Utilizing Principal-Agent Theory and Data Envelopment Analysis to Examine Efficiency of Resource Utilization in Undergraduate Education for Public and Private Non-Profit Four-Year Research Universities

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Dedication

This dissertation is dedicated to my inner-most circle of family and friends, Kiah Blalark, Jennifer Blalark, Carolyn Hardaway, Mary Hardaway, the Harper-Rogers family, the Trenhaile family, the Jacot family, and the Barnson family. While I could write at length about my love and admiration for this group of people, I will keep this brief and highlight a selected few. Words cannot express how much I appreciate Jennifer Blalark for sacrificing her time to support my academic endeavors and aiding in the parenting of our beautiful daughter Kiah through countless long days and nights of study. I am also deeply indebted to Ruth and Larry for taking me under their wing as one of their own and providing additional support and guidance. Over the past 12 years I have enjoyed being referred to as their son and serving as a big brother to my younger sister Maggie. As one of my biggest fans, I am forever grateful for the support of Jay Trenhaile. He is always waiting in the wings to provide a confidence boost when called upon. It is hard to articulate my appreciation for his support.

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Abstract

Utilizing a principal-agent model as a heuristic framework and data envelopment analysis as an analytical framework, this study examined relative efficiencies and resource utilization of U.S. Carnegie 15 (very high research activity) and 16 (high research activity) public and private non-profit four-year research universities in the year 2007/08 measured against baccalaureate degree production and graduation rate efficiency. The empirical findings reveal that, on average, overall technical inefficiency for all sets of research universities is primarily attributed to managerial decisions rather than failure to operate at most productive scale size.

The results for public Carnegie 15 research universities (PCRU-15s), on average, show that resource utilization is better when measured against baccalaureate degree production than against graduation rate efficiency as indicated by LPTIE scores for all PCRU-15s corresponding with baccalaureate degree production (LPTIE % = 14.22) and graduation rate efficiency (LPTIE % = 22.65). The results for public Carnegie 16 research universities (PCRU-16s), on average, show that resource utilization is better when measured against graduation rate efficiency than against baccalaureate degree production as indicated by LPTIE scores for PCRU-16s corresponding with baccalaureate degree production (LPTIE % = 44.54) and graduation rate efficiency (LPTIE % = 40.58).

Comparing the magnitude of LPTIE scores for private non-profit Carnegie 15 research universities (PNCRU-15s) corresponding with baccalaureate degree production (LPTIE %= 8.65) and graduation rate efficiency (LPTIE %= 10.69), results indicate that managerial decisions for PNCRU-15s, on average, are such that resource utilization is

better when measured against baccalaureate degree production than against graduation rate efficiency. Consistent with private non-profit Carnegie 15 research universities, the magnitude of LPTIE scores for private non-profit Carnegie 16 research universities (PNCRU-16s) corresponding with baccalaureate degree production (LPTIE %= 8.53) and graduation rate efficiency (LPTIE %= 13.53), results indicate that managerial decisions for PNCRU-16s, on average, are such that resource utilization is better when measured against baccalaureate degree production than against graduation rate efficiency.

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CHAPTER ONE: INTRODUCTION

Statement of the Problem

Over the past 20 years, mounting pressures for more efficient utilization of public-sector resources dedicated to postsecondary education have placed a spotlight on U.S. higher education institutions. Between 1985 and 2008, state and local government funding for public and private higher education institutions rose more than 205%, from “$29.1 billion in direct support for general operating expenses, to $88.9 billion by 2008” (State Higher Education Executive Officers, 2011, p. 7). In a report on statewide higher education accountability systems, the Institute for Higher Education Policy (IHEP) (2006) proclaims, “The imperative is to increase production, quality, and affordability all across the educational pipeline without a substantial new infusion of public revenues” (p. 3). Considering continued expansion in enrollments, “public funding is becoming increasingly diluted, particularly as competition increases from other public funds such as healthcare” (Katharaki & Katharakis, 2010, p. 115).

Economic pressures have spurred a transition in government-university relationships in such a way that, “The predominant mode for government governance of universities has seemingly shifted from control and regulation to supervision and enforcement of the self-regulative capabilities of the universities” (Kivisto, 2007, p. 1). Evidence of this change in relationships can be found in fundamental shifts in state accountability measures. Burke and Minassians (2003) cited budget shortfalls as one of three apparent causes to the, “continuing triumph of performance reporting and the continuing trails of performance budgeting and funding” (p. 1). Where performance funding models tie institutional funding to performance, Burke and Minassians (2003) categorized performance reporting models as symbolic policies that, “appear to address problems, while having little substantive effect” (p. 14). In a more whimsical manner, Lane (2007) describes the relationship between state governments and higher education institutions as, “an intricate and clumsy dance with both partners often trying to play the role of the lead dancer. As with any effective dance pair, information flow between partners is critical” (p. 615).

According to Kivisto (2007), changes in levels of autonomy and self-regulative capabilities of universities “have been characterized by delegation and a shift from hierarchical, authority-based governance structures to contractual, exchange-based governance structures” (p. 1). Within the context of contractual, exchange-based governance structures, states are faced with deciding on the most appropriate level of financial support for higher education, and how to efficiently affect the production of baccalaureate degrees. Regardless of the preferred option for states, the U.S. Department of Education (2011) suggests that “more than half of all new jobs in the next decade will require a postsecondary certificate or degree. Accordingly, boosting the number of college graduates should be a central goal in every state’s workforce and economic development plan” (p. 1).

To meet the growing demand of workforce needs within the state, the primary internal option for states is to contract with public four-year higher education institutions, contrasted to importing college-educated workers from outside of the state. States have more contracting choices for external arrangements, such as cross-state contracting, the private non-profit sector, and the (proprietary) private for-profit sector. However, examples of effective cross-state contracting are scarce, because of issues related to state sovereignty. Even though private for-profit four-year institutions in the U.S. have increased in number more than 728% from 64 in 1991 to 530 in 2009 (National Center for Education Statistics: Digest of Education Statistics), “the private non-profit is the principal external option for the final outputs (degrees conferred) of higher education” (Ferris, 1991, p. 3), where a 3.7% increase in institutions occurred from 1,482 in 1991 to 1,537 in 2009 (National Center for Education Statistics: Digest of Education Statistics).

In a recent effort aimed directly at helping state governors lead the college completion agenda, the U.S. Department of Education (DOE) (2011) released the publication *A College Completion Toolkit.* This “toolkit” highlighted several benefits to states for increasing college completion rates. For example, the DOE (2011) suggests that:

> Each four-year college graduate student generates, on average, $5,900 more per year in state, federal, and local tax revenue than each high school graduate. Over a lifetime, each generates, on average, $177,000 more in tax revenue than those with only a high school degree” (p. 1).

Framing the issue of states increasing baccalaureate degree production as an economic imperative, the DOE (2011) suggested that the benefits of college completion “will accrue not only to individuals but also to business in the form of higher earnings and to state, federal, and local governments in the form of increased tax revenue” (p. 1). For example, the DOE (2011) projected that a 10% increase in bachelor’s degree attainment levels in the state of Mississippi would yield “over $200 million dollars in additional tax revenue each year” (p. 1).

