granted, on average, was 77% undergraduate and 23% graduate degrees. The number of scholarly publications reported by the departments was greatest at 106 works and lowest at 0 works (*M* = 22, *SD* = 18).

The instructional faculty, including professors, lecturers, and graduate teaching assistants, made up 49% of the faculty and staff population in the departments. Research faculty, including postdoctoral fellows and graduate research assistants, represented 35% of the departmental faculty and staff population. Other faculty and staff that supported the departments in all areas of operations, such as administrative faculty, classified staff, and letters of appointment, made up 16% of the population.

The departmental operating budgets were, on average, 2% of the total state appropriated funds dispersed to the departments (*M* = $45,289, *SD* = $31,841). The departmentally designated total state appropriated funds ranged from a low of $747,930 to a high of $4,973,112 (*M* = $2,162,837, *SD* = $924,745). Research expenditures varied over the 2008 to 2014 period, ranging from a low of $0 to a high of $8,583,410 (*M* = $1,584,392, *SD* = $1,851,263). Similarly, departmental awards varied from a low of $0 to a high of $19,737,688 (*M* = $1,818,974, *SD* = $2,589,542).

Inefficient Decision Making Units. The efficiency scores for nine of the 16 departments were found to be below one using the CRS method: Chemical and Materials Engineering, Civil

Engineering, Computer Science and Engineering, Electrical Engineering, Mechanical Engineering, Chemistry, Geography, Geological Sciences, and Physics.

Academic departments identified as inefficient were assigned one or more peer departments through the DEA. Corresponding peers were efficient departments that produced optimal outputs with similar inputs to the inefficient departments. The assigned peer departments were weighted to indicate the extent to which the inefficient departments should rely on the efficient department as a peer. Table 9 shows the corresponding peer departments for the CRS model.

Table 9. *Peer departments assigned in the using the CRS model.*

Department	2008	2009	2010	2011	2012	2013	2014
Biochemistry (1)	-	-	-	-	-	-	-
Chemical and Materials Engineering (2)	1, 3, 12	-	1, 3	4, 16, 1	1, 3	1, 15	3, 5, 7
Civil Engineering (3)	-	-	-	-	-	1, 5	-
Computer Science and Engineering (4)	1, 7, 16, 12	12, 7, 1, 2, 3	1, 12, 3	-	8, 15, 1	5, 11, 7, 15, 1	-
Electrical Engineering (5)	6, 12, 1	1, 12	7, 3, 11, 12	4, 1, 8	15, 11, 8, 1	-	-
Mechanical Engineering (6)	-	-	-	11, 1, 16	1, 12, 11	8, 11, 1, 12	5, 11, 12
Economics (7)	-	-	-	-	-	-	-
Anthropology (8)	-	-	-	-	-	-	-
English (9)	-	-	-	-	-	-	-
History (10)	-	-	-	-	-	-	-
Political Science (11)	-	-	-	-	-	-	-
Psychology (12)	-	-	-	-	-	-	-
Chemistry (13)	12, 7, 14, 8, 16	12, 7, 16	12, 3	16, 8	1, 7	7, 9, 8, 5	-
Geography (14)	-	-	16, 12, 3	8, 1, 16, 4	1, 3, 12	-	4, 1, 5
Geological Sciences (15)	7, 1	-	12, 3, 1	8, 4	-	-	-
Physics (16)	-	-	-	-	-	7, 1	4, 1, 3, 12

Efficient departments do not have any reported slacks; however, for inefficient departments, slacks are reported through DEA. The slacks represent the augmentation needed for a department to reach the efficiency frontier. The descriptive statistics for slack targets for the CRS model per input and output is reported in Table 10. On average, the slack targets for the inputs and outputs varied considerably. This suggested that the inefficient departments slack targets varied among inputs and outputs and also the amount of the augmentation over the 2008 to 2014 period.

Table 10. *Slack targets for inputs and outputs, 2008 to 2014 (n = 112).*

Slack Targets	Mean	Standard Deviation	Variance	Minimum	Maximum	Range	Coefficient of Variation
Output Targets							
Awards ($)	809,606	1,460,315	2.13E+12	0	8,583,016	8,583,016	1.17
Scholarly Publications	10.3	16.5	273.5	0	65.0	65.0	1.00
SCH	1,865.3	3,092.4	9.56E+06	0	12,423.1	12,423.1	1.03
FTE	130.8	215.5	4.64E+04	0	843.2	843.2	1.03
Undergrad Degrees	28	45	2,049	0	187	187	1.03
Grad Degrees	8	12	151	0	38	38	0.99
Input Targets							
Operating Budget ($)	12,846	19,873	3.95E+08	0	76,960	76,960	0.95
State Appropriated ($)	677,652	1,044,491	1.09E+12	0	3,504,408	3,504,408	0.94
Research Expenditures ($)	561,496	1,000,247	1.00E+12	0	5,038,740	5,038,740	1.14

The average percent of slacks augmentation for the CRS model per input and output is reported in Table 11. The average slacks augmentation was highest at 53% in 2009 and lowest at 25% in 2008. The largest slack augmentation identified for the outputs was undergraduate degrees granted at 132%, while the awards was the lowest at 25%. The largest slack augmentation identified for the inputs was operating budgets at -7%. The least slack augmentation for all inputs and outputs combined was the research expenditures at 0%.

Table 11. *Slack augmentations per inputs and outputs, per year.*

	2008	2009	2010	2011	2012	2013	2014	Average
Outputs								
Awards	21%	14%	16%	20%	59%	13%	13%	25%
Scholarly Publications	24%	27%	42%	34%	70%	88%	103%	55%
SCH	39%	20%	47%	50%	38%	25%	14%	32%
FTE	38%	20%	47%	48%	37%	24%	13%	32%
Undergrad Degrees	88%	367%	105%	87%	84%	99%	111%	132%
Grad Degrees	25%	32%	49%	29%	41%	39%	30%	37%
Average	39%	80%	51%	45%	55%	48%	47%	52%
Inputs								
Operating	-5%	-3%	-13%	-7%	-11%	-9%	-5%	-7%
State Appropriated	-1%	0%	0%	0%	-0%	-3%	0%	-1%
Research Expenditures	-1%	0%	-3%	-1%	-4%	-1%	0%	0%
Average	-2%	-1%	-5%	-3%	-5%	-4%	-2%	-3%
Total Year Augmentation	25%	53%	32%	29%	35%	31%	31%	34%

The descriptive statistics, including inputs, outputs, departmental information, and efficiency analysis results are presented for each department in the following sections.

Chemical and Materials Engineering. The Chemical and Materials Engineering (CME) department, when compared to the averaged data of all departments, may be considered a smaller than average department. The average data for the undergraduate and graduate programs, as well as the faculty and staff statistics were below the averages for the departments overall. Research awards and expenditures for CME were more than the averages for the departments, while the operating budget and state appropriated funds were less than the averages. The instructional contributions and scholarly publications were less than the averages overall. The CME department data is presented in Appendix C.

Student full time equivalent for CME, on average, was 75% undergraduate and 25% graduate. The undergraduate FTE ranged from 69% to 73% during 2008-2012 and increased to 82% and 85% in 2013 and 2014, respectively. The graduate FTE ranged from 27% to 31% during 2008-2012 and decreased to 18% and 15% in 2013 and 2014, respectively. The student credit hours varied over the 2008 to 2014 period, ranging from a low of 975 in 2008 to a high of 1,557 in 2014 (M = 1,198, SD = 197, CV = .16). The number of scholarly publications reported by the department was lowest in 2014 with 0 works and greatest in 2008 at 15 works (M = 7, SD = 5, CV = .71).

The average percent of CME student population was mostly undergraduate majors at 84%, followed by doctoral students at 9% and master's students at 7%. The percent of undergraduate majors ranged from a low of 77% in 2008 to a high of 89% in 2013. Over the 2008 to 2014 period, the percent of master's students ranged from 2% to 15% and the doctoral student population ranged from 8% to 12%. The percent of degrees granted, on average, were 65% undergraduate and 35% graduate degrees. The lowest percent of undergraduate degrees granted was in 2010 at 46%. The highest percent of undergraduate degrees were granted in 2014 at 90%. The lowest percent of graduate degrees was 10% of the total degrees granted in 2014 and were the highest in 2010 at 54%.

The instructional faculty, including professors, lecturers, and graduate teaching assistants, made up 39% of the faculty and staff population in the department. The instructional faculty, on average, was made up of 52% of professors, 45% of graduate teaching assistants, and 3% continuing lecturers. Research faculty, including postdoctoral fellows and graduate research assistants, represented 53% of the departmental faculty and staff population. On average, the research faculty consisted of 77% of graduate research assistants, 14% of postdoctoral fellows, and 9% of academic research faculty. Other faculty and staff that supported the department in all areas of operations, such as administrative faculty, classified staff, and letters of appointment, made up 8% of the population. The number of faculty and staff members supported by the department was greatest in 2008, 63 total, declined to 39 members in 2011 and 2012, and increased to 43 members in 2014.

The CME operating budget was, on average, 2% of the total state appropriated funds dispersed to the department (*M* = \$28,830, *SD* = \$1,925, *CV* = .07). The CME designated total state appropriated funds ranged from a low of \$1,481,505 in 2009 to a high of \$1,754,021 in 2014 (*M* = \$1,588,581, *SD* = \$101,233, *CV* = .06). Research expenditures varied over the 2008 to 2014 period, ranging from a low of \$1,721,903 to a high of \$3,288,472 (*M* = \$2,671,184, *SD* = \$669,617, *CV* = .25). Similarly, CME department awards varied from a low of \$1,287,629 in 2014 to a high of \$3,860,010 in 2009 (*M* = \$2,397,883, *SD* = \$1,111,266, *CV* = .46).

The CME department efficiency scores ranged from a low of .30 in 2012 to a high of 1.0 in 2009. The average efficiency score for the department was .68. The CME peer departments for 2012 were Biochemistry, with a weight of 1.574 and Civil Engineering (weight = 0.149). All of the outputs required target augmentation with the percent of increase between 232% and 800%. Awards required the least amount of increase and scholarly publications required the most increase to reach an optimal efficiency score. The input targets augmentation percent ranged from 0% to -14%; the most augmentation in operating budget and the least in the state appropriated funds. In general, to reach the efficiency frontier, the most output target increase for CME was scholarly publications and the least amount of increase was awards.

Civil and Environmental Engineering. The Civil and Environmental Engineering (CEE) department, when compared to the averaged data of all departments, may be considered a larger than average department. The average data for the undergraduate and graduate programs, as well as the faculty and staff statistics were above the averages for the departments overall. Research awards and expenditures for CEE were more than the averages for the departments, while the operating budget and state appropriated funds were approximately the same as the averages. The instructional contributions were less than the averages and the scholarly publications were average. The CEE department data is presented in Appendix D.

Student full time equivalent for CEE, on average, was 77% undergraduate and 23% graduate. The undergraduate FTE ranged variably from 75% to 81% during 2008 to 2014. Similar to the undergraduate FTE, the graduate FTE ranged variably from 19% to 25% during 2008 to 2014. The student credit hours varied over the 2008 to 2014 period, ranging from 3,028 to 3,794 (M = 3,303, SD = 256). The number of scholarly publications reported by the department was lowest in 2009 with 13 works and greatest in 2013 at 36 works (M = 22, SD = 7, CV = .32).

The average percent of CEE student population was mostly undergraduate majors at 83%, followed by master's students at 10% and doctoral students at 7%. The percent of undergraduate majors ranged from a low of 80% in 2014 to a high of 86% in 2008. Over the 2008 to 2014 period, the percent of master's students ranged from 8% to 11% and the doctoral student population ranged from 6% to 9%. The percent of degrees granted, on average, were 73% undergraduate and 27% graduate degrees. The lowest percent of undergraduate degrees granted was in 2010 and 2014 at 71%. The highest percent of undergraduate degrees were granted in 2008 at 80%. The lowest percent of graduate degrees was 20% of the total degrees granted in 2008 and were the highest in 2010 and 2014 at 29%.

The instructional faculty, including professors, lecturers, and graduate teaching assistants, made up 27% of the faculty and staff population in the department. Of the instructional faculty, 50% were professors, 46% were graduate teaching assistants, and 4% were continuing lecturers on average. Research faculty, including postdoctoral fellows and graduate research assistants, represented 57% of the departmental faculty and staff population. On average, the research faculty consist of 90% graduate research assistants, 7% of academic research faculty, and 3% of postdoctoral fellows. Other faculty and staff that supported the department in all areas of operations, such as administrative faculty, classified staff, and letters of appointment, made up 16% of the population. The number of faculty and staff members supported by the department was greatest in 2012, 111 total, and was lowest in 2009 at 92 members.

The CEE operating budget was, on average, 2% of the total state appropriated funds dispersed to the department (M = \$44,555, SD = \$3,762, CV = .08). The CEE designated total state appropriated funds ranged from \$2,346,652 in 2009 to \$2,763,098 in 2014 (M = \$2,479,533, SD = \$162,047, CV = .07). Research expenditures varied over the 2008 to 2014 period, ranging from \$4,385,180 to \$8,583,410 (M = \$5,933,294, SD = \$1,565,465, CV = .26). Similarly, CEE department awards varied from a high of \$19,737,688 in 2010 to a low of \$5,731,530 in 2014 (M = \$8,654,787, SD = \$4,942,068, CV = .57).

The CEE department was efficient every year until 2013 when the efficiency score fell to .79 and then rebounded to a score of 1.0 in 2014. The average efficiency score for the department was .97 for the 2008 to 2014 period. The CEE peer departments for 2013 were Biochemistry, with a weight of 2.263 and Electrical Engineering (weight = 0.142). All of the outputs required target augmentation with the percent of increase between 27% and 119%. Awards required the least amount of increase and undergraduate degrees required the most increase to reach an optimal efficiency score. The input targets augmentation percent ranged from 0% to -27%; the only augmentation indicated was a decrease in state appropriated funds.

Computer Science and Engineering. The Computer Science and Engineering (CSE) department, when compared to the averaged data of all departments, may be considered a midsized department. The average data for the undergraduate and graduate programs, as well as the faculty and staff statistics were approximately the same as the averages for the departments overall. Research awards and expenditures for CSE were more than the averages for the departments, while the operating budget and state appropriated funds were approximately the same as the averages. The instructional contributions were less than the average and the scholarly publications were average. The CSE department data is presented in Appendix E.

Student full time equivalent for CSE, on average, was 80% undergraduate and 20% graduate. The undergraduate FTE ranged from 76% to 77% during 2008-2011 and increased from 82% to 86% during 2012-2014. Unlike the undergraduate FTE, the graduate FTE was steady at 24% during 2008-2011 and decreased to a range of 18% to 14% during 2012-2014. The student credit hours increased over the 2008 to 2014 period, ranging from 2,539 to 4,278 (M = 3,325, SD = 642, CV = .19). The number of scholarly publications reported by the department was lowest in 2011 with 12 works and greatest in 2014 at 37 works (M = 21, SD = 9, CV = .43).

The average percent of CSE student population was mostly undergraduate majors at 83%, followed by master's students at 9% and doctoral students at 8%. The percent of undergraduate majors ranged from 77% to 80% during 2008-2010 to 82% to 88% during 2011-2014. Over the 2008 to 2014 period, the percent of master's students ranged from 6% to 13% and the doctoral student population ranged from 7% to 11%. The percent of degrees granted, on average, were 65% undergraduate and 35% graduate degrees. The lowest percent of undergraduate degrees granted was in 2011 at 55%. The highest percent of undergraduate degrees were granted in 2014 at 76%. The graduate degrees granted were the highest in 2011 at 45% and the lowest was 24% of the total degrees granted in 2014.

The instructional faculty, including professors, lecturers and graduate teaching assistants, made up 46% of the faculty and staff population in the department. The instructional faculty included an average of 50% of professors, 46% of graduate teaching assistants, and 4% continuing lecturers. Research faculty, including postdoctoral fellows and graduate research assistants, represented 48% of the departmental faculty and staff population. On average, the research faculty was made up of 94% of graduate research assistants, 3% of postdoctoral fellows, and 3% of academic research faculty. Other faculty and staff that supported the department in all areas of operations, such as administrative faculty, classified staff, and letters of appointment, made up 6% of the population. The number of faculty and staff members supported by the department was greatest in 2011, 71 total, and the lowest number in 2009 and 2013 at 47.

The CSE operating budget was, on average, 2% of the total state appropriated funds dispersed to the department (*M* = $42,417, *SD* = $5,534, *CV* = .13). The CSE designated total state appropriated funds ranged from $1,967,489 in 2009 to $2,499,293 in 2014 (*M* = $2,085,194, *SD* = $186,554, *CV* = .09). Research expenditures varied over the 2008 to 2014 period, ranging from $1,696,722 to $2,119,973 ($M$ = $1,944,648, SD = $128,706, CV = .07). Similarly, CSE department awards varied from a low of $873,976 in 2012 to a high of $2,830,602 in 2014 ($M$ = $2,008,164, SD = $748,790, CV = .37).

The CSE department efficiency scores ranged from a low of .50 in 2008 to a high of 1.0 in 2011 and 2014. The average efficiency score for the department was .81. The CSE peer departments for 2008 were Psychology (weight = 0.506), Biochemistry (weight = 0.259), Physics (weight = 0.090), and Economics (weight = 0.063). All of the outputs required target augmentation with the percent of increase between 99% and 121%. Awards and FTE required the least amount of increase and scholarly publications required the most increase to reach an optimal efficiency score. The input targets augmentation percent ranged from 0% to -20%; the most augmentation in research expenditures. In general, to reach the efficiency frontier, the most output target increase indicated for CSE was undergraduate degrees and the least amount of increase was awards.

Electrical Engineering. The Electrical Engineering (EE) department, when compared to the averaged data of all departments, may be considered a smaller than average department. The average data for the undergraduate and graduate programs, as well as the faculty and staff statistics were below the averages for the departments overall. Research awards and expenditures for EE were less than the averages for the departments. Additionally, the operating budget and state appropriated funds were less than the departmental averages. The instructional contributions and the scholarly publications were less than the average. The EE department data is presented in Appendix F.

Student full time equivalent for EE, on average, was 83% undergraduate and 17% graduate. The undergraduate FTE ranged from approximately 78% to 80% during 2008-2011 and increased to a range of 84% to 90% during 2012-2014. Contrary to the undergraduate FTE, the graduate FTE ranged from 19% to 22% during 2008-2011 and decreased to a range of 16% to 10% during 2012-2014. The student credit hours increased over the 2008 to 2014 period, ranging from 1,441 to 2,120 (M = 1,656, SD = 231, CV = .14). The number of scholarly publications reported by the department was lowest in 2008 with 7 works greatest in 2014 at 22 works (M = 12, SD = 5, CV = .42).

The average percent of EE student population was mostly undergraduate majors at 82%, followed by doctoral students at 9% and master’s students at 9%. Gradually increasing over the period, the percent of undergraduate majors ranged from 76% in 2008 to 89% in 2014. The percent of master’s students ranged from a high of 14% in 2008 and decreased to 5% in 2014. Similarly, the doctoral student population ranged from a high in 14% in 2009 and decreased to 7% in 2014. The percent of degrees granted, on average, were 76% undergraduate and 24% graduate degrees. The lowest percent of undergraduate degrees granted was in 2011 at 62%. The highest percent of undergraduate degrees were granted in 2014 at 90%. The lowest percent of graduate degrees was 10% of the total degrees granted in 2014 and highest in 2011 at 38%.

The instructional faculty, including professors, lecturers, and graduate teaching assistants, made up 58% of the faculty and staff population in the department. Of the instructional faculty, on average, 53% were professors, 46% were graduate teaching assistants, and 1% were continuing lecturers. Research faculty, including postdoctoral fellows and graduate research assistants, represented 26% of the departmental faculty and staff population. On average, the research faculty was made up of 90% graduate research assistants and 10% postdoctoral fellows. Other faculty and staff that supported the department in all areas of operations, such as administrative faculty, classified staff, and letters of appointment, made up 16% of the population. The number of faculty and staff members supported by the department was greatest in 2010 and 2011, 32 total, and declined to 23 members in 2013.

The EE operating budget was, on average, 2% of the total state appropriated funds dispersed to the department (M = \$37,116, SD = \$3,732, CV = .10). The EE designated total state appropriated funds ranged from a low of \$1,480,147 in 2011 to a high of \$1,631,692 in 2008 (M = \$1,551,690, SD = \$67,267, CV = .04). Research expenditures varied over the 2008 to 2014 period, ranging from \$278,572 to \$839,072 (M = \$540,360, SD = \$185,008, CV = .34). Similarly, EE department awards varied from a low of \$161,081 in 2011 to a high of \$1,081,135 in 2010 (M = \$613,142, SD = \$324,428, CV = .53).