While many agree that there is a definite need for universities to increase baccalaureate degree production, some highlight sobering barriers to achieving this goal. One such barrier results from the impact of changing demographics in the U.S. on student success. Jones (2010) projects that “students who will have to be well-served are going to be more diverse and poorer than the students colleges and universities have successfully served in the past” (p. 2). Examining disparities in postsecondary degree attainment among racial/ethnic and gender groups in the U.S. 1990-2000, Kelly (2005) concluded that “one reason that the U.S. is losing ground [in degree attainment] is our nation’s inability to raise the [postsecondary] educational attainment of our minority populations to nearly the rates of whites” (p. 12).

Analyzing data from the U.S. Census Bureau Public Microdata Samples on postsecondary degree attainment in the U.S. for workforce populations ages 25 to 64 and ages 25 to 34, Kelly (2005) concluded, “In the decade from 1990 to 2000, Hispanics, African-Americans, and Native Americans made the least progress [in postsecondary degree attainment], and the gap between their attainment and that of Whites widened” (p. 15). In addition, data from the Beginning Postsecondary Students Longitudinal Study, 1996-2001 Data Analysis System (BPS: 96/01) put forth by the NEA (2004) indicated that Asian/Pacific Islander (70.5%) and White non-Hispanic (66.8%) race/ethic groups had the highest six-year baccalaureate degree completion rates. The two ethnic groups with the lowest six-year degree completion rates were Hispanics (47.3%) and Black non-Hispanic (45.7 %).

Relatively low six-year baccalaureate degree completion rates for Hispanics are especially concerning because U.S. Census Bureau national population projections 2000 to 2050 indicate the highest projected population growth in younger populations (ages 0-17, 18-24) is among those classified as Hispanic (of any race), with a projected population growth of 217% for persons ages 0-17, and projected growth of 212% for persons ages 18-24. Based on U.S. Census Bureau race classifications in 2000 (i.e., whites (26.1%), blacks (14.3%), Asian and Pacific Islanders (44.1%), American Indian and Alaska native (11.5%), and white non-Hispanics (27.0%)), Hispanics (of any race) (10.4%) had the lowest percent of the population 25 years and over with a bachelor's degree or higher. In the year 2000, compared to educational attainment levels of young workforce populations (ages 25-34) in other countries, for workforce populations in the U.S. (ages 25-34), "Asian/Pacific Islanders are the only ethnic group that exceeds the educational attainment of top countries" (Kelly, 2005, p. 16). Data from the 2000 Census suggest that for projected changes in the U.S. population for ages 18-24 and 25-44 from 2000 to 2020, Asian/Pacific Islanders (330,000 / 1.41 million) will see the least population gains compared to African-Americans (420,000 / 2.03 million) and Hispanic/Latinos (1.87 million / 5.49 million). Considering students a valuable resource, the National Education Association (NEA) (2004) concluded, "Stressing institutional graduation rates has the potential to reduce the willingness of colleges to enroll non-traditional, high-risk students" (p. 5). Jones and Kelly (2007) propose that an unwillingness to enroll such students is problematic because, "growing parts of the population are exactly the ones who have been least likely to achieve high levels of educational attainment" (p. vi).

Agency Relationship Challenges in U.S. Higher Education

The U.S. Department of Education (DOE) (2011) suggests that the culmination of efforts to increase baccalaureate degree production rates is to "help the nation as a whole regain its world leadership in college completion and attainment" (p. 2). Even though the federal government plays a key role in achieving this goal, the DOE (2011) clearly states that "it is a supporting role to accelerate and expand on state-led work" (p. 2).

Using the metaphor of a contract, the focus of agency theory is on "determining the optimal contract between the principal (i.e., the state) and an agent (i.e., the college or university" (Eisenhardt, 1988, p. 490). As principals, states often have several objectives in contracting with institutions. Ferris (1991) suggests that these objectives include efforts to:

> 1) Sharpen the accountability of public funds; 2) to strengthen the institution's commitment to achieving state goals and objectives, whether they are cost savings, increased academic quality, increased access, increased graduation rates, or other desired outcomes; and 3) to encourage the institution to attract funds through service contracts from various sources, not solely from the state. (p. 13)

Reframed through the lens of agency theory, the state (principal) has delegated work to internal (public) and external (private) higher education institutions (agents), who in turn award baccalaureate degrees. Within agency relationships, Eisenhardt (1989) explains that agency problems arise when, "the desires or a goal of the principal and the agent conflict, and/or it is difficult and expensive for the principal to verify what the agent is actually doing" (p. 58). Furthermore, the problem of risk sharing "arises when the principal and the agent have different attitudes toward risk" (Eisenhardt, 1989, p. 58). Such differentiating attitudes toward risk are problematic because researchers such as Jones and Kelly (2007) warn that institutional measures to protect or increase graduation rates by limiting the enrollment of "non-traditional, high-risk students" (p. 5) could have negative impacts on overall baccalaureate degree attainment.

Information Asymmetry

The extent to which desired institutional performance is achieved is often influenced by the application of corrective measures and methods used to verify inputs employed or outputs produced. Highlighting the difficulties of evaluating and comparing performance in higher education within and across states over the past decade, The National Center for Public Policy and Higher Education (2008) explains, "During this time, one trend has held constant: not all the information needed by policymakers is available to them" (p. 20). Utilizing agency theory as a framework for analyzing relationships between state- and institution-level inputs and outputs of four-year research universities, one can focus on peculiarities within the agency relationship. Such peculiarities often emerge in two separate cases: 1) when the state knows exactly how higher education institutions within the state are performing; and 2) when the state does not know how higher education institutions are performing. In terms of U.S. higher education, the latter case of information asymmetry is often due to limitations of tracking student degree completion/attainment once a student transfers from one institution to another within a state or between states. However, Lane (2007) explains, "Empirical scholarship about how state governments elicit and receive information about public colleges and universities remains limited" (p. 615).

In principal-agent relationships where there is evidence of information asymmetry, Eisenhardt (1988) explains that the principal can: “1) discover the agent’s behavior by investing in information; or 2) to contract at least partially on the basis of outcomes of the agent’s behavior” (p. 490). For higher education institutions, recent state investments in gathering information on institutional performance have come in the form of robust state-level student unit record systems (which exist in 40 of 50 states), and the National Student Clearinghouse (NSC) “StudentTracker” service (which has over 3,300 participating colleges). The original intent of state-level student unit records systems was to meet reporting requirements of No Child Left Behind by developing kindergarten through twelfth-grade databases containing student academic data. For the post-secondary arena, the NSC Student Tracker database allows for access to post-secondary enrollment data for more than 110 million current and former students of participating institutions.