The EE department efficiency scores increased from a low of .41 in 2008 to a high of 1.0 in 2013 and 2014. The average efficiency score for the department was .70. The EE peer departments for 2008 were Psychology (weight = 0.522), Biochemistry (weight = 0.105), and Mechanical Engineering (weight = 0.057). All of the outputs required target augmentation with the percent of increase between 143% and 200%. Undergraduate degrees required the least amount of increase and FTE required the most increase to reach an optimal efficiency score. The input targets augmentation percent ranged from 0% to -22%; the most augmentation in operating budget. In general, to reach the efficiency frontier, the most output target increase indicated for EE were student credit hours and FTE, and the least amount of increase was scholarly publications.

Mechanical Engineering. The Mechanical Engineering (ME) department, when compared to the averaged data of all departments, may be considered a smaller than average department. The average data for the undergraduate and graduate programs, as well as the faculty and staff statistics were below the averages for the departments overall. Research awards and expenditures for ME were more than the averages for the departments. The operating budget and state appropriated funds were less than the departmental averages. The instructional contributions and the scholarly publications were less than the departmental averages. The ME department data is presented in Appendix G.

Student full time equivalent for ME, on average, was 87% undergraduate and 13% graduate. Gradually increasing, the undergraduate FTE ranged from approximately 80% to 93% during 2008 to 2014. Contrary to the undergraduate FTE, the graduate FTE range decreased from 20% to 7% during 2008 to 2014. The student credit hours increased over the 2008 to 2014 period, ranging from 2,336 to 3,601 (M = 2,744, SD = 431, CV = .16). The number of scholarly publications reported by the department was lowest in 2012 with 19 works and greatest in 2008 at 26 works (M = 23, SD = 2, CV = .09).

The average percent of ME student population was mostly undergraduate majors at 93%, followed by master's students at 4% and doctoral students at 3%. Gradually increasing over the period, the percent of undergraduate majors ranged from 89% in 2009 to 95% in 2014. The percent of master's students ranged from 2% to 6% during the 2008 to 2014, overall decreasing over the period. Similarly, the doctoral student population ranged from 2% to 5% during the 2008 to 2014 period, overall decreasing over the period. The percent of degrees granted, on average, were 85% undergraduate and 15% graduate degrees. The lowest percent of undergraduate degrees granted was in 2009 at 71%. The highest percent of undergraduate degrees were granted in 2013 at 93%. The lowest percent of graduate degrees was 7% of the total degrees granted in 2013 and highest in 2009 at 29%.

The instructional faculty, including professors, lecturers, and graduate teaching assistants, made up 42% of the faculty and staff population in the department. On average, the instructional faculty included 50% graduate teaching assistants, 48% professors, and 2% continuing lecturers. Research faculty, including postdoctoral fellows and graduate research assistants, represented 44% of the departmental faculty and staff population. The research faculty consisted of 88% graduate research assistants, 6% postdoctoral fellows, and 6% academic research faculty. Other faculty and staff that supported the department in all areas of operations, such as administrative faculty, classified staff, and letters of appointment, made up 14% of the population. The number of faculty and staff members supported by the department was greatest in 2009, 65 total, and declined to 51 members in 2013 and 2014.

The ME operating budget was, on average, 2% of the total state appropriated funds dispersed to the department (*M* = \$42,174, *SD* = \$4,558, *CV* = .11). The ME designated total state appropriated funds ranged from a low of \$1,629,344 in 2009 to a high of \$2,189,616 in 2014 (*M* = \$1,835,458, *SD* = \$195,627, *CV* = .11). Research expenditures varied over the 2008 to 2014 period, ranging from \$1,132,697 to \$2,230,366 (*M* = \$1,780,706, *SD* = \$420,244, *CV* = .24). Similarly, ME department awards varied from a low of \$768,337 in 2014 to a high of \$3,834,276 in 2008 (*M* = \$1,956,264, *SD* = \$964,091, *CV* = .49).

The ME department efficiency scores ranged from low of .63 in 2012 and a high of 1.0 in 2008 and 2009. The average efficiency score for the department was .83. The ME peer departments for 2012 were Psychology (weight = 0.490), Biochemistry (weight = 0.364), and Political Science (weight = 0.123). All of the outputs required target augmentation with the percent of increase between 58% and 149%. Scholarly publications required the least amount of increase and FTE required the most increase to reach an optimal efficiency score. The input targets augmentation percent ranged from 0% to -20%; the most augmentation in operating budget. In general, to reach the efficiency frontier, the most output target increase indicated for

ME was graduate degrees and the least amount of increase were undergraduate degrees and scholarly publications.

Chemistry. The Chemistry department, when compared to the averaged data of all departments, may be considered an average to larger department. The average data for the undergraduate and graduate programs for the Chemistry department was overall comparable to the departmental averages. The faculty and staff statistics were greater than the averages for the departments overall. Research awards and expenditures for Chemistry were less than the averages for the departments. The operating budget and state appropriated funds were more than the departmental averages. The instructional contributions and the scholarly publications were more than the averages. The Chemistry department data is presented in Appendix H.

Student full time equivalent for Chemistry, on average, was 91% undergraduate and 9% graduate. The undergraduate FTE ranged from 90% to 92% during 2008 to 2014. The graduate FTE ranged from 8% to 10% during 2008 to 2014. The student credit hours increased over the 2008 to 2014 period, ranging from 6,395 to 9,862 (M = 7,680, SD = 1,273, CV = .17). The number of scholarly publications reported by the department was lowest in 2009 with 15 works and greatest in 2014 at 32 works (M = 23, SD = 6, CV = .26).

The average percent of Chemistry student population was mostly undergraduate majors at 65%, followed by doctoral students at 31% and master's students at 4%. The percent of undergraduate majors ranged from 59% to 67%, with the lowest number of majors in 2008 and the greatest number in 2010. The percent of master's students ranged from 3% to 7% during 2008 to 2014. The doctoral student population ranged from 28% to 35% during the 2008 to 2014 period, with the lowest number of doctoral students in 2012 and the greatest number in 2008. The percent of degrees granted, on average, were 57% undergraduate and 43% graduate degrees.

The lowest percent of undergraduate degrees granted was in 2009 at 25%. The highest percent of undergraduate degrees were granted in 2010 at 68%. The lowest percent of graduate degrees was 32% of the total degrees granted in 2010 and highest in 2009 at 75%.

The instructional faculty, including professors, lecturers, and graduate teaching assistants, made up 60% of the faculty and staff population in the department. On average, the instructional faculty was made up of 71% graduate teaching assistants, 26% professors, and 3% continuing lecturers. Research faculty, including postdoctoral fellows and graduate research assistants, represented 23% of the departmental faculty and staff population. The research faculty on average, consisted of 79% of graduate research assistants, 19% of postdoctoral fellows, and 2% of academic research faculty. Other faculty and staff that supported the department in all areas of operations, such as administrative faculty, classified staff, and letters of appointment, made up 17% of the population. The number of faculty and staff members supported by the department was greatest in 2008, 107 total, declined to 85 members in 2009 and increased to 102 in 2014.

The Chemistry operating budget was, on average, 4.5% of the total state appropriated funds dispersed to the department (*M* = $151,185, *SD* = $14,924, *CV* = .10). The Chemistry designated total state appropriated funds ranged from a low of $3,197,344 in 2012 to a high of $3,644,700 in 2014 (*M* = $3,366,730, *SD* = $158,593, *CV* = .05). Research expenditures varied over the 2008 to 2014 period, ranging from $571,600 to $1,623,609 (*M* = $1,026,316, *SD* = $343,525, *CV* = .33). Similarly, Chemistry department awards varied from a low of $566,507 in 2011 to a high of $1,806,206 in 2009 (*M* = $1,161,428, *SD* = $425,521, *CV* = .37).

The Chemistry department efficiency scores ranged from a high of 1.0 in 2014 to a low of .62 in 2011. The average efficiency score for the department was .75. The Chemistry peer departments for 2011 were Anthropology (weight = 2.755) and Physics (weight = 0.125). All of the outputs required target augmentation with the percent of increase between 62% and 522%. Awards and FTE required the least amount of increase and undergraduate degrees required the most increase to reach an optimal efficiency score. The input targets augmentation percent ranged from 0% to -50%; the most augmentation in operating budget. In general, to reach the efficiency frontier, the most output target increase indicated for Chemistry was undergraduate degrees and the least amount of increase were student credit hours and FTE.

Geography. The Geography department, when compared to the averaged data of all departments, may be considered a smaller department. The average data for the undergraduate and graduate programs for the Geography department, along with the faculty and staff statistics were less than the averages for the departments overall. Research awards and expenditures for Geography were less than the averages for the departments. The operating budget and state appropriated funds were less than the departmental averages. The instructional contributions and the scholarly publications were less than the departmental averages. The Geography department data is presented in Appendix I.

Student full time equivalent for Geography, on average, was 79% undergraduate and 21% graduate. The undergraduate FTE fluctuated between 75% and 84% during 2008 to 2014. The graduate FTE ranged from 16% to 25% during 2008 to 2014. The student credit hours varied over the 2008 to 2014 period, ranging from 1,580 to 1,792 (M = 1,712, SD = 76, CV = .04). The number of scholarly publications reported by the department was lowest in 2012 with 13 works and greatest in 2013 at 30 works (M = 21, SD = 6, CV = .29).

The average percent of Geography student population was mostly undergraduate majors at 62%, followed by master's students at 22% and doctoral students at 15%. The percent of undergraduate majors ranged from 57% to 70%, with the lowest number of majors in 2011 and the greatest number in 2008. The percent of master's students ranged from 11% to 30% during the 2008 to 2014. The doctoral student population ranged from 5% to 25% during the 2008 to 2014 period, with the lowest number of doctoral students in 2008 and the greatest number in 2014. The percent of degrees granted, on average, were 63% undergraduate and 37% graduate degrees. The lowest percent of undergraduate degrees granted was in 2011 at 41%. The highest percent of undergraduate degrees were granted in 2012 at 77%. The lowest percent of graduate degrees was 23% of the total degrees granted in 2012 and highest in 2011 at 59%.

The instructional faculty, including professors, lecturers, and graduate teaching assistants, made up 50% of the faculty and staff population in the department. On average, the instructional faculty was made up of 57% graduate teaching assistants, 42% professors, and 1% continuing lecturers. Research faculty, including postdoctoral fellows and graduate research assistants, represented 29% of the departmental faculty and staff population. The research faculty on average, consisted of 95% of graduate research assistants and 5% of postdoctoral fellows. Other faculty and staff that supported the department in all areas of operations, such as administrative faculty, classified staff, and letters of appointment, made up 21% of the population. The number of faculty and staff members supported by the department was greatest in 2011 and 2014, 42 total, and was lowest in 2009 and 2012 at 36 members.

The Geography operating budget was, on average, 3% of the total state appropriated funds dispersed to the department (*M* = \$31,609, *SD* = \$4,524, *CV* = .14). The Geography designated total state appropriated funds ranged from a low of \$1,155,964 in 2013 to a high of \$1,377,356 in 2014 (*M* = \$1,224,615, *SD* = \$72,891, *CV* = .06). Research expenditures varied over the 2008 to 2014 period, ranging from \$960,151 to \$1,878,873 (*M* = \$1,387,789, *SD* =

\$355,758, *CV* = .26). Similarly, Geography department awards varied from a low of \$394,957 in 2009 to a high of \$2,528,247 in 2012 (*M* = \$1,572,359, *SD* = \$785,038, *CV* = .50).

The Geography department efficiency scores ranged from a high of 1.0 in 2008-2009 and 2013 to a low of .80 in 2012. The average efficiency score for the department was .92. The Geography peer departments for 2012 were Civil Engineering (weight = 0.281), Psychology (weight = 0.181), and Biochemistry (weight = 0.089). All of the outputs required target augmentation with the percent of increase between 23% and 212%. Scholarly publications required the least amount of increase and undergraduate degrees required the most increase to reach an optimal efficiency score. The input targets augmentation percent ranged from 0% to -27%; the most augmentation in operating budget. In general, to reach the efficiency frontier, the most output target increase indicated for Geography was undergraduate degrees and the least amount of increase were scholarly publications and awards.

Geological Sciences. The Geological Sciences (GS) department, when compared to the averaged data of all departments, may be considered a smaller department for the undergraduate program, but based on the GS graduate program and faculty statistics, the department may be considered midsized. The GS department on average was large compared to the overall average graduate programs and the faculty and staff statistics were similar to the averages for the departments overall. Research awards and expenditures for GS were less than the averages for the departments. The operating budget and state appropriated funds were more than the departmental averages. The instructional contributions and the scholarly publications were less than the departmental average. The GS department data is presented in Appendix J.

Student full time equivalent for GS, on average, was 74% undergraduate and 26% graduate. The undergraduate FTE fluctuated between 70% and 78% during 2008 to 2014.

Similarly, the graduate FTE fluctuated between 22% and 30% during 2008 to 2014. The student credit hours varied over the 2008 to 2014 period, ranging from 2,587 to 3,212 (M = 2,852, SD = 208, CV = .07). The number of scholarly publications reported by the department was lowest in 2014 with 13 works and greatest in 2010 at 34 works (M = 24, SD = 7, CV = .29).

The average percent of GS student population was mostly undergraduate majors at 71%, followed by master's students at 18% and doctoral students at 11%. Varying over the period, the percent of undergraduate majors ranged from 68% to 74%. The percent of master's students ranged from 14% to 20% during 2008 to 2014, fluctuating over the period. Similarly, the doctoral student population ranged from 10% to 13% during the 2008 to 2014 period. The percent of degrees granted, on average, were 46% undergraduate and 54% graduate degrees. The lowest percent of undergraduate degrees granted was in 2008 at 41%. The highest percent of undergraduate degrees were granted in 2012 at 50%. The lowest percent of graduate degrees was 50% of the total degrees granted in 2012 and highest in 2008 at 59%.

The instructional faculty, including professors, lecturers, and graduate teaching assistants, made up 54% of the faculty and staff population in the department. On average, the instructional faculty included 48% graduate teaching assistants, 41% professors, and 11% continuing lecturers. Research faculty, including postdoctoral fellows and graduate research assistants, represented 39% of the departmental faculty and staff population. The research faculty consisted of 94% graduate research assistants, 5% postdoctoral fellows, and 1% academic research faculty. Other faculty and staff that supported the department in all areas of operations, such as administrative faculty, classified staff, and letters of appointment, made up 7% of the population. The number of faculty and staff members supported by the department was greatest in 2008, 62 total, and varied during the period 2008 to 2014, with the lowest number of members at 49 in 2009 and 2013.

The GS operating budget was, on average, 2% of the total state appropriated funds dispersed to the department (*M* = $54,734, *SD* = $9,856, *CV* = .18). The GS designated total state appropriated funds ranged from a low of $2,384,216 in 2013 to a high of $2,881,081 in 2008 (*M* = $2,576,894, *SD* = $176,819, *CV* = .07). Research expenditures decreased over the 2008 to 2014 period, ranging from $718,121 to $1,267,886 (*M* = $954,954, *SD* = $249,893, *CV* = .26). The GS department awards varied from a low of $360,713 in 2011 to a high of $1,581,324 in 2008 (*M* = $964,998, *SD* = $402,409, *CV* = .42).

The GS department efficiency scores ranged from a high of 1.0 in 2009 and 2012-2014 to a low of .82 in 2008. The average efficiency score for the department was .95. The GS peer departments for 2008 were Psychology (weight = 0.509), Biochemistry (weight = 0.408), and Economics (weight = 0.266). All of the outputs required target augmentation with the percent of increase between 20% and 271%. Graduate degrees required the least amount of increase and undergraduate degrees required the most increase to reach an optimal efficiency score. The input targets augmentation percent ranged from 0% to -19%; the most augmentation in state appropriated funds. In general, to reach the efficiency frontier, the most output target increase indicated for GS was undergraduate degrees and the least amount of increase was graduate degrees.

Physics. The Physics department, when compared to the averaged data of all departments, may be considered an average to larger than average department, although the average data for the Physics undergraduate program was less than average. The Physics graduate program, as well as the faculty and staff statistics were greater than the averages for the departments overall. Research awards and expenditures for Physics were more than the averages for the departments. The operating budget and state appropriated funds were more than the departmental averages. The instructional contributions and the scholarly publications were more than the departmental averages. The Physics department data is presented in Appendix K.

Student full time equivalent for Physics, on average, was 88% undergraduate and 12% graduate. The undergraduate FTE increased over the 2008 to 2014 period, ranging from 85% to 90%. Contrary to the undergraduate FTE, the graduate FTE decreased in range from 15% to 10% during 2008 to 2014. The student credit hours varied over the 2008 to 2014 period, ranging from 4,494 to 6,789 (M = 5,558, SD = 882, CV = .16). The number of scholarly publications reported by the department was lowest in 2013 with 30 works and greatest in 2008 at 106 works (M = 71, SD = 26, CV = .37).

The average percent of Physics student population was mostly undergraduate majors at 57%, followed by doctoral students at 29% and master's students at 14%. Gradually increasing over the period, the percent of undergraduate majors ranged from 46% in 2008 to 63% in 2012, dipping in 2013 to 58% and increasing to 62% in 2014. The percent of master's students ranged from a high of 17% in 2012 and low of 8% in 2009. Similarly, the doctoral student population ranged variably over the period 2008 to 2014 from 20% to 42%. The percent of degrees granted, on average, were 47% undergraduate and 53% graduate degrees. The lowest percent of undergraduate degrees granted was in 2008 at 40%. The highest percent of undergraduate degrees were granted in 2013 at 64%. The lowest percent of graduate degrees was 36% of the total degrees granted in 2013 and highest in 2008 at 60%.

The instructional faculty, including professors, lecturers, and graduate teaching assistants, made up 35% of the faculty and staff population in the department. Of the instructional faculty, on average, 30% were professors, 53% were graduate teaching assistants, and 17% were continuing lecturers. Research faculty, including postdoctoral fellows and graduate research assistants, represented 48% of the departmental faculty and staff population. On average, the research faculty was made up of 73% graduate research assistants, 19% academic research faculty, and 8% postdoctoral fellows. Other faculty and staff that supported the department in all areas of operations, such as administrative faculty, classified staff, and letters of appointment, made up 17% of the population. The number of faculty and staff members supported by the department was greatest in 2008, 114 total, declining to 83 members in 2014.

The Physics operating budget was, on average, 3% of the total state appropriated funds dispersed to the department (*M* = \$65,166, *SD* = \$23,916, *CV* = .37). The Physics designated total state appropriated funds ranged from a low of \$2,377,137 in 2010 to a high of \$2,665,941 in 2014 (*M* = \$2,525,950, *SD* = \$102,973, *CV* = .04). Research expenditures decreased over the 2008 to 2014 period, ranging from \$3,640,864 to \$7,015,274 (*M* = \$5,556,271, *SD* = \$1,256,557, *CV* = .23). The Physics department awards varied from a low of \$1,827,596 in 2014 to a high of \$7,150,872 in 2008 (*M* = \$5,256,144, *SD* = \$1,971,289, *CV* = .38).

The Physics department efficiency scores ranged from a high of 1.0 in 2008-2012 to a low of .68 in 2013. The average efficiency score for the department was .95. The Physics peer departments for 2013 were Biochemistry (weight = 1.399) and Economics (weight = 0.812). All of the outputs required target augmentation with the percent of increase between 48% and 838%. Awards, student credit hours, and FTE required the least amount of increase and undergraduate degrees required the most increase to reach an optimal efficiency score. The input targets augmentation percent ranged from 0% to -62%; the most augmentation in operating funds. In general, to reach the efficiency frontier, the most output target increase indicated for Physics was undergraduate degrees and the least amount of increase was awards.

Efficient Decision Making Units. Seven departments were identified as efficient using the CRS method: Biochemistry, Economics, Anthropology, English, History, Political Science, and Psychology. The descriptive statistics, including inputs, outputs, and departmental information, are presented for each efficient department in the following sections. Since these departments were identified as efficient throughout the 2008 to 2014 period, they resided on the frontier and were performing at optimal operations. Therefore, no slack augmentations or peer departments are reported for the efficient departments.