Attempts by states to assess performance of higher education institutions have proven to be challenging due to issues that are both technological and conceptual in nature. Technologically, current data collection and reporting methods present challenges for improving performance across institutions. Conceptually, performance comparisons present additional challenges related to consistent performance indicator definition and assessment across the set of non-homogeneous institutions. While not as common in the United States, there is an array of international literature that is relevant to the evaluation of universities’ efficiency through performance indicators (Chalmers, 2008; OECD, 2007; Ward, 2007), and the utilization of a non-parametric method for the estimation of production frontiers more commonly referred to as data envelopment analysis (Abbott &

Doucouliagos, 2003; Casu & Thanassoulis, 2006; Salerno, 2006; Katharaki & Katharakis, 2010). In the U.S., several states such as Washington State, Ohio, Indiana, Tennessee, and Texas have adopted a practice of including performance measures in higher education funding formulas. According to the DOE (2011), such measures are categorized as "general outcome indicators, subgroup outcome indicators, high-need subject outcome indicators, and progress indicators" (p. 6).

Risk Sharing

States contracting with higher education institutions for the delivery of education partially on the basis of outcomes comes with its own set of consequences. While such contracts help to align principal and agent preferences, they also create an environment ripe for shirking and risk-averse agents. According to Kivisto (2007), "Shirking is a form of opportunistic behavior where agents either do less than expected or where they do not perform the expected kind of action" (p. 83). As Eisenhardt (1989) explained:

> As the agent becomes increasingly less risk averse (e.g., a wealthy agent), it becomes more attractive to pass risk to the agent using an outcome based contract. Conversely, as the agent becomes more risk averse, it is increasingly expensive to pass risk to the agent. (p. 62)

This transfer of risk is problematic because states often employ various, and sometimes counterproductive methods, to influence higher education baccalaureate degree production. Such methods include, but are not limited to, financial aid to students, regulation of tuition, financial contracts and grants to institutions, and/or operating subsidies. Regardless of the methods used to study student success, researchers warn that there are additional institutional and state barriers to student success. After examining the impacts of endogenous financial aspects of state higher education on the efficiency of bachelor's degree productivity, Titus (2009a) concluded:

> With respect to bachelor's degree production, states are locked in the past. Much of this past may include flawed persistence practices within higher education institutions and ingrained state higher education organizational structures that stifle innovation or do not adequately award institutional performance such as increased graduation rates or degree production. (p. 22)

In many cases the state and the institution must measure their risk preferences in terms of gain versus loss, where states risk providing funding to more diverse populations in efforts to increase degree production, institutions may not prefer to enroll such students because of potential adverse effects on increasing degree completion rates. Succinctly clarifying the contradiction between efforts to improve institutional graduation rates and efforts to improve degree attainment rates, Jones and Kelly (2007) stress:

> Even if students in all states graduate from high school at the rate of the best performing state, high school graduates in all states enter college at the rate of the best performing state, these students graduate from college at the rate of the best-performing state, and educated immigrants continue to enter the country at the levels of the recent past; the U.S. will likely be unable to regain its place or primacy by 2025 if it relies solely on strategies focused on traditional-aged students. (p. vii)

In this study, I utilize the principal-agent model as a heuristic framework and data envelopment analysis as an analytical framework to examine relative inefficiencies and resource utilization of public and private non-profit four-year or above research universities in the United States. As suggested by Titus (2009a):

> State support influences the overall supply of higher education. Additionally, because the higher education market is not perfectly competitive and consequently may not always result in an efficient allocation of resources between institutions and individuals, state government intervention may be necessary. The intervention may take the form of financial support to colleges and universities as well as financial aid to individuals who enter higher education institutions. (p.10)

Examining baccalaureate degree production and graduation rate efficiency via principal-agent theory and data envelopment analysis is an alternative to the dominant paradigm focused on institutional retention and graduation rates, and those student characteristics and institutional experiences correlated with retention and timely graduation. Considering a seemingly imperfect education market which may necessitate state intervention, I focus mainly on the efficiency of institutional resource utilization as opposed to correlations of variables that effect student academic performance. Through the lens of the principal-agent model, the relationship is framed as a contractual, exchange-based governance structure in which the state decides the appropriate level of funding support for higher education, and how to most efficiently affect the delivery of higher education. According to Titus (2009a), “The state (the principal) makes an effort to influence higher education institutions (agents) and individual students to jointly produce a socially optimal level of bachelor's degrees via selected state higher education policies” (p. 9). Such policy interventions may include, “state financial support to higher education institutions, in the form of appropriations for institutions and financial aid to students” (Titus, 2009b, p. 443). Titus (2009a) asserts “differences in the production of bachelor’s degrees among states are overwhelmingly due to differences in technical efficiency” (p. 22). In other words, the differences in the collective ability for higher education institutions within a state to produce bachelor’s degrees depends on their ability to “convert a certain bundle of inputs to the maximum possible amount of output (as evidenced by the best performance observed within sample)” (Agasisti & Johnes, 2009, p. 60).

Data envelopment analysis allows for the identification of a frontier on which the relative performance of all institutions in the sample can be compared. According to Archibald and Feldman (2008), “As an alternative we suggest that graduation rates should be compared to best practice measured by a production frontier, not average practice measured by a regression equation” (p. 81). This method is potentially appealing to policy makers because of its focus on best practice, and “the production frontier identifies peer institutions with similar inputs and superior graduation [or degree production] rates” (Archibald & Feldman, 2008, p. 82).

The crux of the matter is that states must decide on the most efficient balance of funding for internal (public) and external (private non-profit) higher education institutions to achieve the goal of increasing baccalaureate degree production. On the other hand, public and private non-profit higher education institutions must choose an appropriate strategy to efficiently utilize internal and external resources to increase graduation rates and baccalaureate degree production. With subtle differences in goals between states and institutions, goal conflict emerges in such a way that institutions might employ strategies to increase graduation rates that could inadvertently negatively impact degree production. With regard to the efficient utilization of public funds, Katharaki and Katharakis (2010) highlight that, “policy makers have found themselves asking if higher education institutions are using their resources productively” (p. 116). By conducting this type of assessment, I will “alleviate the problem of comparing universities with different characteristics” (Katharaki and Katharakis, 2010, p. 116), and better allow policy makers to evaluate efficiency and performance across universities.

CHAPTER TWO: LITERATURE REVIEW

The following sections of chapter two are in-depth reviews of literature on issues related to agency relationships between state governments and higher education institutions. Before outlining the proposed methodology for this study, I provide an overview of the theoretical model, historical and contextual background to goal conflicts between states and institutions, and issues related to improving accountability in agency relationships. To that end, agency theory, government-university agency relationships, goal conflicts between states and universities, and accountability in government-university agency relationships are reviewed.

Agency Theory

Agency theory finds its origins in the late 1960s/early 1970s literature regarding risk sharing among groups of decision makers. Wilson (1968) categorized such groups of decision makers as syndicates. According to Wilson (1968), a syndicate is “a group of individual decision makers who must make a common decision under uncertainty, and who, as a result, will receive jointly a payoff to be shared among them” (p. 119). Exploring risk sharing problems of syndicates, Wilson (1968) honed in on “the decision-making process of a syndicate when the members have diverse risk tolerances and/or diverse probability assessments of the uncertain events affecting the payoff” (p. 119). The problem here is thus twofold, risk aversion and decision-making under uncertain conditions. Considering these challenges, Wilson (1968) arrived at what he called the sharing rule, or “the rule by which the payoff is shared is an essential feature of the group’s decision process, since to every member the merits of a decision depend upon the share he receives from the payoff” (p. 123).

Table 1 presents Eisenhardt's (1989) overview of the key components of agency theory. Jensen and Meckling (1976) broadened agency theory literature to further define the agency relationship as, "A contract under which one or more persons (the principal) engage another person (the agent) to perform some service on their behalf which involves delegating some decision making authority to the agent" (p. 308). Due to issues related to the residual loss between monitoring expenditures of the principal and bonding expenditures of the agent, Jensen and Meckling (1976) suggest that, "Assuming that both parties in an agency relationship are utility maximizers, there is good reason to believe that the agent will not always act in the best interest of the principal" (p. 308). As Jensen and Meckling (1976) further explain:

> In most agency relationships the principal and the agent will incur positive monitoring and bonding costs (non-pecuniary as well as pecuniary), and in addition there will be some divergence between the agents' decisions and the decisions which would maximize the welfare of the principal. (p. 308)

Table 1
Agency Theory Overview

Key Idea	Principal-agent relationships should reflect efficient organization of information and risk-bearing costs
Unit of analysis	Contract between principal and agent
Human assumptions	Self-interest; bounded rationality; risk aversion
Organizational assumptions	Partial goal conflict among participants; efficiency as the effectiveness criterion; information asymmetry between principal and agent
Informational assumption	Information as a purchasable commodity
Contracting problems	Agency (moral hazard and adverse selection); risk sharing
Problem domain	Relationships in which the principal and agent have partly differing goals and risk preferences (e.g., compensation, regulation, leadership, impression management, whistle-blowing, vertical integration, transfer pricing)

Source: Eisenhardt (1989), p. 59

Adding to the literature on agency theory, Eisenhardt (1989) outlines two problems that can occur in agency relationships:

> The first is the agency problem that arises when (a) the desires or goals of the principal and the agent conflict and (b) it is too difficult or expensive for the principal to verify what the agent is actually doing. The second problem is the problem of risk sharing that arises when the principal and the agent have different attitudes toward risk. (p. 58)

Between the 1970s and mid-1980s under the banner of agency theory, principal-agent models began to emerge within the field of economics as a new approach to studying organizations, including higher education institutions. Grounded in informational economics, “agency theory has developed along two lines: positivists and principal-agent” (Eisenhardt, 1989, p. 59). However, Moe (1984) explains that the positivist stream bent toward political theory and “has centered around two basic mechanisms of social choice, voting and markets” (p. 739). Moe (1984) postulated that hierarchy was a third unexplored mechanism of social choice missing from positive political theory. This third mechanism of the hierarchy of social choice “is clearly important for understanding how societies and other aggregates make collective decisions” (Moe, 1984, p. 739), and was further developed by economists within literature related to positive theory of hierarchies. Table 2 contains a summary of agency theory studies in the 1980s. Table 2 presents Eisenhardt’s (1989) overview of the two stream of theoretical agency research; namely positivist and principal-agent. While there have been a few studies that used agency theory as a framework for assessing relationships between state governments and public institutions in terms of oversight/assessment (Harris & Raviv, 1978, Ferris, 1991, Liefner, 2003, Lane, 2007), no studies were located that used agency theory to examine baccalaureate degree production.

Table 2
Summary of Agency Theory Studies

Author(s)	Research Stream	Sample	Independent Variables	Dependent Variables	Results
Amihud & Lev (1981)	Positivist	309 Fortune 500 firms	Manager vs. owner controlled	Conglomerate mergers & diversification	Support
Walking & Long (1984)	Positivist	105 U.S. firms	Management's equity & options	Managerial resistance to takeover bid	Support
Anderson (1985)	Principal -Agent	159 sales districts in 13 electronics firms	Importance of non-selling activities, length of selling cycle, & difficulty evaluating sales performance	Representative vs. corporate sales force	Mixed
Eisenhardt (1985	Principal -Agent	54 retail stores	Information systems, cost of outcome measurement, & outcome uncertainty	Salary vs. commission	Support
Eccles (1985)	Principal -Agent	150 interviews in 13 chemical electronics heavy machinery & machine component firms	Decentralization	Type of transfer price	Inductiv e model
Wolfson (1985)	Positivist	39 oil & gas limited partnerships	General partner's track record	Share price	Support
Argawal & Mandelker (1987)	Positivist	209 major corporations	Executive stock holdings	Acquisitions, divestitures, & debt/equity ratio	Support

Source: Eisenhardt (1989), p. 66

Departing from the positivist stream, the principal-agent approach “is best characterized by three elements: a contractual perspective on organizational relationships, a theoretical focus on hierarchical control, and formal analysis via principal-agent models” (Moe, 1984, p. 749). Eisenhardt (1989) explains that, “the focus of principal-agent literature is on determining the optimal contract, behavior versus outcome, between the principal and the agent” (p. 60). Moving beyond neoclassical theory of the firm, this new contractual paradigm follows the work of Alchian and Demsetz (1972), which focused on economic organizational problems (e.g., measuring outputs, team production, etc.). Alchian and Demsetz (1972) claim that, "the firm exists because it provides a better solution to this problem than markets do" (Moe, 1984, p. 750). According to Moe (1984), Alchian and Demsetz (1972) argue that:

> The particular organizational (contractual) arrangement we identify with the capitalist firm is more efficient than the alternative contractual arrangements occurring purely within the market, and that the existence of firms can be derived from an analysis of rational behavior. (p. 750)

The metering problem exists when there might an economic disconnection between the metering of economic activity and the "rewards to resource owners in accord with that direct measurement of their outputs" (Alchian & Demsets, 1972, p. 778). Alchian and Demsets (1972) explain, "If the economic organization meters poorly, where rewards and productivity are loosely correlated, then productivity will be smaller; but if the economic activity meters well productivity will be greater" (p. 779). On the other hand, team production problems arise when:

> It is difficult, solely by observing total output, to either define or determine each individual's contribution to this output of the cooperating units. This output is yielded by a team, by definition, and it is not a sum of separable outputs of each of its members. (p. 779)

Concisely clarified by Braun (1993), "Agents may shirk (i.e., do less than expected or not the expected kind of action) if they realize that the principal lacks the information to control their activities" (p. 138). Framed as the "prisoner's dilemma," Moe (1984) describes that group cooperative efforts are "plagued by a public goods problem (where the public good is the team reward) that promotes free rider behavior (shirking) among members" (p. 751).