Biochemistry. The Biochemistry department, when compared to the averaged data of all departments, may be considered a smaller than average department. The average data for the undergraduate and graduate programs, as well as the faculty and staff statistics were below the averages for the departments overall. The average research awards for Biochemistry were less than the average for the departments; however, the research expenditures were more than the average. The operating budget and state appropriated funds were less than the departmental averages. The instructional contributions and the scholarly publications were less than the departmental average. The Biochemistry department data is presented in Appendix L.

Student full time equivalent for Biochemistry, on average, was 76% undergraduate and 24% graduate. The undergraduate FTE increased from a low of 68% in 2008 to a high of 83% in 2014. Unlike the undergraduate FTE, the graduate FTE decreased over the period, starting at a high of 32% in 2008 and decreasing to 17% in 2014. The student credit hours varied over the 2008 to 2014 period, ranging from 1,498 to 2,425 (M = 2,000, SD = 375, CV = .19). The number of scholarly publications reported by the department was lowest in 2012 with 15 works and greatest in 2009 at 34 works (*M* = 23, *SD* = 6, *CV* = .26).

The average percent of the Biochemistry student population was mostly undergraduate majors at 91%, followed by doctoral students at 6% and master's students at 3%. The percent of undergraduate majors ranged from a low of 89% in 2010 to a high of 93% in 2014. Over the 2008 to 2014 period, the percent of master's students ranged from 2% to 3% and the doctoral student population ranged from 3% to 8%. The percent of degrees granted, on average, were 78% undergraduate and 22% graduate degrees. The lowest percent of undergraduate degrees granted was in 2012 at 67%. The highest percent of undergraduate degrees were granted in 2009 at 87%. The lowest percent of graduate degrees was 13% of the total degrees granted in 2009 and highest in 2012 at 33%.

The instructional faculty, including professors, lecturers, and graduate teaching assistants, made up 24% of the faculty and staff population in the department. The instructional faculty, on average, was made up of 72% of professors, 9% of graduate teaching assistants, and 19% continuing lecturers. Research faculty, including postdoctoral fellows and graduate research assistants, represented 56% of the departmental faculty and staff population. On average, the research faculty consisted of 70% of graduate research assistants, 21% of postdoctoral fellows, and 9% of academic research faculty. Other faculty and staff that supported the department in all areas of operations, such as administrative faculty, classified staff, and letters of appointment, made up 20% of the population. The number of faculty and staff members supported by the department was greatest in 2008, 84 total and declined to 55 members in 2013 and 2014.

The Biochemistry operating budget was, on average, 2% of the total state appropriated funds dispersed to the department (*M* = \$15,433, *SD* = \$4,416, *CV* = .29). The Biochemistry designated total state appropriated funds ranged from a low of $747,930 in 2011 to a high of $1,010,700 in 2008 (*M* = $845,600, *SD* = $101,125, *CV* = .12). Research expenditures varied over the 2008 to 2014 period, ranging from $1,293,479 to $2,209,419 (*M* = $1,768,009, *SD* = $402,128, *CV* = .23). The Biochemistry department awards varied from a low of $278,563 in 2014 to a high of $3,743,866 in 2013 (*M* = $1,701,031, *SD* = $1,236,069, *CV* = .73).

Economics. The Economics department, when compared to the averaged data of all departments, may be considered an average to smaller than average department. The average data for the Economics undergraduate program was similar to the departmental average. The Economics graduate program, as well as the faculty and staff statistics were smaller than the averages for the departments overall. Research awards and expenditures for Economics were less than the averages for the departments. The operating budget and state appropriated funds were less than the departmental averages. The instructional contributions were more than the departmental average, while the scholarly publications were less than average. The Economics department data is presented in Appendix M.

Student full time equivalent for Economics, on average, was 95% undergraduate and 5% graduate. The undergraduate FTE over the 2008 to 2014 period ranged from 94% to 96%. Similarly to the undergraduate FTE, the graduate FTE ranged from 4% to 6% during 2008 to 2014. The student credit hours varied over the 2008 to 2014 period, ranging from 6,395 to 8,392 (*M* = 7,163, *SD* = 751, *CV* = .10). The number of scholarly publications reported by the department was lowest in 2014 with 14 works and greatest in 2012 at 27 works (*M* = 20, *SD* = 5, *CV* = .025).

The average percent of Economics student population was mostly undergraduate majors at 72%, followed by doctoral students at 14% and master's students at 14%. Varying over the period, the percent of undergraduate majors ranged from 70% in 2009 to 81% in 2014. The percent of master's students ranged from low of 8% in 2013 and 2014 to a high of 30% in 2009. Similarly, the doctoral student population ranged variably over the period 2008 to 2014 to a high of 14% in 2012. The percent of degrees granted, on average, were 89% undergraduate and 11% graduate degrees. The lowest percent of undergraduate degrees granted was in 2009 at 74%, while the graduate degrees granted were the highest in 2009 at 26%. The highest percent of undergraduate degrees were granted in 2011 at 95%. The lowest percent of graduate degrees was 5% of the total degrees granted in 2011.

The instructional faculty, including professors, lecturers, and graduate teaching assistants, made up 44% of the faculty and staff population in the department. Of the instructional faculty, on average, 80% were professors, 3% were graduate teaching assistants, and 17% were continuing lecturers. Research faculty, including postdoctoral fellows and graduate research assistants, represented 30% of the departmental faculty and staff population. On average, the research faculty was made up of 91% graduate research assistants, 9% academic research faculty, and 0% postdoctoral fellows. Other faculty and staff that supported the department in all areas of operations, such as administrative faculty, classified staff, and letters of appointment, made up 26% of the population. The number of faculty and staff members supported by the department was greatest in 2014, 52 total, and least in 2010 with 24 members.

The Economics operating budget was, on average, less than 1% of the total state appropriated funds dispersed to the department (*M* = $17,202, *SD* = $1,618, *CV* = .09). The Economics designated total state appropriated funds ranged from a low of $1,839,188 in 2013 to a high of $2,077,754 in 2010 (*M* = $1,968,112, *SD* = $87,206, *CV* = .04). Research expenditures varied over the 2008 to 2014 period, ranging from $16,112 to $729,233 (*M* = $277,410, *SD* =

$290,625, *CV* = 1.05). The Economics department awards varied from a low of $63,815 in 2011 to a high of $1,230,424 in 2013 (*M* = $544,779, *SD* = $470,003, *CV* = .86).

Anthropology. The Anthropology department, when compared to the averaged data of all departments, may be considered a smaller than average department. The average data for the Anthropology undergraduate program was less than the departmental average. The graduate program, as well as the faculty and staff statistics were smaller than the averages for the departments overall. Research awards and expenditures for Anthropology were less than the averages for the departments. The operating budget and state appropriated funds were less than the departmental averages. The instructional contributions and scholarly publications were less than averages. The Anthropology department data is presented in Appendix N.

Student full time equivalent for Anthropology, on average, was 90% undergraduate and 10% graduate. The undergraduate FTE over the 2008 to 2014 period ranged from 87% to 92%. Similarly to the undergraduate FTE, the graduate FTE varied from 8% to 13% during 2008 to 2014. The student credit hours varied over the 2008 to 2014 period, ranging from 2,793 to 4,907 (*M* = 3,826, *SD* = 700, *CV* = .18). The number of scholarly publications reported by the department was lowest at 11 works and greatest at 17 works (*M* = 15, *SD* = 3, *CV* = .20).

The average percent of Anthropology student population was mostly undergraduate majors at 73%, followed by master's students at 19% and doctoral students at 8%. Varying over the period, the percent of undergraduate majors ranged from 67% in 2008 to 77% in 2011. The percent of master's students ranged from a low of 15% in 2011 to a high of 23% in 2008. Similarly, the doctoral student population ranged over the period 2008 to 2014 from a low of 8% in 2011 to a high of 10% in 2008. The percent of degrees granted, on average, were 77% undergraduate and 23% graduate degrees. The lowest percent of undergraduate degrees granted was in 2008 at 72%. The highest percent of undergraduate degrees were granted in 2013 at 84%. The lowest percent of graduate degrees was 16% of the total degrees granted in 2013 and highest in 2008 at 28%.

The instructional faculty, including professors, lecturers, and graduate teaching assistants, made up 71% of the faculty and staff population in the department. Of the instructional faculty, on average, 41% were professors, 59% were graduate teaching assistants, and 0% were continuing lecturers. Research faculty, which included postdoctoral fellows and graduate research assistants, represented 18% of the departmental faculty and staff population. The research faculty was made up entirely of graduate research assistants. Other faculty and staff that supported the department in all areas of operations, such as administrative faculty, classified staff, and letters of appointment, made up 11% of the population. The number of faculty and staff members supported by the department was greatest in 2014, 38 total, and least in 2009 with 23 members.

The Anthropology operating budget was, on average, 2% of the total state appropriated funds dispersed to the department (*M* = \$26,278, *SD* = \$910, *CV* = .03). The Anthropology designated total state appropriated funds ranged from a low of \$1,068,642 in 2011 to a high of \$1,337,584 in 2014 (*M* = \$1,190,703, *SD* = \$89,167, *CV* = .07). Research expenditures varied over the 2008 to 2014 period, ranging from \$16,585 to \$160,569 (*M* = \$109,961, *SD* = \$46,143, *CV* = .42). The Anthropology department awards varied from a low of \$10,000 in 2011 to a high of \$291,771 in 2012 (*M* = \$113,721, *SD* = \$87,880, *CV* = .77).

English. The English department, when compared to the averaged data of all departments, may be considered a larger than average department. The average data for the English undergraduate program was more than the departmental average. The graduate program, as well as the faculty and staff statistics were greater than the averages for the departments overall. Research awards and expenditures for English were less than the averages for the departments. The operating budget and state appropriated funds were more than the departmental averages. The instructional contributions were more than the departmental average, while the scholarly publications were less than average. The English department data is presented in Appendix O.

Student full time equivalent for English, on average, was 94% undergraduate and 6% graduate. The undergraduate FTE increased over the 2008 to 2014 period, ranging from 91% to 95%. Contrary to the undergraduate FTE, the graduate FTE decreased from 8% to 5% during 2008 to 2014. The student credit hours varied over the 2008 to 2014 period, ranging from 10,160 to 13,988 (M = 12,383, SD = 1,536, CV = .12). The number of scholarly publications reported by the department was lowest at 7 works in 2009 and greatest at 30 works in 2008 (M = 16, SD = 7, CV = .44).

The average percent of English student population was mostly undergraduate majors at 82%, followed by doctoral students at 10% and master's students at 8%. Varying over the period, the percent of undergraduate majors ranged from 79% in 2008 to 85% in 2012. The percent of master's students ranged variably from a low of 7% in 2014 to a high of 10% in 2008. Similarly, the doctoral student population ranged variably over the period 2008 to 2014 with a low of 8% in 2012 to a high of 13% in 2013. The percent of degrees granted, on average, were 81% undergraduate and 19% graduate degrees. The lowest percent of undergraduate degrees granted was in 2011 at 78%. The highest percent of undergraduate degrees were granted in 2014 at 88%. The lowest percent of graduate degrees was 12% of the total degrees granted in 2014 and highest in 2011 at 22%.

The instructional faculty, including professors, lecturers, and graduate teaching assistants, made up 70% of the faculty and staff population in the departments. Of the instructional faculty, on average, 30% were professors, 46% were graduate teaching assistants, and 24% were continuing lecturers. Research faculty, which included postdoctoral fellows and graduate research assistants, represented 3% of the departmental faculty and staff population. On average, the research faculty was made up of 74% graduate research assistants, 0% academic research faculty, and 26% postdoctoral fellows. Other faculty and staff that supported the department in all areas of operations, such as administrative faculty, classified staff, and letters of appointment, made up 27% of the population. The number of faculty and staff members supported by the department was greatest in 2014, 117 total, and least in 2009 with 101 members.

The English operating budget was, on average, 1% of the total state appropriated funds dispersed to the department (M = \$57,360, SD = \$4,680, CV = .08). The English designated total state appropriated funds ranged from a low of \$4,079,378 in 2009 to a high of \$4,973,112 in 2014 (M = \$4,656,111, SD = \$349,563, CV = .08). Research expenditures varied over the 2008 to 2014 period, ranging from \$0 to \$21,771 (M = \$10,151, SD = \$9,688, CV = .95). The English department awards varied from a low of \$1,425 in 2013 to a high of \$76,762 in 2009 (M = \$26,110, SD = \$29,353, CV = 1.12).

History. The History department, when compared to the averaged data of all departments, may be considered a smaller than average department. The average data for the History undergraduate program was less than the departmental average. The graduate program, as well as the faculty and staff statistics were less than the averages for the departments overall. Research awards and expenditures for History were less than the averages for the departments. The operating budget was less than the departmental average and the state appropriated funds were similar to the departmental average. The instructional contributions were less than the departmental average and the scholarly publications were less than average. The History department data is presented in Appendix P.

Student full time equivalent for History, on average, was 90% undergraduate and 10% graduate. The undergraduate FTE varied over the 2008 to 2014 period, ranging from 87% to 93%. Similar to the undergraduate FTE, the graduate FTE varied from 7% to 13% during 2008 to 2014. The student credit hours varied over the 2008 to 2014 period, ranging from 2,444 to 3,301 (M = 2,838, SD = 316, CV = .11). The number of scholarly publications reported by the department was lowest at 2 works in 2008 and greatest at 11 works in 2010 (M = 7, SD = 3, CV = .43).

The average percent of History student population was mostly undergraduate majors at 82%, followed by master's students at 13% and doctoral students at 5%. Varying over the period, the percent of undergraduate majors ranged from 78% in 2013 to 87% in 2008. The percent of master's students ranged from a low of 9% in 2008 to a high of 15% in 2013. Similarly, the doctoral student population ranged variably over the period 2008 to 2014 from a low of 4% in 2008 to a high of 7% in 2013. The percent of degrees granted, on average, were 85% undergraduate and 15% graduate degrees. The lowest percent of undergraduate degrees granted was in 2013 at 76%. The highest percent of undergraduate degrees were granted in 2008 at 93%. The lowest percent of graduate degrees was 7% of the total degrees granted in 2008 and highest in 2013 at 24%.

The instructional faculty, including professors, lecturers, and graduate teaching assistants, made up 89% of the faculty and staff population in the department. Of the instructional faculty, on average, 53% were professors, 39% were graduate teaching assistants, and 8% were continuing lecturers. Research faculty, which included postdoctoral fellows and graduate research assistants, represented 2% of the departmental faculty and staff population. On average, the research faculty was made up of 20% graduate research assistants, 0% academic research faculty, and 80% postdoctoral fellows. Other faculty and staff that supported the department in all areas of operations, such as administrative faculty, classified staff, and letters of appointment, made up 9% of the population. The number of faculty and staff members supported by the department was greatest in 2008, 38 total, and least in 2013 with 29 members.

The History operating budget was, on average, 1% of the total state appropriated funds dispersed to the department (*M* = $25,842, *SD* = $899, *CV* = .03). The History designated total state appropriated funds ranged from a low of $2,112,460 in 2011 to a high of $2,437,014 in 2008 (*M* = $2,271,808, *SD* = $117,216, *CV* = .05). Research expenditures varied over the 2008 to 2014 period, ranging from $0 to $2,175 (*M* = $468, *SD* = $857, *CV* = 1.83). Similarly, the History department awards varied from a low of $0 to a high of $97,000 (*M* = $24,857, *SD* = $42,255, *CV* = 1.70).

Political Science. The Political Science (PS) department, when compared to the averaged data of all departments, may be considered a smaller than average department. The average data for the PS undergraduate program was the one area that was more than the departmental average. The graduate program, as well as the faculty and staff statistics were less than the averages for the departments overall. Research awards and expenditures for PS were less than the averages for the departments. The operating budget was less than the departmental average and the state appropriated funds were similar to the departmental average. The instructional contributions were less than the departmental average and the scholarly publications were less than average. The PS department data is presented in Appendix Q.

Student full time equivalent for PS, on average, was 88% undergraduate and 12% graduate. The undergraduate FTE decreased over the 2008 to 2014 period, ranging from 91% to 86%. Contrary to the undergraduate FTE, the graduate FTE increased from 9% to 14% during 2008 to 2014. The student credit hours varied over the 2008 to 2014 period, ranging from 3,376 to 4,121 (M = 3,692, SD = 330, CV = .09). The number of scholarly publications reported by the department was lowest at 3 works in 2012 and 2013 and greatest at 11 works in 2008 (M = 7, SD = 3, CV = .43).

The average percent of PS student population was mostly undergraduate majors at 90%, followed by master's students at 5% and doctoral students at 5%. Varying over the period, the percent of undergraduate majors ranged from 87% to 92%. The percent of master's students ranged from a low of 4% in 2012 to a high of 7% in 2008. Similarly, the doctoral student population ranged over the period 2008 to 2014 from a low of 4% in 2011 to a high of 6% in 2013. The percent of degrees granted, on average, were 90% undergraduate and 10% graduate degrees. The lowest percent of undergraduate degrees granted was in 2008 at 86%, while the graduate degrees granted were the highest in 2008 at 14%. The highest percent of undergraduate degrees were granted in 2011 at 93%. The lowest percent of graduate degrees was 7% of the total degrees granted in 2011.

The instructional faculty, including professors, lecturers, and graduate teaching assistants, made up 66% of the faculty and staff population in the department. Of the instructional faculty, on average, 64% were professors, 35% were graduate teaching assistants, and 1% were continuing lecturers. Research faculty, which included postdoctoral fellows and graduate research assistants, represented 18% of the departmental faculty and staff population. On average, the research faculty was made up of 92% graduate research assistants, 3% academic research faculty, and 5% postdoctoral fellows. Other faculty and staff that supported the department in all areas of operations, such as administrative faculty, classified staff, and letters of appointment, made up 16% of the population. The number of faculty and staff members supported by the department was greatest in 2013, 35 total, and least in 2009 with 23 members.

The PS operating budget was, on average, 2% of the total state appropriated funds dispersed to the department (*M* = \$29,165, *SD* = \$1,764, *CV* = .06). The PS designated total state appropriated funds ranged from a low of \$1,472,058 in 2011 to a high of \$2,011,084 in 2014 (*M* = \$1,630,675, *SD* = \$184,672, *CV* = .11). Research expenditures varied over the 2008 to 2014 period, ranging from \$23,435 to \$90,569 (*M* = \$57,042, *SD* = \$25,306, *CV* = .44). Similarly, the PS department awards varied from a low of \$18,057 to a high of \$130,034 (*M* = \$55,684, *SD* = \$37,914, *CV* = .68).

Psychology. The Psychology department, when compared to the averaged data of all departments, may be considered a larger than average department. The average data for the Psychology undergraduate program was more than the departmental average. The graduate program, as well as the faculty and staff statistics were more than the averages for the departments overall. Research awards for Psychology were more than the averages for the departments; however, the research expenditures were less than the average. The operating budget and the state appropriated funds were more than the departmental average. The instructional contributions were more than the departmental average and the scholarly publications were more than average. The Psychology department data is presented in Appendix R.

Student full time equivalent for Psychology, on average, was 83% undergraduate and 17% graduate. The undergraduate FTE increased over the 2008 to 2014 period, ranging from

80% to 84%. Contrary to the undergraduate FTE, the graduate FTE decreased from 20% to 16% during 2008 to 2014. The student credit hours varied over the 2008 to 2014 period, ranging from 7,576 to 9,548 (*M* = 8,558, *SD* = 664, *CV* = .08). The number of scholarly publications reported by the department was lowest at 29 works in 2008 and greatest at 51 works in 2014 (*M* = 45, *SD* = 8, *CV* = .18).

The average percent of Psychology student population was mostly undergraduate majors at 85%, followed by doctoral students at 12% and master's students at 3%. Increasing over the period, the percent of undergraduate majors ranged from 83% to 87%. The percent of master's students ranged from a low of 1% in 2008 to a high of 4% in 2014. The doctoral student population decreased over the period 2008 to 2014 from a high of 16% in 2008 to a low of 9% in 2014. The percent of degrees granted, on average, were 82% undergraduate and 18% graduate degrees. The lowest percent of undergraduate degrees granted was in 2008 at 63%. The highest percent of undergraduate degrees were granted in 2014 at 88%. The lowest percent of graduate degrees was 12% of the total degrees granted in 2014 and highest in 2008 at 37%.

The instructional faculty, including professors, lecturers, and graduate teaching assistants, made up 49% of the faculty and staff population in the department. Of the instructional faculty, on average, 39% were professors, 60% were graduate teaching assistants, and 1% were continuing lecturers. Research faculty, which included postdoctoral fellows and graduate research assistants, represented 42% of the departmental faculty and staff population. On average, the research faculty was made up of 94% graduate research assistants, less than 1% academic research faculty, and 5% postdoctoral fellows. Other faculty and staff that supported the department in all areas of operations, such as administrative faculty, classified staff, and letters of appointment, made up 9% of the population. The number of faculty and staff members supported by the department was greatest in 2012, 116 total, and least in 2009 with 94 members.

The Psychology operating budget was, on average, 2% of the total state appropriated funds dispersed to the department (*M* = $55,551, *SD* = $3,274, *CV* = .06). The Psychology designated total state appropriated funds ranged from a low of $2,662,798 in 2012 to a high of $3,260,097 in 2014 (*M* = $2,807,730, *SD* = $209,202, *CV* = .07). Research expenditures varied over the 2008 to 2014 period, ranging from $433,072 to $2,675,801 (*M* = $1,331,704, *SD* = $878,353, *CV* = .66). Similarly, the Psychology department awards varied from a low of $673,121 to a high of $4,449,160 (*M* = $2,052,235, *SD* = $1,348,966, *CV* = .66).

Malmquist

Malmquist DEA (Coelli, 1996) was used to determine the change in efficiency over the period 2008 to 2014. The Malmquist DEA provided a useful way to differentiate between changes in efficiency and shifts in the efficiency frontier over the time period 2008 to 2014 (Flegg, Allen, Field & Thurlow, 2004). The Malmquist productivity index results, as summarized by González-Rodriguez, Martín-Samper, and Giuliani (2015, p. 554), "produce an efficiency measure for a particular year in relation to the previous year, while allowing the best frontier to shift". Table 12 presents the Malmquist index summary of annual means for all departments from one year to the next.

The total factor productivity change (TFPch) ranged from a decrease of 8% from 2013 to 2014 to an increase of 22% from 2009 to 2010. The technical efficiency change (EFFch), technological change (TECHch), pure technical efficiency change (PEch) and scale efficiency change (SEch) are also listed in Table 12. Four of the six time periods experienced a positive TFP change (TFP>1), whereas two of the periods had no additional productivity over the period

(TFP<1). Over the 2008 to 2014 period, on average, TFP of annual means for all departments increased by 4%.

Table 12. *Malmquist index summary of annual means for all departments from one year to the next.*

Year to Year Period	EFFch	TECHch	PEch	SEch	TFPch
2008 to 2009	1.07	1.00	1.07	1.01	1.06
2009 to 2010	0.96	1.27	0.97	0.99	1.22
2010 to 2011	1.05	0.92	1.04	1.01	0.95
2011 to 2012	0.93	1.12	0.93	0.98	1.01
2012 to 2013	1.12	0.95	1.11	1.01	1.06
2013 to 2014	1.04	0.88	1.01	1.03	0.92
Average	1.03	1.02	1.02	1.01	1.04

On average, Electrical Engineering and Chemistry recorded the highest TFP growth with 10%; Economics had the lowest TFP growth with a 13% decrease (Table 13). Overall, the mean TFP change score during the period was 1.00, which means the department TFP, on average, did not change over time. Five of the 16 departments had a positive TFP change (TFP>1), eight departments had no additional productivity over the period (TFP<1) and three had no change. Overall, most of the departments experienced total productivity decrease. Technical efficiency change for the period was above 1 (EFFch>1), while technological efficiency change was below 1 (TECHch<1), revealing that, for the 2008 to 2014 period, these departments invested in management and organization rather than improve new technologies or innovations (González-Rodriguez, Martín-Samper, & Giuliani, 2015). Table 13 also shows the division of technical efficiency (TECHch) in pure technical (PEch) and scaling efficiency (SEch). The different combinations of technical efficiency and scaling efficiency show that, on average, departments had improvements in pure (PEch>1) efficiency, but no change in scale efficiency (SEch=1) (González-Rodriguez, Martín-Samper, and Giuliani, 2015).

Table 13. *Malmquist productivity index summary for departments, 2008 to 2014.*

Department	EFFch	TECHch	PEch	SEch	TFPch
Biochemistry	1.00	0.99	1.00	1.00	0.99
Chemical and Materials Engineering	0.90	1.03	0.94	0.96	0.92
Civil Engineering	1.00	1.03	1.00	1.00	1.03
Computer Science and Engineering	1.12	0.96	1.12	1.00	1.08
Electrical Engineering	1.16	0.95	1.12	1.04	1.10
Mechanical Engineering	0.97	0.99	0.98	1.00	0.97
Economics	1.00	0.87	1.00	1.00	0.87
Anthropology	1.00	0.98	1.00	1.00	0.98
English	1.00	-	1.00	1.00	-
History	1.00	-	1.00	1.00	-
Political Science	1.00	1.03	1.00	1.00	1.03
Psychology	1.00	0.99	1.00	1.00	0.99
Chemistry	1.07	1.03	1.04	1.04	1.10
Geography	0.97	0.98	1.00	0.97	0.94
Geological Sciences	1.03	0.97	1.03	1.00	1.00
Physics	0.99	0.93	1.00	0.99	0.92
Average	1.01	0.98	1.01	1.00	1.00

Summary

Sixteen academic departments were selected for the examination of efficiency throughout the 2008 to 2014 academic years using DEA. The sixteen departments or DMUs identified for this study, offered bachelors, masters, and doctoral degree programs and operated under a college within the university. The inputs considered for this study were total research expenditures, state appropriated budgets, and operational budgets. The outputs considered were graduate and undergraduate degrees granted, FTE produced, student credit hours generated, scholarly works, and amount of grants awarded. The descriptive statistics for the departmental inputs, outputs, and slack targets varied considerably.

The efficiency scores for nine of the 16 departments were found to be below one using the CRS method and considered as inefficient. Seven of the 16 departments had an efficiency score of one and considered to be efficient. Overall, the largest slack augmentation identified for the outputs was undergraduate degrees granted and for six of the nine inefficient departments, required the most increase to reach an optimal efficiency score. The largest slack augmentation identified for the inputs was operating budgets with six of the nine inefficient departments requiring a decrease in operating budgets to reach an optimal efficiency score.

The Malmquist productivity index measurements showed that the mean TFP change, on average, did not change over time. Five of the 16 departments experienced a positive TFP change, eight departments declined in productivity over the period, and three had no change. Therefore, most of the departments experienced total productivity decrease.

Data envelopment analysis produces several outputs that are useful to higher education institutions and their academic departments, including efficiency scores, slacks, peer DMUs, and productivity change over time. The results of a DEA can be used as part of a comprehensive institutional review process focused on examining efficiency and also serve as a starting point for departmental review processes and benchmarking. The following chapter discusses how institutions and departments can use these results and respond to this study's research questions.

Chapter 5

Summary, Conclusions, and Recommendations

The purpose of this study was to explore the efficiency of academic departments in a public, Carnegie classified tier one, high research, comprehensive doctoral university with balanced arts and sciences undergraduate instruction. Specifically, the objectives of this study were to use a data envelopment analysis (DEA) model to determine the relative efficiencies of academic departments over the period 2008 to 2014 and examine the factors contributing to differences in the efficiency scores. Sixteen departments were selected for this study. These sixteen departments offered bachelors, masters, and doctoral degree programs and operated under a college within the university. This chapter presents a summary of the study, followed by a discussion of the research questions and major conclusions. The implications of the study and suggestions for further research conclude this chapter.

Institutions of higher education amass incredible amounts of data. Analyzing the data in a way that can improve decision making is an integral part of complex operational and management processes including resource allocation, programmatic development, and planning. Traditionally, higher education has lagged in its use of the data in operational and management processes (Desouza & Smith, 2016; Siemens & Long, 2011). This study examined the use of the analytical method, DEA, to determine the efficiency of academic departments. Data envelopment analysis was a method developed by Charnes et al. (1981) and designed to measure the relative efficiency of decision making units (DMUs). The DEA model creates a frontier of efficiency comprised of all observed efficiency scores of DMUs. The DMUs that receive an efficiency score of one emerge to create the frontier, thereby enveloping all the remaining DMUs scoring below one. For the purposes of this study, the academic departments were considered the DMUs.

Inputs and outputs for DMUs are used in the DEA model to calculate the efficiency scores. The inputs considered for this study were total research expenditures, state appropriated budgets, and operational budgets. The outputs considered were graduate and undergraduate degrees granted, full time equivalents (FTE) produced, student credit hours (SCH) generated, scholarly works, and amount of grants awarded. An output-oriented, multi-stage DEA model was used to determine the efficiency scores of DMUs. Both constant returns to scale (CRS) and variable returns to scale (VRS) methods were used in DEA calculations; however, CRS outcomes were reported for the DMUs. The CRS results identified more inefficient departments, thereby providing additional information about the factors that influenced department efficiency scores.

In addition to efficiency scores, descriptive statistics (i.e., mean, range, and standard deviation) were calculated for each input and output category of academic departments for each year's data, 2008 to 2014. The efficiency results, descriptive data, departmental slacks results, and peer department comparisons were considered in determining the factors contributing to the efficiency and inefficiency of each DMU. Malmquist indices were used to measure the shifts in efficiency over time.

The following research questions guided this study:

1. What are the relative efficiencies of academic departments?
2. What are the relative inefficiencies of academic departments?
3. What factors contribute to academic department efficiencies?
4. What factors contribute to academic department inefficiencies?

5. What are the trends of academic department efficiency over time?

To answer these questions, the DEA model results, along with an analysis of the descriptive statistics, were examined.

Discussion

Seven of the 16 academic departments were identified as efficient throughout the time period, 2008 to 2014: Biochemistry, Economics, Anthropology, English, History, Political Science, and Psychology. The remaining nine academic departments were identified as inefficient in at least one year throughout the period: Chemical and Materials Engineering (CME), Civil and Environmental Engineering (CEE), Computer Science and Engineering (CSE), Electrical Engineering, Mechanical Engineering, Chemistry, Geography, Geological Sciences, and Physics. The factors contributing to academic department efficiency were high numbers of undergraduate degree completers and low operating budgets. These were the same factors that contributed to the inefficiency of many departments. Other factors that contributed to inefficiency of departments were lower numbers of scholarly publications, graduate degree completers, and student credit hours and FTE.

It was noteworthy that the academic departments with the greatest amount of research awards and expenditures were identified as inefficient at least once during the 2008 to 2014 period. The exception was Electrical Engineering with low average research awards and expenditures. In contrast, the efficient academic departments, with the exception of Biochemistry and Psychology, had lower average amounts of research awards and expenditures. As anticipated, departments with the lowest average operating budgets, yet higher levels of instruction (FTE and SCH) were efficient, while departments with high operating budgets and lower amounts of instruction were inefficient. These findings suggested that the high research departments, on average, were found to be inefficient. Also, the high instruction departments, on average, were efficient, all the while requiring less operating budget than the high research departments.

Two of the core themes of the university mission were research and instruction. At this university, a foundational course for all undergraduates to complete was English, thereby establishing the great amount of instructional activity for that department. Similarly, other departments, such as Psychology, Economics, Physics, and Chemistry, also provided foundational courses required for most degree programs. In order to boost the research mission position, the university may consider establishing a research requirement for all undergraduates. A mandatory research requirement for all undergraduates not only serves as a strong declaration of the university's research core theme across all departments, but also could be a key component for recruitment for and fostering of increased undergraduate degree completers in the inefficient departments with targets identified in this area.

Transforming data into information. The information obtained from the efficiency results and examining the data are key in determining if and what courses of action should be taken on the institutional level, as well as the departmental level. The following is an in depth examination of the findings for the Chemical and Materials Engineering (CME) department for the 2012 year. This is followed by a discussion of the influence of peer departments, and an interpretation of the target inputs and outputs. This discussion of the CME department results is used as an example of how the results of the DEA model can transform institutional data into meaningful information.

In 2012, the CME department scored the lowest efficiency score (.30) of all scores for all departments over the entire period studied. The average efficiency score for the department was

.68, the lowest average of all departments studied. For the CME 2012 results, all of the outputs required target augmentation with the percent of increases between 232% and 800%. Grant awards required the least amount of increase and scholarly publications required the most increase to reach an optimal efficiency score. The input target augmentation percent ranged from 0% to -14%, with the most augmentation in operating budget and the least in the state appropriated funds. In general, in order to reach the efficiency frontier, the most output target increase for CME was scholarly publications and the least amount of increase was awards.

The peer departments assigned to CME for the 2012 results were Biochemistry and Civil and Environmental Engineering (CEE). Biochemistry had the more influence as a peer department (weight = 1.574) than did CEE (weight = 0.149). The CME department degree completion, instructional, and awards statistics were slightly lower than the Biochemistry statistics, while the operating budget, state appropriated funds, and research expenditures were slightly lower than the CEE department statistics. The scholarly publications recorded for CME were significantly lower than both Biochemistry and CEE.

Overview of the data suggests the CEE inputs and Biochemistry outputs were used as projected benchmarks for the CME department. However, in the case of scholarly publications, both CEE and Biochemistry influenced this output. The Biochemistry department, with significantly less inputs, produced a larger number of degree completers, had more instructional hours, greater amount of awards and scholarly publications than did CME. Additionally, with slightly more operating budget and research expenditures, the CEE instructional hours, degree completers, and scholarly publications were significantly greater than the CME department.

The data envelopment analysis model relies on the relativity of the input and output data to assign peers (Charnes et al., 1978). The peer departments received an efficiency score of one.

The peers identified by DEA produced more outputs with a given set of inputs compared to the inefficient department. The efficiency scores and factors contributing to efficient verses inefficient departments was exposed with the examination of a departmental efficiency results and the influence of peer departments on those results. The Biochemistry department was assigned as a peer department more frequently than all other departments over the period studied. This suggests that the Biochemistry department was the most similar to the inefficient departments studied.

The follow up question to these findings is what did the peer departments do differently, and perhaps better, than the inefficient department in terms of operations, student recruitment and programs leading to degree completion, research program operations and expectations, and instructional scheduling? While this question is not answered with examination of the DEA results, the question can be narrowed to specific input or output targets and the peer department having the most influence on those targets. As in the CME example, the peer departments were identified; for CME to obtain an efficiency score of one for the year 2012, the department would have needed to increase its awards by more than 3 million dollars from $1,363,169 to $4,525,957; increase its scholarly publications by 23; increase its student credit hours by 2,847 and FTE by 202; increase undergraduate degree completers by 55 and graduate degree completers by 26. This information can stimulate dialogue within the department and between departments about departmental operations, recruitment, research, and instruction.

Realistically, increasing outputs and decreasing inputs for a department may not be possible. Although the inputs and outputs reflect the statistical characteristics of a department, consideration must still be given to the fact that the department may not have control over the results of several of the inputs and outputs. For example, faculty members can be encouraged to seek and submit more grants, but there is no guarantee of award. An increase in undergraduate or graduate degree completers may be more dependent on the motivation of students than on the faculty and staff of a department. An increase in student credit hours or FTE can be done with an increase in student enrollment into departmental courses and, again, this would be dependent on other factors such as demand for the courses and classroom space.

The DEA modeled targets are useful in detailing which inputs and outputs need to be changed, and by how much, to achieve efficiency. These targets are specific to the department and based on the peer department inputs and outputs which are most similar to the inefficient department. Because the targets are specific to the department, inefficient departments can contemplate their own unique solutions to becoming efficient.

Efficiency over time. Considering the productivity of the departments over time and interpreting the Malmquist results leads to another example of using the DEA model to transform data into meaningful information. This study revealed that the Malmquist analysis of total productivity, on average, for all departments over the period 2008 to 2014, did not change. These results were surprising because during that period, the university started a process of budget reductions in 2008 and curricular review which lead to vertical cuts due to state and national economic decline. Over the period studied, the university responded to the recession by cutting approximately 600 positions, eliminated two academic departments entirely, consolidated academic departments into an organizational unit, and eliminated three undergraduate and several graduate programs (University of Nevada, Reno, 2011).

Overall, the productivity for the academic departments studied over the 2008 to 2014 period was not impacted significantly by the recession and resulting university response to it. However, the total productivity change for the period was substantial for the individual departments of Chemistry and Electrical Engineering at +10% and Economics at -13%. The changes in productivity appeared to be the result of a technology (operations) change through improving the existing technology or through new, innovative technology or both. In other words, the departments improved their operations. For Chemistry and Electrical Engineering, the outputs they were capable of producing increased over the period. The Chemistry department productivity increased due to their ability to use and improve existing technology and inputs more efficiently. The Electrical Engineering department productivity increased due their ability to use existing technology and inputs more efficiently. The Economics department productivity decreased due to a lack of growth in technological change, meaning their focus was on maintaining existing technology to produce outputs.

The Malmquist productivity results provide insight into the changes in productivity over a period of time and also changes in the relative efficiency of departments. The departments can evaluate the results and shifts in their productivity frontiers. From this information, departments can assess the impact of decisions made over a period of time that may have effected a shift in their productivity frontier.

Conclusions

There are many ways to characterize the mathematical relationship of inputs and outputs, such as production functions, stochastic frontier analysis, and data envelopment analysis. This study examined the use of DEA as a means to produce results of efficiency. Data envelopment analysis was an appealing tool because it can handle multiple inputs and outputs to measure the efficiency of higher education systems (Salerno, 2003). The inputs and outputs, while unique to each DEA study, are deterministic and may not capture the quality of the teaching and research performed in higher education. However, the inputs and outputs specified can provide a basis for discussion on improvements to the efficiency in higher education (Moreno & Tadepalli, 2002).

The identification of inputs and outputs is a critical step in the process of using DEA to inform a course of action. The inputs and outputs used this study were selected based on the core themes of the University mission (teaching and research), as well as a review of previous DEA studies. Ultimately, the selection of inputs and outputs should be aligned with the objectives of the organization and reflect relevant measurements of those objectives.

The efficiency scores and optimized targets for inputs and outputs support a rational approach to decision making; nevertheless, the results must be examined thoroughly and systematically in making decisions. The DEA results for an individual DMU or academic department, in the case of this study, are dependent on the inputs and outputs of the study set of DMUs. In other words, the results of one DMU are relative to the other DMUs of the study set. Therefore, in examining the results of a single DMU, the results of the peer DMUs should be considered when making conclusions about the efficiency of a DMU.

The intent of this study was to use DEA to obtain efficiency scores for 16 academic departments, present the model results, and identify the inputs and outputs having the most influence on efficiency. The focus of this study was on the data, results, and analysis, as a means to solve programmatic optimization. The DEA model was used to identify least efficient departments and DEA results included projected targets of inputs and outputs of inefficient departments. These results provided a means to identify factors influencing departmental efficiency scores and could contribute to data supported decision making and responses to departmental efficiency. Although the results are not generalizable given the limitations of the study, the application of DEA as a rational approach in university decision making processes is something that can be done overall.

Recommendations for Future Studies

Identifying ways to increase the efficiency of both teaching and research activities while making the available inputs, such as budgets, go as far as possible is of critical importance in terms of resource allocation, departmental development and improvement, and institutional accountability. The use of a data analysis model introduces an objective feature to what could be regarded as political and self-serving processes. The results from an academic department efficiency study serve as an objective component of the operational and management decision making processes of a university.

Studies determining the DEA results, then providing results to the units and surveying the outcomes and responses to the data analysis would provide a more comprehensive overview of the use of DEA in the decision making process. Also, research on the use of DEA as a predictive analysis in planning for units is an area that could be explored. Repeating this study for comparisons of academic departments or programs within a college, colleges within the university, and units with supporting roles for teaching or research, would provide for a more complete efficiency profile of a university. Additionally, examining the efficiency of academic departments based on different variables, such as time to degree and graduation rates, would also provide another account of departmental activities. Finally, given that this study focused on how efficient departments were in utilizing the resources provided, other studies that assess the effectiveness or quality of research and instruction are warranted.

Overall, the use of data in organizational decision making improves outputs and productivity (Brynjolfsson, Hitt, & Kim, 2011). The research of data analysis techniques for higher education is an area lacking. Institutions of higher education have access to enormous amounts of data on just about every aspect of their operations. Determining how transform the data into information that is meaningful for the institution is where studies like this study are important.

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Appendix A

Studies using data envelopment analysis to evaluate efficiency in higher education.