Government-University Relationships as Agency Relationships

Pondering "Why is there demand for increased attainment" in higher education, Lingenfelter (2007) notes that "unprecedented political, social, and ecological demands on a global scale now confront humanity" (p. 2). In what some refer to as the "information age" or the "knowledge economy," it is becoming clear that individuals must become more educated in order to compete intellectually and financially in an interconnected global environment. In the United States, Lingenfelter (2007) outlines a number of national movements that are "influencing and becoming part of state strategies to increase attainment, quality, and productivity" (p. 4). Such national movements include: accountability for educational attainment, assessments for student learning, alignment of various aspects of educational policy between pre-school and graduate study (Pk-20), and alignment of tuition, appropriations, and financial aid. Collectively, these movements are directed at increasing educational levels of adult populations within states and for the country as a whole. In comparison to educational attainment in other countries, Jones notes (2007), "As other countries show consistent decade-to-decade progress in enhancing the education levels of their adult populations, the U.S. has been stuck at essentially the same level for 30 years" (p. vi).

According to Kivisto (2007), the government-university relationship must contain three essential elements if it is to be considered an agency relationship; namely: "1) tasks which the government delegates to a university; 2) resources which government allocates to a university for accomplishment of the tasks; and 3) government interest in governing the accomplishment of the tasks” (p. 53). In U.S. higher education, defining the principal and the agent within government-university agency relationships has been shown to be a complicated task. Defining the principal and the agent becomes a matter of perspective, because the U.S. does not have a single body responsible for governing all higher education affairs. Due to the fact that the focus of this study is on the impact that state-level inputs might have on institution-level inputs/outputs, the state is characterized as the principal and the institution is characterized as the agent. With principal and agent roles defined as such, Lane (2007) asserts, “the relationship is awash with information asymmetries, leading the principal to have to rely on a complex array of oversight mechanisms and other actors to reduce some of these asymmetries” (p. 616).

In an effort to reduce information asymmetries, many states have made significant investments in state-level student unit record (SUR) databases. With 40 of 50 states maintaining SUR databases, “81% of the nation’s total headcount enrollment and 77% of its full-time equivalent (FTE) enrollment is collectively covered by current state SUR systems” (Ewell & Boeke, 2007, p. 4). While the addition of SUR databases has aided in decreasing information asymmetries, the following issues highlighted by Ewell and Boeke (2007) continue to make verification of higher education performance difficult: multiple independent databases, limited private sector coverage, historical record data, data detail and periodicity, record identification, and links to other databases.

Goal Conflicts between States and the Universities

Understanding the organizational goals of higher education institutions has been controversial, and complex issues have been analyzed throughout studies of higher education. When assessing national higher education systems (HES), Clark (1983) characterized HES as, “market-oriented systems and state-oriented systems” (p. 143). For institutions in marked oriented systems, funding is primarily provided by private actors in the form of “tuition and fees, gifts, grants, or research contracts” (Leifner, 2003, p. 470). On the other hand, institutions in state-oriented systems receive their funding primarily from the government.

For any organization, Scott (2003) explains, “the concept of organizational goals is among the most slippery and treacherous of all those employed by organizational analysts” (p. 292). Depending on the perspective, state-level goals may relate to access to college, college graduation, or international comparisons. On the other hand, institution-level goals may relate to student retention, persistence, time-to-degree, or degree completion rates. Although state-level and institution-level goals may often be related, subtle differences often lead to a “variety of inconsistent, mutually conflicting, and ill-defined preferences” (Kavisto, 2007, p. 67).

Educational administrators, state policy makers, and federal policymakers “share a deep concern that too many students drop out of school before completing their degrees” (Willett & Singer, 1991, p. 427). In a state survey on performance measures used in 1996-1997, Christal (1998) found, “For state governments, graduation rates are the most frequently used performance measure for public colleges and universities” (as cited in Archibald & Feldman, 2008, p. 80). Burke and Minassian (2002) found similar results when comparing indicators used in 29 state higher education performance reports. Within the 29 reports reviewed, graduation or retention indicators were used in 24, making them the top indicators used by state policy makers when assessing performance.

Criticizing college graduation rates in 2006, U.S. Secretary of Education Margaret Spellings commissioned a formal group of more than 18 members to publish a report titled *A Test of Leadership: Charting the Future of U.S. Higher Education*. As one of its conclusions, the commission deemed graduation rates to be unacceptable and recommended that “accreditation agencies should make performance outcomes, including completion rates and student learning, the core of their assessment as a priority over inputs or processes” (U.S. Department of Education, 2006, p. 24). In an editorial (in *The Chronicle of Higher Education)* criticizing the requirements of the Student Right to Know and Campus Security Act of 1990 (SRK), Astin (1993) presented data "showing that an institution's undergraduate retention rate can be a very misleading indicator of its capacity to retain students" (as cited in Astin, 1997, p. 648). The American Federation of Teachers (AFT) (2003) noted that the percentage of part-time students attending college had risen steadily in the 1980s and ‘90s. And, because of the growing number of students inadvertently left out of national graduation rates, there is a need for “more and better student-centered research on the causes of persistence problems” (AFT, 2003, p. 18).

From the perspective of national- and state-level goals, Ewell, Jones, and Kelly (2003) conceptualized the U.S. postsecondary educational pipeline as a series of successive transitions where students work toward: “graduation from high school, entry into postsecondary education, persistence in postsecondary education, completion of postsecondary education, and entry into the workforce” (p. 2). Criticizing efforts of states and institutions, Jones and Kelly (2007) argued that the U.S. higher educational pipeline is "leaking seriously at every point. [Where] too few complete high school, too few high school graduates and GED completers are going to college, and too few college entrants are getting degrees" (p. vi). While the U.S. arguably has one of the best higher education systems in the world, Jones and Kelly (2007) suggest, “the advantage arises because of superior education attainment levels of the generation that is approaching retirement” (p. vi).

In a presentation prepared for the National Commission on Adult Literacy, Jones and Kelly (2007) maintain that for the first time in history, the U.S. is losing ground to other countries in the educational attainment of its workforce. Data from the Organization for Economic Cooperation and Development (OECD) (2008) in Table 3 show that the U.S. was one of four participating countries with less than a 5% increase in tertiary education attainment increases for adults ages 25-34, and one of five countries with less than a 5% increase in tertiary education attainment increases for adults ages 35-54 from 2002 to 2007. According to Adelman (2009):

> If 35% of our current 40 million 25-34-year-olds hold a bachelor’s degree (15 million) and the population of that age group is slated to rise to 46.6 million by 2025, then we need 16.3 million bachelor’s degrees—1.3 million more than at present—in that age group in 2025 just to stay at 35 percent. (p. 24)

Synthesizing data collected by the OECD (2006), Jones and Kelly (2007) found that only the U.S. and Germany had older adult (ages 45-54) populations with higher levels of college attainment than young (ages 25-34) adults. Moreover, Jones and Kelly (2007) warn that “unless the U.S. finds a way to improve its performance in this arena, it will fall further behind a longer list of competitor countries” (p. vi). Since the early 1970s, the percentage of U.S. 18-to-24-year-olds entering the postsecondary educational pipeline into four-year institutions has increased almost 11% (from 17.1% in 1973 to

27.8% in 2008) (National Center for Education Statistics). However, over the past couple of decades, four-year institutions have experienced only a 4% increase (from 23.6% in 1991 to 27.8% in 2008) in enrollment rates of 18-to-24-year-olds from 1991 to 2008 (National Center for Education Statistics).

Table 3
OCED Tertiary Education Attainment, 2002 – 2007

	Tertiary Education: Percentage of Population					
	Age 25-34			Age 35-54		
	2002	2007	% increase	2002	2007	% increase
Australia	35.8	40.7	14%	30.5	32.2	5%
Austria	14.8	18.9	28%	14.7	17.5	19%
Belgium	37.6	41.3	10%	24.7	28.3	15%
Canada	51.2	55.8	9%	40.4	44.6	10%
Czech Republic	12.3	15.5	26%	10.9	14.2	31%
Denmark	30.6	40.1	31%	28.1	30.4	8%
Finland	39.2	39.3	0%	29.6	35.8	21%
France	36.1	41.4	15%	19.3	19.8	3%
Germany	21.7	22.6	4%	25.0	25.1	0%
Greece	24.1	28.1	17%	16.1	20.7	29%
Hungary	15.0	22.0	47%	14.4	15.8	10%
Iceland	29.1	31.0	7%	25.7	27.9	9%
Ireland	36.3	43.9	21%	19.7	25.2	28%
Italy	12.5	18.9	51%	10.3	11.3	10%
Japan	50.3	53.7	7%	31.4	41.4	32%
Korea	41.2	55.5	35%	13.8	21.0	52%
Luxembourg	22.6	35.8	58%	16.0	22.0	37%
Mexico	11.1	19.5	75%	3.6	14.9	316%
Netherlands	27.7	36.7	33%	23.9	30.2	26%
New Zealand	29.3	47.3	61%	31.9	39.4	23%
Norway	39.7	42.7	7%	28.1	30.9	10%
Poland	15.6	30.1	93%	10.6	12.8	21%
Portugal	15.0	21.4	42%	7.3	10.4	43%
Slovak Republic	11.9	17.5	47%	11.8	13.8	18%
Spain	36.7	38.9	6%	17.3	22.7	31%
Sweden	39.2	40.0	2%	31.7	28.9	-9%
Switzerland	26.5	35.0	32%	24.7	30.0	21%
Turkey	10.6	13.6	28%	9.4	8.8	-7%
United Kingdom	31.2	37.1	19%	25.5	30.5	20%
United States	39.3	40.4	3%	39.7	39.6	0%

Source: Organization for Economic Cooperation and Development Statistical Extracts

Despite several decades of research and collective efforts to improve student success, degree completion rates have increased only modestly. As shown in Table 4, data compiled by the National Center for Education Statistics (NCES) indicate that four-, five-, and six-year degree completion rates of 1996-2001 entering cohorts increased for all sectors of four-year institutions.

Table 4
Graduation Rates, Control of Institution, Time between Starting and Graduating: Selected cohorts 1996 and 2001

	1996 Starting Cohort		
	Graduation rates		
Control of institution	4-year	5-year	6-year
All	33.7	50.2	55.4
Public	26.0	45.9	51.7
Private Not-for-profit	48.6	59.2	63.1
Private For-profit	21.8	25.4	28.0

	2001 Starting cohort		
	Graduation rates		
Control of institution	4-year	5-year	6-year
All	36.2	52.6	57.3
Public	29.4	49.1	55.0
Private Not-for-profit	50.9	61.6	64.4
Private For-profit	18.6	22.4	24.5

Note: Graduation rates are of first-time post-secondary students who started as degree seeking full-time students in the fall term
SOURCE: U.S. Department of Education, National Center for Education Statistics

By sector, the greatest increases in degree completion rates between 1996 and 2001 were found in public four-year institutions. Whereas institutions in the public and private not-for-profit sectors both experienced small increases in degree production rates, the private for-profit sector experienced rate decreases. As shown in Table 5, over this same period, the total number of bachelor’s degrees conferred increased by 9.21%: 1,172,879 (1996-97) to 1,291,900 (2001-02).

As accountability pressures from state governments and regional accrediting bodies urge universities to improve graduation rates, “increasing numbers of institutions are performing various kinds of assessments on their undergraduate students” (Astin & Lee, 2003, p. 657). However, not all researchers agree on the best measures of student or institutional performance. Titus (2009a) suggests:

While some (Carey, 2004, 2005; The Futures Project, 2005) have called for states to increase accountability in the form of improved college student retention and graduation rates, other reports (Lumina Foundation for Education, 2006) have advocated for the increasing of the number of the college graduates over the next 25 years. (p. 7)

While there are differing opinions on which measures are more valuable when assessing institutional performance, it is clearly vital to find meaningful ways to gain insight into issues related to degree completion and degree attainment.

Table 5

Bachelor's Degrees Conferred, Enrollment Rates for all 18-24-Year-Olds in Degree Granting Institutions: Selected Cohorts 1996 and 2001

	Selected cohort		
	1996-97	2001-02	% increase
Bachelor's degrees conferred by degree granting institutions	1,172,879	1,291,900	10.15%
Enrollment rates of all 18-24 year olds in four-year degree granting institutions	26.1	26.6	1.9%

SOURCE: U.S. Department of Education, National Center for Education Statistics

Goal of Increasing Degree Production

A brief examination of the historical context for the social transition from valuing physical capital to the importance of more broadly defined human capital, including the impact of technology, is helpful here. During the Industrial Revolution of the 18th and 19th centuries, the British economy and society experienced broad changes fueled by many technological innovations that helped the economy make a transition from a manual and draft-animal-based economy to a more efficient machine-based economy. Ashton (1948) summarized this era with the phrase, "A wave of gadgets swept over England" (p. 42). From a more narrow perspective, scholars such as Crafts and Harley (1992) saw this revolution not as the result of broad innovations, but "as the result of technical change in a few industries" such as cotton and iron (Temin, 1997, p. 63). In either case, Goldin and Katz (2008) claim that during the Industrial Revolution, "investment in physical capital became vital to a nation's economic growth" (p. 11). Defining the demand for "skills" as a demand for highly educated workers, Goldin and Katz (2008) explain, "great technological advances in recent decades have increased the relative demand for skill" (p. 125). Positing that manufacturing as a whole progressed from artisan shops, to factories, and then to continuous processes, Goldin and Katz (2008) argue that "these advances served to increase the relative demand for skilled labor, because the workable capital did not require an abundance of laborers in the production segment" (p. 124). Similarly, Carnevale (2001) found evidence of a decline of farm and labor employment and further suggests, "In recent years, the largest growth—and by far the largest segment of the workforce—is office related" (as cited in Kelly, 2005, p. 4).