Author, Year	Study	Inputs	Outputs
Abbott & Doucouliagos (2003)	36 government universities in Australia	• FTE academic staff • FTE non-academic staff • Expenditures other than labor • Value of non-current assets	• FTE students • Graduate and undergraduate degrees enrolled • Undergraduate degrees conferred • Research Quantum Allocation (Federal support index of research output) • Research grants • Research spending
Ahn, Charnes, & Cooper (1988)	161 doctoral granting universities in the United States	• Instructional expenditures • Physical expenditures • Overhead expenditures	• Undergraduates • Graduates • Federal research grants and contracts
Arcelus & Coleman (1997)	32 units of a university in Canada	• FTE teachers • Support staff • Operating expenses • Library expenses	• Average enrollment per class • Average number of classes taught per department • FTE of undergraduate students in each department's program

Author, Year	Study	Inputs	Outputs
			• Undergraduate students in each department's program receiving their degree in a given year
Athanassopoulos & Shale (1997)	45 universities in the United Kingdom	• General academic expenditure • Research income • FTE graduates • FTE undergraduates • FTE academic staff • Mean A-level entry score • Tuition charges per student	• Successful leavers • Higher degrees awarded • Weighted research rating
Avkiran (2001)	36 universities in Australia	• Academic staff • Non-academic staff	• Overall enrollment • Undergraduate enrollment • Graduate enrollment • Research Quantum • Educational services • Student retention rate • Student progress rate • Graduate full-time employment rate • Fee-paying enrollment • Overseas fee-paying enrollment • Non-overseas fee-paying graduate enrollments
Beasley (1990, 1995)	52 chemistry departments and 50 physics	• General salary expenditures • Equipment expenditure	• Undergraduates • Graduates taught

Author, Year	Study	Inputs	Outputs
	departments in the United Kingdom	• Research income	• Graduates doing research • Research income • Research rating dummy
Breu & Raab (1994)	25 top ranked universities in the United States	• SAT average • Percentage of faculty with doctorates • Faculty to student ratio • Educational and general expenditures per student • Tuition charges per student	• Graduation rate • Freshmen retention rate
Casu & Thanassoulis (2006)	108 universities in the United Kingdom	• Total administrative costs	• Total income from students • Total staff costs • Technology transfer (other services rendered)
Chu Ng & Li (2000)	84 universities in China	• Researches • Research supporting staff • In-budget funds • Out-budget funds	• Manuscripts • Articles • Recognized research output • Contracts • Prices
Colbert, Levary, & Shaner (2000)	24 top ranked Master of Business Administration programs in the United States	• Faculty to student ratio • Average GMAT score of student in the program • Electives offered	• Average salary of graduates • Percentage of alumni who donate the money to the program • Student satisfaction with teaching, curriculum and placement

Author, Year	Study	Inputs	Outputs
			• Recruiter satisfaction with analytical skills, team work and global view
Facanha, Resende, & Marinho (1997)	52 federal institutions of higher learning in Brazil	• Area of buildings • Area of hospitals • Area of laboratories • Total number of students • Academic staff with doctoral degree • Academic staff with master degree • Academic staff with specialization degree • Academic staff with undergraduate degree • Academic staff of second and first degree teaching • Administrative personnel at support level • Administrative personnel with high school background • Administrative personnel with undergraduate degree or higher • Budget for current expenses • Incoming students at undergraduate level	• Undergraduate courses • Master degree level graduate courses • Doctoral degree level graduate courses • Undergraduate degree certificates • Medical school certificates • Master level thesis approved • Weighted average of evaluation of master degree courses • Weighted average of evaluation of doctoral degree courses

Author, Year	Study	Inputs	Outputs
		• Incoming medical residents	
Førsund & Kalhagen (1999)	99 colleges in Norway	• Academic staff • Administrative staff • Net operating expenses • Building size • FTE undergraduates	• Short studies leavers • Long studies • Research publications
Giménez & Martínez (2006)	42 departments at a university in Spain	• Expenditure on temporary hired teaching and research staff • Operational expenditure • Expenditure on permanent teaching and research staff	• New research segments awarded • Teaching load • Teaching quality
Johnes (1995)	60 economics departments in the United Kingdom	• Academic staff paid by institution • Academic staff paid by external funds • Short works	• Articles in academic journals • Income from research council grants • Authored books
Johnes & Johnes (1993)	36 economics departments in the United Kingdom	• Research and teaching staff • Teaching staff • Grants per capita	• Papers in academic journals • Letters in academic journals • Authored books • Contributions to edited works • Papers or communications in journals • Grants
Johnes & Johnes (1995)	36 economics departments in the United Kingdom	• Research and teaching faculty • Per capita value of external research grants	• Papers and letters in economic journals • Papers in academic journals

Author, Year	Study	Inputs	Outputs
		• Time available for research • Research facilities	• Letters in academic journals • Articles in professional journals • Authored books • Edited books • Published official reports • Contributions to edited works
Johnes (2006)	100 universities in the United Kingdom	• FTE undergraduate students studying for a first degree • FTE postgraduate students • Full-time academic staff for teaching and/or research • Capital costs (depreciation and interest) • Expenditures on libraries and information services • Expenditures on central administration and services	• First degrees awarded weighted by degree classification • Higher degrees awarded • Research grant awards
Kao & Hung (2008)	41 departments (6 clusters/colleges) at a university in Taiwan	• Personnel • Operating expenses • Floor area	• Total credit hours • Number of citation indexed papers • External grants
Katharaki & Katharakis (2010)	20 public universities in Greece	• Number of academic staff with teaching and research activity • Number of non-academic staff	• Number of graduates (undergraduate and post-graduate) • Research income

Author, Year	Study	Inputs	Outputs
		• Number of active registered students • Operating expenses other than labor	
Kuah & Wong (2011)	30 hypothetical universities in Asia	• Number of academic staff • Number of taught course students • Average students' qualifications (grade point average) • University expenditures • Number of research staff • Average research staffs' qualifications • Number of research students • Research grants	• Number of graduates from taught courses • Average graduates' results (grade point average) • Graduation rate • Graduates' employment rate • Number of graduates from research • Number of publications • Number of awards • Number of intellectual properties
Lehmann & Warning (2002)	112 universities in the United Kingdom	• Researchers • Teachers • Library spending • Research grants	• Papers • Research grants • Undergraduates • Graduates • Graduation rate • Employment rate
Madden, Savage, & Kemp (1997)	24 economic departments in Australia	• Staff	• Publications in core journals • Publications in other journals • Books • Edited books • Undergraduates

Author, Year	Study	Inputs	Outputs
Martinez & Cabrera (2000)	23 economics departments in Spain	• Professors • Non-academic staff • Books • Thesis	• Graduates • International articles • National articles
McMillan & Datta (1998)	45 universities in Canada	• Full time faculty • Full time faculty eligible for grants • Full time faculty eligible for Canadian grants • Total expenditure less faculty salaries and benefits • Total operating expenditure and sponsored research expenditure	• FTE undergraduates • FTE undergraduates in sciences • FTE undergraduates other than science • Graduates • FTE graduate in master program • FTE graduate in doctoral program • Total sponsored research expenditure • Active grants Canada Council • Active science and medical research grants (SSHRC and MRC)
Moreno & Tadepalli (2002)	42 departments at one public university in the United States	• Faculty salaries • Staff salaries • Operational budget • Equipment budget • Building space appropriated to each academic unit	• Graduate majors • Undergraduate majors • FTE produced • Student credit hours generated • Amount of grants awarded

Author, Year	Study	Inputs	Outputs
Oleson & Petersen (1995)	18 business administration and economics departments in Denmark	• Full professors • Associate and assistant professors • Research fellows	• Books • Articles published in Danish • Articles published in foreign languages • Working papers
Post & Spronk (1999)	50 physics departments in the United Kingdom	• Amount of general expenditure • Amount of equipment expenditure	• Amount of research income • Undergraduate students • Graduate students on taught courses • Graduate students doing research • University Grant Committee research rating
Rhodes & Southwick (1993)	96 public and 54 private universities in the United States	• Full professors • Associate professors • Assistant professors and other teachers • Dollars spent annually on maintenance • Dollars spent annually on library activities	• Undergraduate enrollment • Graduate enrollment • Bachelor degrees awarded • Master degrees awarded • Doctoral degrees awarded • Research funds secured
Sellers-Rubio, Mas-Ruiz, & Casado-Diaz (2010)	48 departments at one university in Spain	• Doctors • Assistants • Grant Holders • Full time lecturers • Research income • Department income	• Variables of matriculation • Quality of teaching • Articles published • Presentations given • Research period incentives • Teaching load

Author, Year	Study	Inputs	Outputs
			• Time dedicated to research • Administrative activity • Experimental character
Sinuany-Stern, Mehrez, & Barboy (1994)	21 departments at one university in Israel	• Operational expenditures • Faculty salaries • Direct departmental operational costs • Departments share in its school's operational costs • Teaching services given by other departments	• Grant money • Publications • Graduate students • Credit hours given by the department • Income from tuition fees • Overhead from external grants • Teaching services given to other departments • Other incomes
Tauer, Fried, & Fry (2007)	26 academic departments at a university in the United States	• Core funds • Professorships • Transfers in from the Dean (research and teaching) • Extension (service)	• FTE teaching, research, and extension • Credit hours taught • Refereed journal articles • Extension hours • Grants and contracts •
Thanassoulis, Kortelainen, Johnes, & Johnes (2011)	121 universities in the United Kingdom	• Total operating cost	• FTE undergraduates in medical or dentistry • FTE undergraduates science students • FTE undergraduate non-science students

Author, Year	Study	Inputs	Outputs
			• FTE postgraduate students in all disciplines • Quality-related funding and research grants • Income from other services
Thursby (2000)	104 universities with a PhD program in economics in the United States	• Private or public university • Faculty size • Federal grant years • Library expenditure • Ratio of the number of economic faculty per 100 undergraduate students at the university • Median time to complete the PhD	• Recent publications • Citation data • PhDs awarded
Thursby & Kemp (2002)	112 universities in the United States	• Professionals employed • Federal support • Total faculty in departments • Quality rating in the PhD granting departments of program area	• Licenses executed • Amount of industry sponsored research • New patent applications • Invention disclosures • Amount of royalties received
Tomkins & Green (1988)	20 accounting departments in the United Kingdom	• Staff numbers • Non-staff expenditure • Academic salaries	• Undergraduates • Research graduates • Taught graduates • Total research income • Publications

Author, Year	Study	Inputs	Outputs
Tyagi, Yadav, & Singh (2009)	19 academic departments at a university in India	• Academic staff • Non-academic staff • Departmental operating cost	• Total enrolled students • Progress (number of students placed for different jobs and number of PhD degrees awarded) • Research index
Warning (2004)	73 universities in Germany	• Expenditure on personnel • Academic salaries	• Graduates taught • Total research income • Publications

Appendix B.

Scale Efficiency Scores for Sixteen Departments for 2008 to 2014.

Department	2008	2009	2010	2011	2012	2013	2014	Department Average
Biochemistry	1	1	1	1	1	1	1	1.00
CME	0.979	1	0.792	0.986	0.77	0.995	0.763	0.90
Civil Engineering	1	1	1	1	1	0.787	1	0.97
Computer Science and Engineering	0.987	0.996	0.913	1	0.7	0.93	1	0.93
Electrical Engineering	0.807	0.841	0.982	0.957	0.99	1	1	0.94
Mechanical Engineering	1	1	0.926	0.943	0.999	0.841	0.994	0.96
Economics	1	1	1	1	1	1	1	1.00
Anthropology	1	1	1	1	1	1	1	1.00
English	1	1	1	1	1	1	1	1.00
History	1	1	1	1	1	1	1	1.00
Political Science	1	1	1	1	1	1	1	1.00
Psychology	1	1	1	1	1	1	1	1.00
Chemistry	0.81	0.829	0.937	0.821	0.818	0.986	1	0.89
Geography	1	1	0.925	0.953	0.993	1	0.835	0.96
Geological Sciences	0.997	1	0.98	0.874	1	1	1	0.98
Physics	1	1	1	1	1	0.678	0.953	0.95
Year Average	0.97	0.98	0.97	0.97	0.95	0.95	0.97	0.97

Appendix C.

Chemical and Materials Engineering Department data, 2008 to 2014.

	2008	2009	2010	2011	2012	2013	2014	Average
Undergraduate Student Data – Majors (Fall Semester Student Count)								
Majors	122	111	140	165	193	203	204	163
Degrees Granted	18	22	17	12	19	28	28	21
Time to Degree	5.2	4.5	5.1	4.8	5.6	4.8	4.9	5.0
Graduate Student Data – Master's and Doctoral (Fall Semester Student Count)								
Master's	23	18	13	10	13	5	8	13
Doctoral	13	14	20	16	23	20	19	18
Degrees Granted	13	11	20	11	9	11	3	11
Time to Degree (MS)	2.7	2.5	2.7	1.9	1.4	1.9	3	2
Time to Degree (PhD)	4	7.3	4.2	4.2	3	3.8	3	4.0
Faculty and Staff Data								
Academic Faculty (Instructional)	8	9	10	9	9	10	10	9
Full Professor	2	2	2	1	1	2	2	2
Associate Professor	4	4	4	4	6	7	6	5
Assistant Professor	2	3	4	4	2	1	2	3
Continuing Lecturers	2	1	0	0	0	0	0	0
Academic Faculty (Research)	4	3	2	3	2	0	2	2
Postdoctoral Fellows	4	2	5	3	1	3	5	3
Administrative Faculty	0	0	0	0	0	0	1	0
Classified Staff	3	3	2	3	2	2	1	2
Letter of Appointment	1	0	2	0	1	2	1	1
Graduate Teaching Assistants	4	4	6	9	13	7	13	8
Graduate Research Assistants	37	25	20	12	11	16	10	19

Total Faculty and Staff	63	47	47	39	39	40	43	45
Budget and Expenditure Data ($)								
Operating	30,188	25,659	30,319	30,319	30,319	27,799	27,208	28,830
Total State Appropriated	1,692,066	1,481,505	1,532,342	1,503,845	1,551,844	1,604,442	1,754,021	1,588,581
Total Research Expenditures	3,288,472	2,392,541	3,275,501	3,121,773	3,025,064	1,721,903	1,873,037	2,671,184
Awards	3,857,477	3,860,010	2,458,926	2,470,548	1,363,169	1,487,419	1,287,629	2,397,883
Instruction and Scholarship Data – FTE (Fall Semester), SCH (Fall Semester), Annual Scholarly Publications								
Undergraduate FTE	49.1	63.5	61.7	53.8	60.1	77.1	92.9	65.5
Graduate FTE	22.0	25.5	22.8	20.0	26.9	16.7	17.0	21.6
Total SCH	975	1,213	1,153	1,009	1,162	1,318	1,557	1,198
Scholarly Publications	15	10	10	7	3	2	0	7

Descriptive Statistics						
Outputs	Mean	Standard Deviation	Variance	Minimum	Maximum	Range
Awards	2,397,883	1,111,266	1.23E+12	1,287,629	3,860,010	2,572,381
Scholarly Publications	7	5	29	-	15	15
SCH	1198.1	196.8	3.87E+04	975.0	1557.0	582.0
FTE	87.0	12.9	167.2	71.2	109.9	38.7
Undergrad Degrees	21	6	35	12	28	16
Grad Degrees	11	5	25	3	20	17

Descriptive Statistics						
Inputs	Mean	Standard Deviation	Variance	Minimum	Maximum	Range
Operating	28,830	1,925	3.71E+06	25,659	30,319	4,660
State Appropriated	1,588,581	101,233	1.02E+10	1,481,505	1,754,021	272,516
Research Expenditures	2,671,184	669,617	4.48E+11	1,721,903	3,288,472	1,566,569

Slack Targets	2008	2009	2010	2011	2012	2013	2014
Output Targets							
Awards ($)	4,208,160	Efficient	3,412,021	3,192,002	4,525,957	2,760,631	2,623,905
% Δ	9%	0%	39%	29%	232%	86%	104%
Scholarly Publications	17	Efficient	32	32	27	26	16
% Δ	13%	0%	220%	357%	800%	1200%	1600%
SCH	2448.9	Efficient	3130.6	3370.6	4008.5	2425.7	3870.7
% Δ	151%	0%	172%	234%	245%	84%	149%
FTE	174.3	Efficient	230.4	238.1	288.5	172.3	266.0
% Δ	145%	0%	173%	223%	232%	84%	142%
Undergrad Completers	45	Efficient	75	33	74	55	58
% Δ	150%	0%	341%	175%	289%	96%	107%
Grad Completers	14	Efficient	28	14	35	20	11
% Δ	8%	0%	40%	27%	289%	82%	267%
Input Targets							
Operating Budget ($)	30,188	Efficient	24,530	30,319	26,222	27,799	27,208
% Δ	0%	0%	-19%	0%	-14%	0%	0%
State Appropriated ($)	1,671,800	Efficient	1,532,342	1,496,949	1,551,844	1,163,713	1,754,021
% Δ	-1%	0%	0%	0%	0%	-27%	0%
Research Expenditures ($)	3,288,472	Efficient	2,856,026	3,121,773	2,824,003	1,721,903	1,873,037
% Δ	0%	0%	-13%	0%	-7%	0%	0%

Appendix D.

Civil and Environmental Engineering Department data, 2008 to 2014.

	2008	2009	2010	2011	2012	2013	2014	Average
Undergraduate Student Data – Majors (Fall Semester Student Count)								
Majors	378	413	424	437	416	390	347	401
Degrees Granted	59	67	72	73	74	72	60	68
Time to Degree	5.2	5.3	5.3	5.5	5.5	5.4	5.6	5.4
Graduate Student Data – Master's and Doctoral (Fall Semester Student Count)								
Master's	37	48	56	49	38	40	48	45
Doctoral	26	32	35	36	40	41	38	35
Degrees Granted	15	21	30	30	25	27	25	25
Time to Degree (MS)	2.4	2.5	2.2	2.3	2.8	1.9	2.3	2
Time to Degree (PhD)	4.2	3.5	4.2	4.8	4.6	5.2	4.2	4.4
Faculty and Staff Data								
Academic Faculty (Instructional)	13	13	14	15	15	14	14	14
Full Professor	8	8	8	8	7	6	5	7
Associate Professor	2	3	4	4	4	6	5	4
Assistant Professor	3	2	2	3	4	2	4	3
Continuing Lecturers	1	1	3	0	1	1	1	1
Academic Faculty (Research)	5	5	5	4	3	4	4	4
Postdoctoral Fellows	2	1	1	2	2	4	1	2
Administrative Faculty	2	3	3	3	2	2	3	3
Classified Staff	7	6	7	7	7	6	6	7
Letter of Appointment	6	7	7	7	8	7	7	7
Graduate Teaching Assistants	13	6	12	11	18	12	18	13
Graduate Research Assistants	46	50	52	55	55	56	56	53
Total Faculty and Staff	95	92	104	104	111	106	110	103

Budget and Expenditure Data ($)								
Operating	42,274	38,046	48,862	48,862	44,811	44,811	44,221	44,555
Total State Appropriated	2,390,119	2,346,652	2,398,611	2,427,499	2,374,540	2,656,210	2,763,098	2,479,533
Total Research Expenditures	5,190,008	4,385,180	7,621,094	8,583,410	4,899,369	5,038,740	5,815,254	5,933,294
Awards	6,634,071	6,249,496	19,737,688	5,731,530	7,731,286	6,750,665	7,748,774	8,654,787
Instruction and Scholarship Data – FTE (Fall Semester), SCH (Fall Semester), Annual Scholarly Publications								
Undergraduate FTE	176.3	186.9	214.9	177.7	176.7	166.3	177.1	182.3
Graduate FTE	42.4	59.6	52.8	56.8	51.5	51.3	59.8	53.5
Total SCH	3,102	3,446	3,794	3,279	3,184	3,028	3,291	3,303
Scholarly Publications	22	13	16	25	21	36	22	22

Descriptive Statistics						
Outputs	Mean	Standard Deviation	Variance	Minimum	Maximum	Range
Awards	8,654,787	4,942,068	2.44E+13	5,731,530	19,737,688	14,006,158
Scholarly Publications	22	7	54	13	36	23
SCH	3303.4	255.7	6.54E+04	3028.0	3794.0	766.0
FTE	235.7	17.4	301.8	217.6	267.6	50.0
Undergrad Degrees	68	6	40	59	74	15
Grad Degrees	25	5	28	15	30	15
Descriptive Statistics						
Inputs	Mean	Standard Deviation	Variance	Minimum	Maximum	Range
Operating	44,555	3,762	1.42E+07	38,046	48,862	10,816
State Appropriated	2,479,533	162,047	2.63E+10	2,346,652	2,763,098	416,446
Research Expenditures	5,933,294	1,565,465	2.45E+12	4,385,180	8,583,410	4,198,230

Slack Targets	2008	2009	2010	2011	2012	2013	2014
Output Targets							
Awards ($)	Efficient	Efficient	Efficient	Efficient	Efficient	8,583,016	Efficient
% Δ	0%	0%	0%	0%	0%	27%	0%
Scholarly Publications	Efficient	Efficient	Efficient	Efficient	Efficient	65	Efficient
% Δ	0%	0%	0%	0%	0%	81%	0%
SCH	Efficient	Efficient	Efficient	Efficient	Efficient	5,738	Efficient
% Δ	0%	0%	0%	0%	0%	89%	0%
FTE	Efficient	Efficient	Efficient	Efficient	Efficient	405	Efficient
% Δ	0%	0%	0%	0%	0%	86%	0%
Undergrad Completers	Efficient	Efficient	Efficient	Efficient	Efficient	158	Efficient
% Δ	0%	0%	0%	0%	0%	119%	0%
Grad Completers	Efficient	Efficient	Efficient	Efficient	Efficient	35	Efficient
% Δ	0%	0%	0%	0%	0%	30%	0%
Input Targets							
Operating Budget ($)	Efficient	Efficient	Efficient	Efficient	Efficient	44,811	Efficient
% Δ	0%	0%	0%	0%	0%	0%	0%
State Appropriated ($)	Efficient	Efficient	Efficient	Efficient	Efficient	1,945,295	Efficient
% Δ	0%	0%	0%	0%	0%	-27%	0%
Research Expenditures ($)	Efficient	Efficient	Efficient	Efficient	Efficient	5,038,740	Efficient
% Δ	0%	0%	0%	0%	0%	0%	0%

Appendix E.

Computer Science and Engineering Department data, 2008 to 2014.

	2008	2009	2010	2011	2012	2013	2014	Average
Undergraduate Student Data – Majors (Fall Semester Student Count)								
Majors	255	237	277	323	379	494	473	348
Degrees Granted	29	28	39	34	33	46	41	36
Time to Degree	5.3	4.8	5.1	5.5	5	5.8	5.4	5.3
Graduate Student Data – Master's and Doctoral (Fall Semester Student Count)								
Master's	31	39	45	37	38	31	33	36
Doctoral	34	31	37	33	33	38	39	35
Degrees Granted	17	16	20	28	22	19	13	19
Time to Degree (MS)	3.2	2.9	3	2.8	3	3.2	3.1	3
Time to Degree (PhD)	5.4	5.6	4.5	5.8	5	6.4	6.8	5.6
Faculty and Staff Data								
Academic Faculty (Instructional)	13	13	13	13	12	14	16	13
Full Professor	5	5	5	5	5	5	6	5
Associate Professor	1	3	3	3	5	5	5	4
Assistant Professor	7	5	5	5	2	4	5	5
Continuing Lecturers	0	0	0	1	1	2	3	1
Academic Faculty (Research)	0	1	1	1	1	1	1	1
Postdoctoral Fellows	0	1	1	2	2	0	0	1
Administrative Faculty	1	1	3	2	2	1	1	2
Classified Staff	1	1	1	1	1	1	1	1
Letter of Appointment	1	1	1	1	2	1	0	1
Graduate Teaching Assistants	10	8	10	9	12	13	25	12
Graduate Research Assistants	23	21	33	41	29	14	20	26
Total Faculty and Staff	49	47	63	71	62	47	67	58

Budget and Expenditure Data ($)								
Operating	40,341	32,272	47,355	47,355	47,355	41,119	41,119	42,417
Total State Appropriated	2,007,591	1,967,489	2,018,549	1,987,097	2,027,064	2,089,274	2,499,293	2,085,194
Total Research Expenditures	1,935,924	1,935,924	1,969,606	2,023,520	1,930,864	1,696,722	2,119,973	1,944,648
Awards	1,212,826	2,556,633	1,947,811	1,948,366	873,976	2,686,934	2,830,602	2,008,164
Instruction and Scholarship Data – FTE (Fall Semester), SCH (Fall Semester), Annual Scholarly Publications								
Undergraduate FTE	138.9	151.2	165.9	166.4	212.1	235.3	255.5	189.3
Graduate FTE	44.4	47.3	53.6	51.0	46.1	39.3	43.9	46.5
Total SCH	2,539	2,770	3,053	3,036	3,670	3,926	4,278	3,325
Scholarly Publications	14	25	17	12	18	24	37	21

Descriptive Statistics						
Outputs	Mean	Standard Deviation	Variance	Minimum	Maximum	Range
Awards	2,008,164	748,790	5.61E+11	873,976	2,830,602	1,956,627
Scholarly Publications	21	9	73	12	37	25
SCH	3324.6	641.8	4.12E+05	2539.0	4278.0	1739.0
FTE	235.9	42.5	1.80E+03	183.3	299.5	116.2
Undergrad Degrees	36	7	43	28	46	18
Grad Degrees	19	5	23	13	28	15
Descriptive Statistics						
Inputs	Mean	Standard Deviation	Variance	Minimum	Maximum	Range
Operating	42,417	5,534	3.06E+07	32,272	47,355	15,083
State Appropriated	2,085,194	186,554	3.48E+10	1,967,489	2,499,293	531,804
Research Expenditures	1,944,648	128,706	1.66E+10	1,696,722	2,119,973	423,251

Slack Targets	2008	2009	2010	2011	2012	2013	2014
Output Targets							
Awards ($)	2,415,032	2,872,145	2,662,533	Efficient	3,168,284	2,947,674	Efficient
% Δ	99%	12%	37%	0%	263%	10%	0%
Scholarly Publications	31	28	36	Efficient	34	26	Efficient
% Δ	121%	12%	112%	0%	89%	8%	0%
SCH	5079.0	4626.4	5350.7	Efficient	6084.8	5111.7	Efficient
% Δ	100%	67%	75%	0%	66%	30%	0%
FTE	365.0	328.2	383.7	Efficient	428.4	355.6	Efficient
% Δ	99%	65%	75%	0%	66%	29%	0%
Undergrad Completers	62	76	81	Efficient	75	110	Efficient
% Δ	114%	171%	108%	0%	127%	139%	0%
Grad Completers	34	18	27	Efficient	36	21	Efficient
% Δ	100%	13%	35%	0%	64%	11%	0%
Input Targets							
Operating Budget ($)	40,341	32,272	38,078	Efficient	40,135	41,119	Efficient
% Δ	0%	0%	-20%	0%	-15%	0%	0%
State Appropriated ($)	2,007,591	1,967,489	2,018,549	Efficient	2,027,064	2,089,274	Efficient
% Δ	0%	0%	0%	0%	0%	0%	0%
Research Expenditures ($)	1,540,589	1,935,924	1,969,606	Efficient	1,930,864	1,696,722	Efficient
% Δ	-20%	0%	0%	0%	0%	0%	0%

Appendix F.

Electrical Engineering Department data, 2008 to 2014.

	2008	2009	2010	2011	2012	2013	2014	Average
Undergraduate Student Data – Majors (Fall Semester Student Count)								
Majors	137	134	159	182	193	237	243	184
Degrees Granted	23	25	26	23	25	29	45	28
Time to Degree	6.6	4.9	4.9	5.3	6.1	6	2.2	5.1
Graduate Student Data – Master's and Doctoral (Fall Semester Student Count)								
Master's	25	19	22	25	18	15	13	20
Doctoral	18	24	24	21	17	17	18	20
Degrees Granted	12	6	5	14	14	5	5	9
Time to Degree (MS)	2.4	3.6	4	3	2.4	3.8	4.5	3.4
Time to Degree (PhD)	5.2	5.5	4	7.2	5.9	6	4.3	5.4
Faculty and Staff Data								
Academic Faculty (Instructional)	9	10	10	8	8	7	9	9
Full Professor	6	6	5	5	5	4	5	5
Associate Professor	1	1	1	1	1	1	2	1
Assistant Professor	2	3	4	2	2	2	2	2
Continuing Lecturers	0	0	0	0	0	0	1	0
Academic Faculty (Research)	0	0	0	0	0	0	0	0
Postdoctoral Fellows	0	1	1	1	1	1	0	1
Administrative Faculty	0	0	0	0	0	0	0	0
Classified Staff	2	2	2	2	2	2	2	2
Letter of Appointment	2	2	5	1	1	2	5	3
Graduate Teaching Assistants	6	4	5	9	12	8	10	8
Graduate Research Assistants	10	8	9	11	2	3	4	7
Total Faculty and Staff	29	27	32	32	26	23	31	29

Budget and Expenditure Data ($)								
Operating	45,050	32,886	36,375	36,375	36,375	36,376	36,376	37,116
Total State Appropriated	1,631,692	1,595,660	1,551,699	1,480,147	1,495,376	1,481,110	1,626,149	1,551,690
Total Research Expenditures	692,415	546,338	839,072	496,424	539,395	278,572	390,303	540,360
Awards	698,471	488,653	1,081,135	161,081	269,636	788,748	804,273	613,142
Instruction and Scholarship Data – FTE (Fall Semester), SCH (Fall Semester), Annual Scholarly Publications								
Undergraduate FTE	81.3	84.3	92.9	89.7	90.3	106.6	131.3	96.6
Graduate FTE	21.1	24.0	25.1	21.7	17.1	16.9	14.5	20.1
Total SCH	1,441	1,507	1,651	1,575	1,530	1,771	2,120	1,656
Scholarly Publications	7	12	8	14	8	10	22	12

Descriptive Statistics						
Outputs	Mean	Standard Deviation	Variance	Minimum	Maximum	Range
Awards	613,142	324,428	1.05E+11	161,081	1,081,135	920,055
Scholarly Publications	12	5	27	7	22	15
SCH	1656.4	230.7	5.32E+04	1441.0	2120.0	679.0
FTE	116.7	14.6	212.9	102.4	145.7	43.3
Undergrad Degrees	28	8	60	23	45	22
Grad Degrees	9	4	19	5	14	9
Descriptive Statistics						
Inputs	Mean	Standard Deviation	Variance	Minimum	Maximum	Range
Operating	37,116	3,732	1.39E+07	32,886	45,050	12,164
State Appropriated	1,551,690	67,267	4.52E+09	1,480,147	1,631,692	151,545
Research Expenditures	540,360	185,008	3.42E+10	278,572	839,072	560,500

Slack Targets	2008	2009	2010	2011	2012	2013	2014
Output Targets							
Awards ($)	1,706,541	1,270,541	2,103,767	287,153	884,314	Efficient	Efficient
% Δ	144%	160%	95%	78%	228%	0%	0%
Scholarly Publications	19	28	16	18	12	Efficient	Efficient
% Δ	171%	133%	100%	29%	50%	0%	0%
SCH	4250.7	4570.1	4291.4	5151.7	1990.1	Efficient	Efficient
% Δ	195%	203%	160%	227%	30%	0%	0%
FTE	307.3	327.7	296.1	355	141.9	Efficient	Efficient
% Δ	200%	203%	151%	218%	32%	0%	0%
Undergrad Completers	56	85	51	59	33	Efficient	Efficient
% Δ	143%	240%	96%	157%	32%	0%	0%
Grad Completers	32	18	10	18	18	Efficient	Efficient
% Δ	167%	200%	100%	29%	29%	0%	0%
Input Targets							
Operating Budget ($)	35,118	32,757	24,594	34,164	32,491	Efficient	Efficient
% Δ	-22%	0%	-32%	-6%	-11%	0%	0%
State Appropriated ($)	1,631,692	1,595,660	1,551,699	1,480,147	1,495,376	Efficient	Efficient
% Δ	0%	0%	0%	0%	0%	0%	0%
Research Expenditures ($)	692,415	546,338	839,072	496,424	539,395	Efficient	Efficient
% Δ	0%	0%	0%	0%	0%	0%	0%

Appendix G.

Mechanical Engineering Department data, 2008 to 2014.

	2008	2009	2010	2011	2012	2013	2014	Average
Undergraduate Student Data – Majors (Fall Semester Student Count)								
Majors	340	348	427	517	548	657	670	501
Degrees Granted	44	41	56	78	67	75	96	65
Time to Degree	5.2	5.8	5.5	5.3	5.5	6	5.3	5.5
Graduate Student Data – Master's and Doctoral (Fall Semester Student Count)								
Master's	24	25	19	17	13	23	18	20
Doctoral	16	20	18	16	18	16	18	17
Degrees Granted	10	17	17	7	13	6	10	11
Time to Degree (MS)	2.2	2.0	2	2	2.6	2.2	2.1	2.2
Time to Degree (PhD)	7.5	4.5	5	3.5	4.1	0	6.3	5.2
Faculty and Staff Data								
Academic Faculty (Instructional)	12	11	11	12	11	13	11	12
Full Professor	5	4	4	4	3	4	4	4
Associate Professor	4	4	3	4	4	4	2	4
Assistant Professor	3	3	4	4	4	5	5	4
Continuing Lecturers	0	0	0	1	1	1	1	1
Academic Faculty (Research)	3	2	2	1	2	0	0	1
Postdoctoral Fellows	1	2	4	1	0	0	2	1
Administrative Faculty	0	0	0	0	1	1	1	0
Classified Staff	3	3	3	2	3	3	3	3
Letter of Appointment	8	8	4	5	2	4	1	5
Graduate Teaching Assistants	6	10	13	8	15	12	21	12
Graduate Research Assistants	30	29	22	24	22	17	11	22
Total Faculty and Staff	63	65	59	54	57	51	51	57

Budget and Expenditure Data ($)								
Operating	37,573	33,815	44,766	44,766	44,766	44,766	44,766	42,174
Total State Appropriated	1,788,939	1,629,344	1,720,850	1,738,375	1,766,208	2,014,872	2,189,616	1,835,458
Total Research Expenditures	1,814,205	2,230,366	2,088,935	2,181,896	1,635,236	1,381,608	1,132,697	1,780,706
Awards	3,834,276	2,181,620	2,224,739	1,726,304	1,416,182	1,542,393	768,337	1,956,264
Instruction and Scholarship Data – FTE (Fall Semester), SCH (Fall Semester), Annual Scholarly Publications								
Undergraduate FTE	138.3	148.9	174.9	174.6	141.3	156.7	227.9	166.1
Graduate FTE	33.6	27.6	24.2	24.9	21.2	19.9	18.0	24.2
Total SCH	2,431	2,525	2,877	2,873	2,336	2,567	3,601	2,744
Scholarly Publications	26	25	24	22	19	22	25	23

Descriptive Statistics

Outputs	Mean	Standard Deviation	Variance	Minimum	Maximum	Range
Awards	1,956,264	964,091	9.29E+11	768,337	3,834,276	3,065,940
Scholarly Publications	23	2	6	19	26	7
SCH	2744.3	430.6	1.85E+05	2336.0	3601.0	1265.0
FTE	190.3	28.1	790.0	162.6	245.9	83.3
Undergrad Degrees	65	20	389	41	96	55
Grad Degrees	11	4	20	6	17	11

Descriptive Statistics

Inputs	Mean	Standard Deviation	Variance	Minimum	Maximum	Range
Operating	42,174	4,558	2.08E+07	33,815	44,766	10,951
State Appropriated	1,835,458	195,627	3.83E+10	1,629,344	2,189,616	560,272
Research Expenditures	1,780,706	420,244	1.77E+11	1,132,697	2,230,366	1,097,669

Slack Targets	2008	2009	2010	2011	2012	2013	2014
Output Targets							
Awards ($)	Efficient	Efficient	2,880,075	2,091,565	2,970,667	2,165,867	1,393,964
% Δ	0%	0%	29%	21%	110%	40%	81%
Scholarly Publications	Efficient	Efficient	31	27	30	31	29
% Δ	0%	0%	29%	23%	58%	41%	16%
SCH	Efficient	Efficient	4279.3	4251.0	5686.4	6144.0	4930.1
% Δ	0%	0%	49%	48%	143%	139%	37%
FTE	Efficient	Efficient	308.1	297.5	404.1	425.60	346.0
% Δ	0%	0%	55%	49%	149%	141%	41%
Undergrad Completers	Efficient	Efficient	72	95	107	105	112
% Δ	0%	0%	29%	22%	60%	40%	17%
Grad Completers	Efficient	Efficient	25	14	21	20	15
% Δ	0%	0%	47%	100%	62%	233%	50%
Input Targets							
Operating Budget ($)	Efficient	Efficient	31,426	32,983	35,718	41,252	38,827
% Δ	0%	0%	-30%	-26%	-20%	-8%	-13%
State Appropriated ($)	Efficient	Efficient	1,720,850	1,738,375	1,766,208	2,014,872	2,189,616
% Δ	0%	0%	0%	0%	0%	0%	0%
Research Expenditures ($)	Efficient	Efficient	2,088,935	2,181,896	1,521,876	1,381,608	1,132,697
% Δ	0%	0%	0%	0%	-7%	0%	0%

Appendix H.

Chemistry Department data, 2008 to 2014.

	2008	2009	2010	2011	2012	2013	2014	Average
Undergraduate Student Data – Majors (Fall Semester Student Count)								
Majors	81	91	114	121	126	125	148	115
Degrees Granted	11	3	13	18	17	16	18	14
Time to Degree	6.3	4.5	4.4	4.9	5.1	5	4.6	5.0
Graduate Student Data – Master's and Doctoral (Fall Semester Student Count)								
Master's	9	5	5	9	10	8	6	7
Doctoral	48	45	50	53	54	59	67	54
Degrees Granted	16	9	6	10	9	10	11	10
Time to Degree (MS)	2.7	3.2	3	4	3.5	3.8	3.5	3.3
Time to Degree (PhD)	5.7	6.5	5	6.3	5.6	5	5.6	5.7
Faculty and Staff Data								
Academic Faculty (Instructional)	16	14	15	14	14	15	17	15
Full Professor	8	8	8	6	5	7	7	7
Associate Professor	5	4	5	5	5	3	3	4
Assistant Professor	3	2	2	3	4	5	7	4
Continuing Lecturers	2	3	2	2	1	2	2	2
Academic Faculty (Research)	1	1	1	0	0	0	0	0
Postdoctoral Fellows	8	4	6	2	2	4	3	4
Administrative Faculty	2	2	2	2	2	3	2	2
Classified Staff	9	8	8	9	8	8	8	8
Letter of Appointment	11	7	7	9	7	2	3	7
Graduate Teaching Assistants	26	26	38	41	46	55	56	41
Graduate Research Assistants	32	20	16	17	15	10	11	17
Total Faculty and Staff	107	85	95	96	95	99	102	97

Budget and Expenditure Data ($)								
Operating	136,631	129,408	175,953	153,153	153,153	155,000	155,000	151,185
Total State Appropriated	3,504,408	3,340,839	3,256,807	3,251,744	3,197,344	3,371,271	3,644,700	3,366,730
Total Research Expenditures	946,960	1,264,864	1,623,609	968,568	1,059,580	571,600	749,029	1,026,316
Awards	1,186,712	1,806,206	1,144,721	566,507	734,625	1,164,211	1,527,014	1,161,428
Instruction and Scholarship Data – FTE (Fall Semester), SCH (Fall Semester), Annual Scholarly Publications								
Undergraduate FTE	399.9	406.3	441.7	457.1	502.7	550.1	621.5	482.8
Graduate FTE	42.5	40.8	43.9	43.6	45.3	56.0	58.8	47.3
Total SCH	6,395	6,472	7,034	7,268	7,962	8,770	9,862	7,680
Scholarly Publications	30	15	20	19	23	20	32	23

Descriptive Statistics						
Outputs	Mean	Standard Deviation	Variance	Minimum	Maximum	Range
Awards	1,161,428	425,521	1.81E+11	566,507	1,806,206	1,239,699
Scholarly Publications	23	6	38	15	32	17
SCH	7680.4	1273.2	1.62E+06	6395.0	9862.0	3467.0
FTE	530.0	87.6	7.67E+03	442.4	680.2	237.8
Undergrad Degrees	14	5	29	3	18	15
Grad Degrees	10	3	9	6	16	10
Descriptive Statistics						
Inputs	Mean	Standard Deviation	Variance	Minimum	Maximum	Range
Operating	151,185	14,924	2.23E+08	129,408	175,953	46,545
State Appropriated	3,366,730	158,593	2.52E+10	3,197,344	3,644,700	447,356
Research Expenditures	1,026,316	343,525	1.18E+11	571,600	1,623,609	1,052,009

Slack Targets	2008	2009	2010	2011	2012	2013	2014
Output Targets							
Awards ($)	1,811,160	2,681,959	1,632,995	919,042	1,342,294	1,181,062	Efficient
% Δ	53%	48%	43%	62%	83%	1%	0%
Scholarly Publications	46	57	53	40	46	20	Efficient
% Δ	53%	280%	165%	111%	100%	0%	0%
SCH	9760.1	9610.0	10034.3	11884.2	12423.1	9028.6	Efficient
% Δ	53%	48%	43%	64%	56%	3%	0%
FTE	675.2	686.7	711.6	812.4	843.2	614.9	Efficient
% Δ	53%	54%	47%	62%	54%	1%	0%
Undergrad Completers	91	167	114	112	124	72	Efficient
% Δ	727%	5467%	777%	522%	629%	350%	0%
Grad Completers	32	36	35	38	14	14	Efficient
% Δ	100%	300%	483%	280%	56%	40%	0%
Input Targets							
Operating Budget ($)	58,160	67,782	67,321	76,960	28,063	49,401	Efficient
% Δ	-57%	-48%	-62%	-50%	-82%	-68%	0%
State Appropriated ($)	3,504,408	3,340,839	3,256,807	3,251,744	3,197,344	3,371,271	Efficient
% Δ	0%	0%	0%	0%	0%	0%	0%
Research Expenditures ($)	946,960	1,264,864	1,061,426	796,637	532,750	571,600	Efficient
% Δ	0%	0%	-35%	-18%	-50%	0%	0%

Appendix I.