While nations during the 20th century continued to see economic progress, Goldin and Katz (2008) suggest that there was a stark difference in national investment strategies. In the 18th and 19th centuries, physical capital was vital to economic breakthroughs; however, in the 20th century, "the path to ongoing economic success for nations and individuals eventually became investment in human capital" (Goldin & Katz, 2008, p. 11). For many countries, investment in human capital meant investing in the education of its citizenry. Analyzing the relationship between national investment in human capital and economic outcomes, Barro and Lee (2000) concluded:

> Human capital is multifaceted and includes a complex set of human attributes, and the stock of human capital held by individuals is hard to measure with precision in quantitative form. Educational attainment is the best proxy for the component of the human capital stock obtained at schools. (p. 3)

Today, the focus of production reflects this shift in emphasis from manufacturing to educational attainment. Over the last century (1910-2010), the number of bachelor's degrees conferred has increased more than 4,330%; from 37,199 in 1909-10 to an estimated 1,648,000 in 2009-10 (National Center for Education Statistics). However, within the past 20 years the number of bachelor's degrees conferred increased only 42% from 1,094,538 in 1990-91 to 1,563,063 in 2007-08 (National Center for Education Statistics). During the mid-20th century, U.S. education attainment levels increased steadily at a remarkable pace. As illustrated in Table 6, average years of school completed for age groups 25 and older, 25-34, 35-54, and 55 years and older increased steadily from 1940 to 1980, when median increases began to level off (US Census Bureau). It is also worth noting that persons between the ages of 25-34 consistently had the highest average years of school completed between the selected years 1940 to 1990. This continuous increase in educational attainment helped the U.S. gain "at least a 35-year advantage over most of Europe. In 1950, no European country enrolled 30% of its older teens in full-time secondary school. [During this time] in the U.S., 70% of older teens were in school" (Brooks, 2008, p. 1). At the onset of the 20th century, a century which Goldin and Katz (2008) refer to as the "Human Capital Century," America heavily invested in human capital by way of "instituting mass secondary schooling and then establishing a flexible multifaceted higher education system" (p. 18). According to Goldin and Katz (2008), "By the early 20th century America educated its youth to a far greater extent than did most, if not every European country . . . . Even by the 1930s America was virtually alone in providing universally free and accessible secondary schools" (p. 12).

Table 6
Average Years of School Completed by People 25 Years and Older: Selected Years 1940 to 1990

Age	Years 1940	1950	1960	1970	1980	1990
25 years and older	8.6	9.3	10.6	12.2	12.5	12.7
25 to 34 years	10.0	11.9	12.4	12.5	12.9	12.9
35 to 54 years	8.6	9.7	11.3	12.3	12.6	12.9
55 years and older	8.2	8.3	8.5	9.2	12.0	12.3

Source: U.S. Census Bureau, CPS Historical Time Series Tables

David Brooks (2008) referred to this "skills slowdown" as "the biggest issue facing the country" (p. 1). Analyzing data from the 1940 to 2000 Census of Population Integrated Public Use Micro-data Samples (IPUMS), Goldin and Katz (2008) found that U.S. children born in 1975 experienced gains in educational attainment levels of just half a year over children born in 1945. By contrast, children born in 1951 experienced gains of more than double those born in 1921. Analyzing data from the *Current Population Survey*, maintained by the U.S. Bureau of Labor Statistics and the U.S. Census Bureau, Bowen, Chingos, and McPherson (2009) also found evidence of a flattening of attainment for 25-29-year olds from 1968 to 2007. Bowen et al. (2009) further explain that the "failure of educational attainment to continue to increase steadily is the result of problems at all stages of education, starting with pre-school and the moving through primary and secondary levels of education and on to college" (p. 3).

According to *New York Times* columnist David Loenhardt (2009), "Education—educating more people and educating them better—appears to be the best single bet that a society can make" (p. 1). Crystallizing this point, he adds, "There is really no mystery about why education would be the lifeblood of economic growth . . . . [Education] helps a society leverage every other investment it makes, be it in medicine, transportation, or alternative energy" (as cited in Bowen, Chingos, & McPherson, 2009, p. 2). Echoing these remarks in an address to a joint session of Congress, U.S. President Barack Obama (2009) stated, "In a global economy where the most valuable skill you can sell is your knowledge, a good education is no longer just the pathway to opportunity—it is a prerequisite" (p. 1). Setting a clear national goal for degree attainment, President Obama (2009) proclaimed, "By 2020, America will once again have the highest proportion of college graduates in the world" (p. 1).

Highlighting significant American investments in higher education such as the 1862 Morrill Act and the Serviceman's Readjustment Act of 1944, Carey (2004) praises American national commitment to education. However, Carey (2004) also notes that in 2001, data from the U.S. Census Bureau Population Survey show "even among the students most likely to succeed—those who begin their college career as full-time freshmen in four-year colleges and universities—only six out of every 10 of them, on average, get a B.A.[degree] within six years" (p. 1). By Carey's (2004) estimation, such low completion rates result in more than half a million collegians every year falling "short of acquiring the credentials, skills, and knowledge they seek" (p. 1).

In reviewing data produced by the Organization for Economic Co-operation and Development (OECD, 2008), Bowen, Chingos, and McPherson (2009) note:

> In 2006, the United States ranked 10th among the members of the OECD in its tertiary attainment rate. This is a large drop from preceding years: the United States ranked 5th in 2001 and 3rd in 1998. Moreover, in the United States only 56% of entering students finished college, an outcome that placed this country second to the bottom of the rank-ordering of countries by completion rate. (p. 4)

Goldin and Katz (2008) argue that the familiar American dream of children doing better than their parents, "began to unravel in the latter part of the 20th century at least with regard to educational attainment" (p. 19). They contend, “The slowdowns in the growth of the high school graduation rate and the growth of the college completion rate for post-1950 U.S. birth cohorts have been the main reasons for the evaporating U.S. lead in educational attainment” (2008, pp. 327-328). More specifically, as shown in Table 7, the number of persons between the ages 25-34 who have completed at least four years of high school has significantly decreased since 1980.

Table 7
Persons Ages 25 to 54 with 4 Years of High School Completed: Selected Years 1940 to 2009

	4 Years of High School Completed							
Age	1940	1950	1960	1970	1980	1990	2000	2009
25 to 34 years	4,702	7,660	8,166	10,929	14,481	17,635	11,546	11,351
35 to 54 years	4,217	7,262	12,517	18,200	19,584	24,434	26,481	26,121

Note: Numbers in thousands
Source: U.S. Census Bureau, CPS Historical Time Series Tables

Findings from the U.S. Department of Education report (2006) *A Test of Leadership: Charting the Future of U.S. Higher Education* reveal that that there will be approximately four million new job openings combined in the economic sectors of health care, education, and computer and mathematical sciences projected between the years 2004-2014. And, “90% of the fastest-growing jobs in the new information and service economy will require some postsecondary education” (U.S. Department of Education, 2006, p. 6). Bowen, Chingos, and McPherson (2009) point out that:

> growth in the supply of college educated workers has been sluggish and has not kept up with increases in demand—especially increases in the demand for individuals with strong problem solving skills and degrees from more selective undergraduate programs and leading professional schools. (pp. 5-6)

Additional evidence of this shift in demand for highly educated workers can be found in data on the increases in median annual earnings of full-time full-year wage and salary workers ages 25-34. As shown in Table 8, median annual earnings for full-year wage workers ages 25-34 with a bachelor's degree or higher increased $3,000. Over the same time period, median annual earnings for full-year wage workers ages 25-34 with a high school diploma or equivalent decreased by $6,600.