Geography Department data, 2008 to 2014.

	2008	2009	2010	2011	2012	2013	2014	Average
Undergraduate Student Data – Majors (Fall Semester Student Count)								
Majors	66	59	49	50	60	47	45	54
Degrees Granted	24	17	18	9	17	13	9	15
Time to Degree	5.4	6.4	7.3	4.8	7.4	5	5.7	6.0
Graduate Student Data – Master's and Doctoral (Fall Semester Student Count)								
Master's	23	26	25	23	15	14	8	19
Doctoral	5	7	10	15	18	20	18	13
Degrees Granted	11	13	7	13	5	9	6	9
Time to Degree (MS)	3.4	2.6	3	2	2.7	3.0	4.0	2.9
Time to Degree (PhD)	n/a	n/a	n/a	4.5	5.0	7	5.0	5.4
Faculty and Staff Data								
Academic Faculty (Instructional)	8	9	8	7	7	9	10	8
Full Professor	3	3	3	4	5	4	4	4
Associate Professor	2	2	3	2	1	3	3	2
Assistant Professor	3	4	2	1	1	2	3	2
Continuing Lecturers	1	0	0	0	0	0	0	0
Academic Faculty (Research)	0	0	0	0	0	0	0	0
Postdoctoral Fellows	0	0	0	0	0	2	2	1
Administrative Faculty	1	2	3	4	4	3	3	3
Classified Staff	2	3	2	1	1	2	1	2
Letter of Appointment	2	3	10	5	0	2	3	4
Graduate Teaching Assistants	10	10	10	12	13	10	13	11
Graduate Research Assistants	14	9	8	13	11	12	10	11
Total Faculty and Staff	38	36	41	42	36	40	42	39

Budget and Expenditure Data ($)								
Operating	26,377	24,983	37,573	33,073	33,073	31,181	35,000	31,609
Total State Appropriated	1,196,261	1,199,845	1,243,948	1,179,725	1,219,206	1,155,964	1,377,356	1,224,615
Total Research Expenditures	1,167,454	970,012	1,544,956	1,582,238	1,878,873	1,610,837	960,152	1,387,789
Awards	1,959,134	394,957	1,914,441	1,269,927	2,528,247	2,183,570	756,241	1,572,359
Instruction and Scholarship Data – FTE (Fall Semester), SCH (Fall Semester), Annual Scholarly Publications								
Undergraduate FTE	98.9	87.0	95.3	95.4	99.1	89.3	103.9	95.6
Graduate FTE	26.9	24.4	26.8	31.6	22.3	29.4	20.2	25.9
Total SCH	1,792	1,580	1,725	1,772	1,717	1,641	1,760	1,712
Scholarly Publications	25	25	23	16	13	30	18	21

Descriptive Statistics						
Outputs	Mean	Standard Deviation	Variance	Minimum	Maximum	Range
Awards	1,572,359	785,038	6.16E+11	394,957	2,528,247	2,133,290
Scholarly Publications	21	6	36	13	30	17
SCH	1712.4	76.3	5.83E+03	1580.0	1792.0	212.0
FTE	121.5	5.3	27.7	111.4	127.0	15.6
Undergrad Degrees	15	5	29	9	24	15
Grad Degrees	9	3	11	5	13	8
Descriptive Statistics						
Inputs	Mean	Standard Deviation	Variance	Minimum	Maximum	Range
Operating	31,609	4,524	2.05E+07	24,983	37,573	12,590
State Appropriated	1,224,615	72,891	5.31E+09	1,155,964	1,377,356	221,392
Research Expenditures	1,387,789	355,758	1.27E+11	960,152	1,878,873	918,721

Slack Targets	2008	2009	2010	2011	2012	2013	2014
Output Targets							
Awards ($)	Efficient	Efficient	2,193,788	1,394,470	3,173,983	Efficient	918,021
% Δ	0%	0%	15%	10%	26%	0%	21%
Scholarly Publications	Efficient	Efficient	26	18	16	Efficient	22
% Δ	0%	0%	13%	13%	23%	0%	22%
SCH	Efficient	Efficient	3387.7	2773.9	2744.5	Efficient	2232.2
% Δ	0%	0%	96%	57%	60%	0%	27%
FTE	Efficient	Efficient	239.2	195.8	195.8	Efficient	155.1
% Δ	0%	0%	96%	54%	61%	0%	25%
Undergrad Completers	Efficient	Efficient	32	36	53	Efficient	46
% Δ	0%	0%	78%	300%	212%	0%	411%
Grad Completers	Efficient	Efficient	12	14	13	Efficient	9
% Δ	0%	0%	71%	8%	160%	0%	50%
Input Targets							
Operating Budget ($)	Efficient	Efficient	26,704	25,459	24,022	Efficient	29,338
% Δ	0%	0%	-29%	-23%	-27%	0%	-16%
State Appropriated ($)	Efficient	Efficient	1,243,948	1,179,725	1,219,206	Efficient	1,377,356
% Δ	0%	0%	0%	0%	0%	0%	0%
Research Expenditures ($)	Efficient	Efficient	1,544,956	1,582,238	1,878,872	Efficient	960,152
% Δ	0%	0%	0%	0%	0%	0%	0%

Appendix J.

Geological Sciences Department data, 2008 to 2014.

	2008	2009	2010	2011	2012	2013	2014	Average
Undergraduate Student Data – Majors (Fall Semester Student Count)								
Majors	141	128	141	130	155	163	171	147
Degrees Granted	21	23	27	23	30	31	27	26
Time to Degree	5.4	5.3	4.9	4.8	6.0	5	4.8	5.1
Graduate Student Data – Master's and Doctoral (Fall Semester Student Count)								
Master's	38	31	32	37	44	42	32	37
Doctoral	21	18	21	22	28	29	29	24
Degrees Granted	30	30	29	27	30	37	29	30
Time to Degree (MS)	2.8	3.2	4	3	3.0	2.5	2.5	2.9
Time to Degree (PhD)	5.8	4.5	4	8.0	6.6	7	4.5	5.8
Faculty and Staff Data								
Academic Faculty (Instructional)	14	13	13	11	11	12	11	12
Full Professor	11	12	12	10	10	10	8	10
Associate Professor	3	1	0	0	0	0	0	1
Assistant Professor	0	0	1	1	1	2	3	1
Continuing Lecturers	4	4	4	2	2	3	3	3
Academic Faculty (Research)	0	0	0	1	1	0	0	0
Postdoctoral Fellows	2	1	3	1	0	0	0	1
Administrative Faculty	0	0	0	0	0	0	0	0
Classified Staff	4	3	3	3	3	3	2	3
Letter of Appointment	1	0	0	0	1	0	2	1
Graduate Teaching Assistants	17	9	16	16	18	11	12	14
Graduate Research Assistants	20	19	14	20	23	20	25	20
Total Faculty and Staff	62	49	53	54	59	49	55	54

Budget and Expenditure Data ($)								
Operating	42,018	39,797	66,107	58,107	58,107	59,000	60,000	54,734
Total State Appropriated	2,881,081	2,735,051	2,555,749	2,415,679	2,569,797	2,384,216	2,496,688	2,576,894
Total Research Expenditures	1,243,746	1,267,886	1,136,859	823,814	729,930	764,323	718,121	954,954
Awards	1,581,324	819,143	1,222,669	360,713	1,209,982	706,839	854,317	964,998
Instruction and Scholarship Data – FTE (Fall Semester), SCH (Fall Semester), Annual Scholarly Publications								
Undergraduate FTE	147.1	174.9	160.5	145.5	145.6	150.4	142.9	152.4
Graduate FTE	61.8	54.3	55.6	48.6	50.5	54.5	41.1	52.3
Total SCH	2,877	3,212	3,003	2,703	2,737	2,845	2,587	2,852
Scholarly Publications	24	29	34	20	20	27	13	24

Descriptive Statistics						
Outputs	Mean	Standard Deviation	Variance	Minimum	Maximum	Range
Awards	964,998	402,409	1.62E+11	360,713	1,581,324	1,220,611
Scholarly Publications	24	7	48	13	34	21
SCH	2852.0	207.7	4.31E+04	2587.0	3212.0	625.0
FTE	204.8	15.1	227.1	184.0	229.2	45.2
Undergrad Degrees	26	4	14	21	31	10
Grad Degrees	30	3	10	27	37	10
Descriptive Statistics						
Inputs	Mean	Standard Deviation	Variance	Minimum	Maximum	Range
Operating	54,734	9,856	9.71E+07	39,797	66,107	26,310
State Appropriated	2,576,894	176,819	3.13E+10	2,384,216	2,881,081	496,865
Research Expenditures	954,954	249,893	6.24E+10	718,121	1,267,886	549,765

Slack Targets	2008	2009	2010	2011	2012	2013	2014
Output Targets							
Awards ($)	2,114,195	Efficient	1,247,549	784,104	Efficient	Efficient	Efficient
% Δ	34%	0%	2%	117%	0%	0%	0%
Scholarly Publications	29	Efficient	44	23	Efficient	Efficient	Efficient
% Δ	21%	0%	29%	15%	0%	0%	0%
SCH	6268.4	Efficient	7634.0	7399.7	Efficient	Efficient	Efficient
% Δ	118%	0%	154%	174%	0%	0%	0%
FTE	445.5	Efficient	543.4	509.3	Efficient	Efficient	Efficient
% Δ	113%	0%	151%	162%	0%	0%	0%
Undergrad Completers	78	Efficient	94	74	Efficient	Efficient	Efficient
% Δ	271%	0%	248%	222%	0%	0%	0%
Grad Completers	36	Efficient	30	31	Efficient	Efficient	Efficient
% Δ	20%	0%	3%	15%	0%	0%	0%
Input Targets							
Operating Budget ($)	42,018	Efficient	51,218	57,840	Efficient	Efficient	Efficient
% Δ	0%	0%	-23%	0%	0%	0%	0%
State Appropriated ($)	2,339,930	Efficient	2,555,749	2,415,679	Efficient	Efficient	Efficient
% Δ	-19%	0%	0%	0%	0%	0%	0%
Research Expenditures ($)	1,243,746	Efficient	1,136,859	823,814	Efficient	Efficient	Efficient
% Δ	0%	0%	0%	0%	0%	0%	0%

Appendix K.

Physics Department data, 2008 to 2014.

	2008	2009	2010	2011	2012	2013	2014	Average
Undergraduate Student Data – Majors (Fall Semester Student Count)								
Majors	60	79	86	100	87	105	124	92
Degrees Granted	6	10	10	15	14	16	14	12
Time to Degree	4.8	5.6	5.1	4.6	5.4	5	5.2	5.1
Graduate Student Data – Master's and Doctoral (Fall Semester Student Count)								
Master's	16	11	21	30	24	28	24	22
Doctoral	54	54	50	44	28	49	52	47
Degrees Granted	9	13	13	17	17	9	18	14
Time to Degree (MS)	n/a	4.0	2	3	2.8	2.8	2.9	2.9
Time to Degree (PhD)	4.5	6.2	6	6.0	6.2	6	7.5	6.1
Faculty and Staff Data								
Academic Faculty (Instructional)	10	9	8	11	11	10	11	10
Full Professor	4	3	4	8	8	7	7	6
Associate Professor	5	5	3	1	1	1	1	2
Assistant Professor	1	1	1	2	2	2	3	2
Continuing Lecturers	7	8	6	5	5	4	6	6
Academic Faculty (Research)	11	10	9	10	8	7	5	9
Postdoctoral Fellows	5	5	3	4	2	3	4	4
Administrative Faculty	5	5	6	3	2	3	3	4
Classified Staff	12	11	8	8	9	9	8	9
Letter of Appointment	3	3	3	3	3	6	4	4
Graduate Teaching Assistants	19	14	16	18	19	17	22	18
Graduate Research Assistants	42	40	37	37	33	25	20	33
Total Faculty and Staff	114	105	96	99	92	84	83	96

Budget and Expenditure Data ($)								
Operating	50,860	48,171	56,111	50,511	50,511	100,000	100,000	65,166
Total State Appropriated	2,639,361	2,479,070	2,377,137	2,463,959	2,489,577	2,566,603	2,665,941	2,525,950
Total Research Expenditures	7,015,274	6,762,482	6,002,291	6,022,067	5,186,331	4,264,591	3,640,864	5,556,272
Awards	7,150,872	6,894,346	5,068,855	7,149,186	4,474,093	4,228,063	1,827,596	5,256,144
Instruction and Scholarship Data – FTE (Fall Semester), SCH (Fall Semester), Annual Scholarly Publications								
Undergraduate FTE	285.9	300.3	341.1	336.5	360.5	411.1	423.8	351.3
Graduate FTE	51.2	53.9	50.9	49.3	52.5	46.9	44.8	49.9
Total SCH	4,785	5,040	5,621	5,549	4,494	6,629	6,789	5,558
Scholarly Publications	106	80	89	59	84	30	51	71

Descriptive Statistics						
Outputs	Mean	Standard Deviation	Variance	Minimum	Maximum	Range
Awards	5,256,144	1,971,289	3.89E+12	1,827,596	7,150,872	5,323,276
Scholarly Publications	71	26	671	30	106	76
SCH	5558.1	881.7	7.77E+05	4494.0	6789.0	2295.0
FTE	401.3	49.2	2.42E+03	337.1	468.6	131.5
Undergrad Degrees	12	4	13	6	16	10
Grad Degrees	14	4	14	9	18	9
Descriptive Statistics						
Inputs	Mean	Standard Deviation	Variance	Minimum	Maximum	Range
Operating	65,166	23,916	5.72E+08	48,171	100,000	51,829
State Appropriated	2,525,950	102,973	1.06E+10	2,377,137	2,665,941	288,804
Research Expenditures	5,556,272	1,256,557	1.58E+12	3,640,864	7,015,274	3,374,410

Slack Targets	2008	2009	2010	2011	2012	2013	2014
Output Targets							
Awards ($)	Efficient	Efficient	Efficient	Efficient	Efficient	6,237,473	1,917,941
% Δ	0%	0%	0%	0%	0%	48%	5%
Scholarly Publications	Efficient	Efficient	Efficient	Efficient	Efficient	52	54
% Δ	0%	0%	0%	0%	0%	73%	6%
SCH	Efficient	Efficient	Efficient	Efficient	Efficient	9817.6	7124.6
% Δ	0%	0%	0%	0%	0%	48%	5%
FTE	Efficient	Efficient	Efficient	Efficient	Efficient	675.7	502.3
% Δ	0%	0%	0%	0%	0%	48%	7%
Undergrad Completers	Efficient	Efficient	Efficient	Efficient	Efficient	150	187
% Δ	0%	0%	0%	0%	0%	838%	1236%
Grad Completers	Efficient	Efficient	Efficient	Efficient	Efficient	29	37
% Δ	0%	0%	0%	0%	0%	222%	106%
Input Targets							
Operating Budget ($)	Efficient	Efficient	Efficient	Efficient	Efficient	37,888	54,189
% Δ	0%	0%	0%	0%	0%	-62%	-46%
State Appropriated ($)	Efficient	Efficient	Efficient	Efficient	Efficient	2,566,603	2,665,941
% Δ	0%	0%	0%	0%	0%	0%	0%
Research Expenditures ($)	Efficient	Efficient	Efficient	Efficient	Efficient	3,683,528	3,640,864
% Δ	0%	0%	0%	0%	0%	-14%	0%

Appendix L.

Biochemistry Department data, 2008 to 2014.

	2008	2009	2010	2011	2012	2013	2014	Average
Undergraduate Student Data – Majors (Fall Semester Student Count)								
Majors	326	296	357	395	403	441	409	375
Degrees Granted	39	39	44	54	40	68	82	52
Time to Degree	4.5	4.5	4.8	4.8	5.2	5	4.4	4.7
Graduate Student Data – Master's and Doctoral (Fall Semester Student Count)								
Master's	6	7	14	10	15	16	15	12
Doctoral	27	27	30	30	30	18	15	25
Degrees Granted	15	6	16	10	20	15	20	15
Time to Degree (MS)	n/a	n/a	4	3	2.0	5.5	3.0	3.5
Time to Degree (PhD)	5.1	5.0	8	6.0	6.4	5	6.1	5.9
Faculty and Staff Data								
Academic Faculty (Instructional)	14	13	11	12	11	10	11	12
Full Professor	7	6	6	6	7	7	7	7
Associate Professor	5	5	5	6	4	3	3	4
Assistant Professor	2	2	0	0	0	0	1	1
Continuing Lecturers	2	3	3	2	4	3	5	3
Academic Faculty (Research)	3	1	1	5	6	5	4	4
Postdoctoral Fellows	10	11	8	9	5	9	5	8
Administrative Faculty	0	0	0	0	2	0	0	0
Classified Staff	17	16	17	11	10	9	10	13
Letter of Appointment	2	1	2	1	0	0	2	1
Graduate Teaching Assistants	0	0	1	2	5	1	1	1
Graduate Research Assistants	36	34	29	30	24	18	17	27
Total Faculty and Staff	84	79	72	72	67	55	55	69

Budget and Expenditure Data ($)								
Operating	17,115	12,259	12,402	12,402	12,402	17,527	23,927	15,433
Total State Appropriated	1,010,700	948,151	825,642	747,930	760,305	767,002	859,468	845,600
Total Research Expenditures	2,093,316	2,095,293	1,293,479	1,424,916	1,328,676	2,209,419	1,930,965	1,768,009
Awards	1,998,628	2,422,520	717,132	605,606	2,140,906	3,743,866	278,563	1,701,031
Instruction and Scholarship Data – FTE (Fall Semester), SCH (Fall Semester), Annual Scholarly Publications								
Undergraduate FTE	76.1	84.5	92.9	116.7	126.2	140.1	137.2	110.5
Graduate FTE	35.8	33.1	38.5	38.1	35.4	31.1	27.5	34.2
Total SCH	1,498	1,591	1,773	2,129	2,244	2,425	2,343	2,000
Scholarly Publications	21	34	20	19	15	28	24	23

Descriptive Statistics						
Outputs	Mean	Standard Deviation	Variance	Minimum	Maximum	Range
Awards	1,701,031	1,236,069	1.53E+12	278,563	3,743,866	3,465,303
Scholarly Publications	23	6	40	15	34	19
SCH	2000.4	375.3	1.41E+05	1498.0	2425.0	927.0
FTE	144.8	24.1	578.9	111.9	171.2	59.3
Undergrad Degrees	52	17	284	39	82	43
Grad Degrees	15	5	26	6	20	14
Descriptive Statistics						
Inputs	Mean	Standard Deviation	Variance	Minimum	Maximum	Range
Operating	15,433	4,416	1.95E+07	12,259	23,927	11,668
State Appropriated	845,600	101,125	1.02E+10	747,930	1,010,700	262,770
Research Expenditures	1,768,009	402,128	1.62E+11	1,293,479	2,209,419	915,940

Appendix M.

Economics Department data, 2008 to 2014.

	2008	2009	2010	2011	2012	2013	2014	Average
Undergraduate Student Data – Majors (Fall Semester Student Count)								
Majors	81	49	63	97	120	153	170	105
Degrees Granted	53	34	38	70	73	67	105	63
Time to Degree	5.6	5.5	5.3	4.8	5.2	5	5.1	5.3
Graduate Student Data – Master's and Doctoral (Fall Semester Student Count)								
Master's	24	21	16	25	25	15	16	20
Doctoral	n/a	n/a	n/a	13	24	23	24	21
Degrees Granted	5	12	4	4	8	10	11	8
Time to Degree (MS)	2.0	2.7	2	2	2.4	4.0	3.3	2.7
Time to Degree (PhD)	n/a	n/a	n/a	n/a	3.5	2	6.5	4.0
Faculty and Staff Data								
Academic Faculty (Instructional)	12	12	12	13	14	13	14	13
Full Professor	7	8	8	8	8	7	8	8
Associate Professor	3	2	3	5	5	5	4	4
Assistant Professor	2	2	1	0	1	1	2	1
Continuing Lecturers	3	3	3	3	2	2	3	3
Academic Faculty (Research)	1	1	0	2	1	1	1	1
Postdoctoral Fellows	0	0	0	0	0	0	0	0
Administrative Faculty	0	0	0	5	4	4	3	2
Classified Staff	1	1	1	1	2	2	2	1
Letter of Appointment	5	5	5	3	5	8	9	6
Graduate Teaching Assistants	1	0	0	1	1	0	1	1
Graduate Research Assistants	9	4	3	6	12	17	19	10
Total Faculty and Staff	32	26	24	34	41	47	52	37

Budget and Expenditure Data ($)								
Operating	17,325	16,459	16,459	16,459	16,459	16,459	20,797	17,202
Total State Appropriated	2,025,121	1,982,807	2,077,754	1,933,756	1,881,050	1,839,188	2,037,111	1,968,112
Total Research Expenditures	109,340	123,994	16,112	33,272	302,751	729,233	627,165	277,410
Awards	190,075	108,858	413,525	63,815	773,516	1,230,424	1,033,238	544,779
Instruction and Scholarship Data – FTE (Fall Semester), SCH (Fall Semester), Annual Scholarly Publications								
Undergraduate FTE	434.5	409.2	419.6	435.3	466.3	506.2	543.9	459.3
Graduate FTE	21.0	22.2	16.6	28.4	30.1	30.9	22.6	24.5
Total SCH	6,767	6,395	6,487	6,871	7,315	7,912	8,392	7,163
Scholarly Publications	22	16	21	21	27	16	14	20

Descriptive Statistics						
Outputs	Mean	Standard Deviation	Variance	Minimum	Maximum	Range
Awards	544,779	470,003	2.21E+11	63,815	1,230,424	1,166,609
Scholarly Publications	20	5	20	14	27	13
SCH	7162.7	750.9	5.64E+05	6395.0	8392.0	1997.0
FTE	483.8	51.8	2.68E+03	431.4	566.6	135.2
Undergrad Degrees	63	24	582	34	105	71
Grad Degrees	8	3	12	4	12	8
Descriptive Statistics						
Inputs	Mean	Standard Deviation	Variance	Minimum	Maximum	Range
Operating	17,202	1,618	2.62E+06	16,459	20,797	4,338
State Appropriated	1,968,112	87,206	7.60E+09	1,839,188	2,077,754	238,566
Research Expenditures	277,410	290,625	8.45E+10	16,112	729,233	713,121

Appendix N.

Anthropology Department data, 2008 to 2014.

	2008	2009	2010	2011	2012	2013	2014	Average
Undergraduate Student Data – Majors (Fall Semester Student Count)								
Majors	93	102	113	134	125	132	129	118
Degrees Granted	23	21	26	40	26	38	34	30
Time to Degree	4.8	5.0	4.7	4.8	4.5	6	5.6	5.0
Graduate Student Data – Master's and Doctoral (Fall Semester Student Count)								
Master's	32	30	27	26	29	30	37	30
Doctoral	14	14	12	13	14	15	15	14
Degrees Granted	9	6	6	13	10	7	12	9
Time to Degree (MS)	4.3	4.3	4	4	3.2	3.3	2.9	3.7
Time to Degree (PhD)	5.0	5.0	8	5.8	5.2	7	n/a	5.9
Faculty and Staff Data								
Academic Faculty (Instructional)	9	8	8	8	9	9	12	9
Full Professor	2	2	2	1	1	1	2	2
Associate Professor	1	2	2	3	3	4	4	3
Assistant Professor	6	4	4	4	5	4	6	5
Continuing Lecturers	0	0	0	0	0	0	0	0
Academic Faculty (Research)	0	0	0	0	0	0	0	0
Postdoctoral Fellows	0	0	0	0	0	0	0	0
Administrative Faculty	0	0	0	0	0	0	0	0
Classified Staff	2	2	2	1	1	1	1	1
Letter of Appointment	2	1	3	3	1	1	2	2
Graduate Teaching Assistants	12	7	11	11	16	15	17	13
Graduate Research Assistants	4	5	5	7	7	4	6	5
Total Faculty and Staff	29	23	29	30	34	30	38	30

Budget and Expenditure Data ($)								
Operating	28,047	26,645	26,645	25,645	25,654	25,654	25,654	26,278
Total State Appropriated	1,210,057	1,216,429	1,192,707	1,068,642	1,093,083	1,216,420	1,337,584	1,190,703
Total Research Expenditures	126,087	130,529	99,231	16,585	135,026	160,569	101,696	109,961
Awards	88,541	117,424	57,500	10,000	291,771	121,075	109,738	113,721
Instruction and Scholarship Data – FTE (Fall Semester), SCH (Fall Semester), Annual Scholarly Publications								
Undergraduate FTE	168.1	190.3	235.9	255.0	240.7	260.7	299.3	235.7
Graduate FTE	25.0	24.6	21.9	22.4	28.2	27.8	38.4	26.9
Total SCH	2,793	3,123	3,772	4,062	3,919	4,209	4,907	3,826
Scholarly Publications	17	15	17	12	17	17	11	15

Descriptive Statistics						
Outputs	Mean	Standard Deviation	Variance	Minimum	Maximum	Range
Awards	113,721	87,881	7.72E+09	10,000	291,771	281,771
Scholarly Publications	15	3	7	11	17	6
SCH	3826.4	700.5	4.91E+05	2793.0	4907.0	2114.0
FTE	262.6	47.8	2.28E+03	193.1	337.7	144.6
Undergrad Degrees	30	8	57	21	40	19
Grad Degrees	9	3	8	6	13	7
Descriptive Statistics						
Inputs	Mean	Standard Deviation	Variance	Minimum	Maximum	Range
Operating	26,278	910	8.28E+05	25,645	28,047	2,402
State Appropriated	1,190,703	89,167	7.95E+09	1,068,642	1,337,584	268,942
Research Expenditures	109,961	46,143	2.13E+09	16,585	160,569	143,984

Appendix O.

English Department data, 2008 to 2014.

	2008	2009	2010	2011	2012	2013	2014	Average
Undergraduate Student Data – Majors (Fall Semester Student Count)								
Majors	292	301	311	318	330	288	275	302
Degrees Granted	76	63	68	66	87	64	64	70
Time to Degree	5.9	5.8	5.3	5.2	5.4	6	5.0	5.5
Graduate Student Data – Master's and Doctoral (Fall Semester Student Count)								
Master's	35	32	35	37	28	25	22	31
Doctoral	41	31	34	35	32	45	38	37
Degrees Granted	20	18	16	19	15	18	9	16
Time to Degree (MS)	3.1	2.4	3	2	2.2	3.1	2.2	2.6
Time to Degree (PhD)	6.9	5.8	7	7.0	6.5	8	6.3	6.9
Faculty and Staff Data								
Academic Faculty (Instructional)	23	23	23	24	24	22	24	23
Full Professor	6	6	7	7	6	7	7	7
Associate Professor	9	9	8	11	12	10	12	10
Assistant Professor	8	8	8	6	6	5	5	7
Continuing Lecturers	24	21	19	17	17	20	17	19
Academic Faculty (Research)	0	0	0	0	0	0	0	0
Postdoctoral Fellows	1	1	1	0	1	1	1	1
Administrative Faculty	0	0	0	0	0	0	0	0
Classified Staff	3	4	4	4	3	4	4	4
Letter of Appointment	19	15	32	31	33	35	27	27
Graduate Teaching Assistants	41	31	34	32	38	33	44	36
Graduate Research Assistants	1	6	3	7	0	0	0	2
Total Faculty and Staff	112	101	116	115	116	115	117	113

Budget and Expenditure Data ($)								
Operating	64,376	61,157	61,157	53,657	53,725	53,725	53,725	57,360
Total State Appropriated	4,257,369	4,079,378	4,872,408	4,684,614	4,800,107	4,925,792	4,973,112	4,656,111
Total Research Expenditures	15,795	0	0	0	17,016	21,771	16,476	10,151
Awards	2,000	76,762	1,803	44,480	12,713	1,425	43,588	26,110
Instruction and Scholarship Data – FTE (Fall Semester), SCH (Fall Semester), Annual Scholarly Publications								
Undergraduate FTE	643.3	640.9	820.3	828.5	844.3	861.5	900.3	791.3
Graduate FTE	56.8	50.9	51.3	49.4	41.7	47.1	47.3	49.2
Total SCH	10,247	10,160	12,846	12,943	13,093	13,404	13,988	12,383
Scholarly Publications	30	7	12	17	17	18	14	16

Descriptive Statistics						
Outputs	Mean	Standard Deviation	Variance	Minimum	Maximum	Range
Awards	26,110	29,353	8.62E+08	1,425	76,762	75,337
Scholarly Publications	16	7	50	7	30	23
SCH	12383.0	1535.9	2.36E+06	10160.0	13988.0	3828.0
FTE	840.5	101.9	1.04E+04	691.9	947.6	255.7
Undergrad Degrees	70	9	78	63	87	24
Grad Degrees	16	4	14	9	20	11
Descriptive Statistics						
Inputs	Mean	Standard Deviation	Variance	Minimum	Maximum	Range
Operating	57,360	4,680	2.19E+07	53,657	64,376	10,719
State Appropriated	4,656,111	349,563	1.22E+11	4,079,378	4,973,112	893,734
Research Expenditures	10,151	9,688	9.39E+07	0	21,771	21,771

Appendix P.

History Department data, 2008 to 2014.

	2008	2009	2010	2011	2012	2013	2014	Average
Undergraduate Student Data – Majors (Fall Semester Student Count)								
Majors	147	151	170	156	146	113	130	145
Degrees Granted	28	29	36	33	46	28	28	33
Time to Degree	5.8	5.1	6.0	5.6	5.6	6	6.2	5.7
Graduate Student Data – Master's and Doctoral (Fall Semester Student Count)								
Master's	16	27	30	22	23	21	22	23
Doctoral	6	8	12	11	8	10	9	9
Degrees Granted	2	6	4	7	5	9	7	6
Time to Degree (MS)	2.0	4.6	5	3	4.7	4.4	5.8	4.2
Time to Degree (PhD)	n/a	6.0	10	6.0	n/a	n/a	9.8	7.8
Faculty and Staff Data								
Academic Faculty (Instructional)	16	16	15	15	15	15	18	16
Full Professor	7	7	6	4	4	4	4	5
Associate Professor	8	8	9	9	9	9	9	9
Assistant Professor	1	1	0	2	2	2	5	2
Continuing Lecturers	5	2	3	2	3	2	1	3
Academic Faculty (Research)	0	0	0	0	0	0	0	0
Postdoctoral Fellows	0	0	0	1	1	1	1	1
Administrative Faculty	0	1	1	1	0	0	0	0
Classified Staff	1	1	1	1	1	1	1	1
Letter of Appointment	3	1	1	1	2	2	1	2
Graduate Teaching Assistants	13	11	12	14	11	8	12	12
Graduate Research Assistants	0	1	0	0	0	0	0	0
Total Faculty and Staff	38	33	33	35	33	29	34	34

Budget and Expenditure Data ($)								
Operating	27,587	26,208	26,208	25,208	25,227	25,227	25,227	25,842
Total State Appropriated	2,437,014	2,368,347	2,263,664	2,112,460	2,145,456	2,243,775	2,331,940	2,271,808
Total Research Expenditures	0	0	0	0	2,175	0	1,099	468
Awards	97,000	0	75,000	0	0	2,000	0	24,857
Instruction and Scholarship Data – FTE (Fall Semester), SCH (Fall Semester), Annual Scholarly Publications								
Undergraduate FTE	183.5	194.2	198.8	170.7	156.1	147.2	165.5	173.7
Graduate FTE	14.9	23.5	28.7	12.7	20.2	22.1	17.5	19.9
Total SCH	2,917	3,180	3,301	2,792	2,560	2,444	2,674	2,838
Scholarly Publications	2	7	11	6	4	7	9	7

Descriptive Statistics						
Outputs	Mean	Standard Deviation	Variance	Minimum	Maximum	Range
Awards	24,857	42,255	1.79E+09	0	97,000	97,000
Scholarly Publications	7	3	9	2	11	9
SCH	2838.3	316.0	99850.9	2444.0	3301.0	857.0
FTE	194.8	21.4	459.1	169.3	227.5	58.2
Undergrad Degrees	33	7	45	28	46	18
Grad Degrees	6	2	5	2	9	7
Descriptive Statistics						
Inputs	Mean	Standard Deviation	Variance	Minimum	Maximum	Range
Operating	25,842	899	8.08E+05	25,208	27,587	2,379
State Appropriated	2,271,808	117,216	1.37E+10	2,112,460	2,437,014	324,554
Research Expenditures	468	857	7.34E+05	0	2,175	2,175

Appendix Q.

Political Science Department data, 2008 to 2014.

	2008	2009	2010	2011	2012	2013	2014	Average
Undergraduate Student Data – Majors (Fall Semester Student Count)								
Majors	322	380	408	460	401	377	418	395
Degrees Granted	76	72	84	125	122	96	96	96
Time to Degree	4.8	5.1	5.2	4.6	5.0	5	5.2	5.0
Graduate Student Data – Master's and Doctoral (Fall Semester Student Count)								
Master's	26	30	25	19	17	18	29	23
Doctoral	21	19	21	22	27	27	24	23
Degrees Granted	12	6	9	9	10	15	10	10
Time to Degree (MS)	5.7	3.0	3	4	2.6	3.6	2.2	3.3
Time to Degree (PhD)	14.5	n/a	n/a	n/a	7.0	18	12.6	13.0
Faculty and Staff Data								
Academic Faculty (Instructional)	13	12	12	11	11	12	12	12
Full Professor	5	5	5	3	3	3	3	4
Associate Professor	4	3	3	5	5	5	5	4
Assistant Professor	4	4	4	3	3	4	4	4
Continuing Lecturers	0	0	0	0	0	0	1	0
Academic Faculty (Research)	0	0	0	0	0	1	0	0
Postdoctoral Fellows	0	0	0	0	0	1	1	0
Administrative Faculty	0	0	0	0	0	0	0	0
Classified Staff	1	1	1	1	1	1	1	1
Letter of Appointment	2	1	4	3	8	5	2	4
Graduate Teaching Assistants	7	6	7	8	5	6	7	7
Graduate Research Assistants	2	3	2	6	6	9	5	5
Total Faculty and Staff	25	23	26	29	31	35	29	28

Budget and Expenditure Data ($)								
Operating	31,801	30,211	30,211	27,711	27,274	27,274	29,674	29,165
Total State Appropriated	1,702,971	1,587,772	1,609,117	1,472,058	1,495,167	1,536,559	2,011,084	1,630,675
Total Research Expenditures	90,569	64,871	25,636	23,435	57,046	57,436	80,303	57,042
Awards	55,354	43,730	18,057	35,008	77,289	30,313	130,034	55,684
Instruction and Scholarship Data – FTE (Fall Semester), SCH (Fall Semester), Annual Scholarly Publications								
Undergraduate FTE	253.9	204.6	253.5	219.0	205.1	204.8	233.5	224.9
Graduate FTE	25.1	29.0	29.8	26.3	29.3	33.9	36.6	30.0
Total SCH	4,076	3,387	4,121	3,563	3,376	3,426	3,897	3,692
Scholarly Publications	11	7	7	6	3	3	9	7

Descriptive Statistics						
Outputs	Mean	Standard Deviation	Variance	Minimum	Maximum	Range
Awards	55,684	37,914	1.44E+09	18,057	130,034	111,977
Scholarly Publications	7	3	9	3	11	8
SCH	3692.3	330.1	108966.6	3376.0	4121.0	745.0
FTE	254.9	21.8	473.5	233.6	283.2	49.6
Undergrad Degrees	96	21	439	72	125	53
Grad Degrees	10	3	8	6	15	9
Descriptive Statistics						
Inputs	Mean	Standard Deviation	Variance	Minimum	Maximum	Range
Operating	29,165	1,764	3.11E+06	27,274	31,801	4,527
State Appropriated	1,630,675	184,672	3.41E+10	1,472,058	2,011,084	539,026
Research Expenditures	57,042	25,306	6.40E+08	23,435	90,569	67,134

Appendix R.

Psychology Department data, 2008 to 2014.

	2008	2009	2010	2011	2012	2013	2014	Average
Undergraduate Student Data – Majors (Fall Semester Student Count)								
Majors	575	564	614	765	753	826	819	702
Degrees Granted	95	146	96	139	158	161	218	145
Time to Degree	6.1	4.9	5.4	5.3	5.2	5	4.7	5.2
Graduate Student Data – Master's and Doctoral (Fall Semester Student Count)								
Master's	7	10	12	29	26	31	38	22
Doctoral	109	98	95	96	102	92	89	97
Degrees Granted	57	31	29	25	25	31	31	33
Time to Degree (MS)	3.1	3.4	4	4	3.8	3.4	3.9	3.7
Time to Degree (PhD)	7.3	7.5	8	7.3	7.0	7	7.7	7.5
Faculty and Staff Data								
Academic Faculty (Instructional)	21	21	20	21	20	20	22	21
Full Professor	10	11	10	10	9	9	11	10
Associate Professor	6	5	5	6	6	7	6	6
Assistant Professor	5	5	5	5	5	4	5	5
Continuing Lecturers	0	0	1	0	0	1	1	0
Academic Faculty (Research)	0	0	0	0	0	1	0	0
Postdoctoral Fellows	2	3	5	4	2	1	1	3
Administrative Faculty	4	4	0	0	0	1	3	2
Classified Staff	6	4	3	5	5	5	4	5
Letter of Appointment	1	3	1	0	4	5	6	3
Graduate Teaching Assistants	31	27	30	37	40	22	36	32
Graduate Research Assistants	42	32	43	45	45	47	42	42
Total Faculty and Staff	107	94	103	112	116	103	115	107

Budget and Expenditure Data ($)								
Operating	59,740	56,753	56,753	56,753	56,797	51,030	51,030	55,551
Total State Appropriated	2,727,599	2,731,815	2,744,645	2,671,684	2,662,798	2,855,469	3,260,097	2,807,730
Total Research Expenditures	707,617	770,253	718,259	433,072	2,102,949	1,913,977	2,675,802	1,331,704
Awards	2,450,214	2,019,722	898,551	673,121	4,449,160	1,000,886	2,873,988	2,052,235
Instruction and Scholarship Data – FTE (Fall Semester), SCH (Fall Semester), Annual Scholarly Publications								
Undergraduate FTE	436.0	463.6	509.3	502.3	538.1	513.9	569.0	504.6
Graduate FTE	111.3	104.6	97.0	101.2	107.2	105.1	106.4	104.7
Total SCH	7,576	7,929	8,549	8,510	9,084	8,712	9,548	8,558
Scholarly Publications	29	46	45	50	50	43	51	45

Descriptive Statistics						
Outputs	Mean	Standard Deviation	Variance	Minimum	Maximum	Range
Awards	2,052,235	1,348,966	1.82E+12	673,121	4,449,160	3,776,039
Scholarly Publications	45	8	58	29	51	22
SCH	8,558.3	663.7	440,473.6	7,576.0	9,548.0	1,972.0
FTE	609.3	43.5	1,889.2	547.3	675.4	128.1
Undergrad Degrees	145	42	1,782	95	218	123
Grad Degrees	33	11	122	25	57	32
Descriptive Statistics						
Inputs	Mean	Standard Deviation	Variance	Minimum	Maximum	Range
Operating	55,551	3,274	1.07E+07	51,030	59,740	8,710
State Appropriated	2,807,730	209,202	4.38E+10	2,662,798	3,260,097	597,299
Research Expenditures	1,331,704	878,353	7.72E+11	433,072	2,675,802	2,242,730