Table 8
Median Annual Earnings and Percentage of Full-Time, Full-Year Wage and Salary Workers Ages 25–34, by Educational Attainment: Selected years, 1980–2008

	Median earnings [in constant 2008 dollars]						
	1980	1985	1990	1995	2000	2005	2008
High school diploma or equivalent	36,600	34,000	31,700	29,400	31,300	30,800	30,000
Bachelor's degree or higher	47,000	50,000	48,300	46,600	50,000	48,500	50,000

Note: Full-time, full-year wage workers as a percentage of the population ages 25-34 who reported working or looking for work in 2008.
Source: U.S. Department of Commerce, Census Bureau, Current Population Survey (CPS), March and Annual Social and Economic Supplement, selected years, 1981–2009.

Focusing on science, technology, engineering, and mathematics (STEM) fields in the state of California, Offenstein and Shulock (2009) found evidence of a convergence of factors contributing to an "increased demand for a STEM educated labor force" (p. 6). These factors included: an increasing knowledge based economy in California, increased demands on healthcare services by aging populations, and the upcoming retirements of more educated workers. Of the average annually expected 46,100 job openings in the STEM occupational fields, over half will require "at least a bachelor's degree between 2006 and 2016" (Offenstein & Shulock, 2009, p. 7). Heckman (2008) notes that unfortunately:

> The decline in high school graduation rates since 1970 (for cohorts born after 1950) has flattened college attendance and completion rates and has slowed

growth in the skill level of the U.S. workforce at a time when the economic return to skill has increased. (p. 8)

Goal of Increasing Graduation Rate Efficiency

Performance indicators of student success identified in student attrition studies come in many different forms, and not all are precise. One such indicator is persistence, which is often described as a measure of a student's continuous full-time (more than 12 credits) enrollment in a postsecondary institution. "Persistence includes several subtopics that are frequently discussed in the research literature: dropouts, transfers, withdrawal, retention, and stopouts. Without persistence in college, no progress is made and no degrees are attained" (Carroll, 1989, p. 1). The other such indicator is degree completion, which is commonly referred to as a measure of the traditional pattern of enrolling in college the fall after high school graduation and earning a bachelor’s degree within four years. However, Hill and Owings (1986) highlighted that, “according to the Center for Education Statistics (CES), less than half of the students who earned a bachelor’s degree followed this . . . pattern” (p. 2). According to Planty, Kena, and Hannes (2009):

> The rate at which high school completers enrolled in college in the fall immediately after high school was approximately 50% between 1972 and 1980. The rate increased to 67% in 1997, declined to about 62% in 2001 and then increased again to the current rate of 67% in 2007. (p. 16)

Along with increasing pressures on postsecondary institutions to bolster accountability to state and federal agencies, is the belief that "the public investment in colleges and universities provides insufficient payoff for many students" (NEA, 2004, p. 1). As illustrated in Table 9, there are significant percentages of students who have not completed their bachelor's degrees within six years of entering college. Of all races of college attendees, African Americans and American Indian/Alaska Native students consistently have the lowest four-, five-, and six-year graduation rates at public, private not-for-profit, and private for-profit four-year institutions. Private for-profit institutions consistently have the lowest four-, five-, and six-year graduation rates for all races of students at any type of four-year institution.

Table 9

Graduation Rates, Race/Ethnicity, Time Between Starting and Graduating, and Control of Institution Where Student Started: Selected cohort 2001

	Percent completing within 4 years		
	Type of 4-year Institution		
Race	Public	Private Not-for-profit	For-profit
White	31.8	53.9	24.6
Black	17.3	30.2	19.1
Hispanic	19.0	43.4	22.4
Asian/Pacific Islander	34.8	61.3	27.3
American Indian/ Alaska Native	16.5	37.8	13.8
Non-resident alien	33.3	53.9	17.5

	Percent completing within 5 years		
	Type of 4-year Institution		
Race	Public	Private Not-for-profit	For-profit
White	52.0	64.4	28.2
Black	33.7	41.6	22.4
Hispanic	37.8	55.5	27.1
Asian/Pacific Islander	57.2	72.1	32.3
American Indian/ Alaska Native	31.8	47.6	16.2
Non-resident alien	50.0	64.3	21.5

	Percent completing within 6 years		
	Type of 4-year Institution		
Race	Public	Not-for-profit	For-profit
White	57.5	66.9	30.3
Black	40.1	45.9	23.8
Hispanic	45.7	58.7	28.8
Asian/Pacific Islander	64.5	75.2	34.3
American Indian/ Alaska Native	37.2	50.3	16.6
Non-resident alien	55.0	66.8	22.5

SOURCE: U.S. Department of Education, National Center for Education Statistics

Persistence. There are various broad criticisms about research on student attrition that have emerged over the years. As early as the 1960s Gekowskis and Schwartz (1961) observed, "Studies of attrition tend to concentrate on factors related to the academic achievement of college students on the assumption that college achievement is positively related to persistence" (as cited in Pantages & Creedon, 1978, p. 50). Factors such as aptitude, which commonly show a statistically significant correlation with academic achievement, are hastily assumed to affect college retention rates (Pantages & Creedon, 1978).

Continuous year-to-year enrollment of students at colleges and universities has long been a concern for administrators at postsecondary institutions, but the results of retention and persistence studies are often misleading and contradictory. Murtaugh, Burns, and Schuster (1999) argue that:

> Published work on student persistence has focused on several themes: 1) examining the relationship between precollege characteristics of freshman students and their success at a college or university; 2) examining the causes of student attrition, with recommendations to colleges and universities for interventions to reduce the rate at which students leave school before graduating; 3) describing and evaluating specific campus programs that were designed and implemented to improve retention of students in general and for specific groups of students; and 4) exploring the relationship between innovative or improved teaching techniques and student retention. (p. 356)

In seeking an answer to this conundrum involving predictive variables, graduation rates, and disrupted academic progress, Eckland (1964a) found different studies that traced college careers of new freshmen (and transfers) beyond the customary four-year college career. The first was a seven-year follow-up study of students at Vanderbilt

University conducted by Batts (1958). In this study, the enrollment status of the 1950 cohort of the Colleges of Arts and Sciences and the School of Engineering was investigated in 1957. Batts's results indicated a 49% dropout rate (excluding transfers), but more than half of the dropouts had "returned to graduate or were potential graduates after seven years" (as cited in Eckland, 1964a, p. 61). The second, a ten-year follow-up at the University of Illinois at Urbana-Champaign, conducted in 1962, traced the college careers of males born in 1934 who enrolled as new freshmen in 1952. "Again not counting transfer as a drop, results indicated a 50% dropout rate for the Illinois group with slightly less than half dropouts returning to graduate or still potential graduates after ten years" (as cited in Eckland, 1964a, p. 61). As seen in both studies, several predictive variables associated with early attrition did not predict the return and eventual graduation of students who dropped out, but other variables not initially associated with early attrition appeared to be significantly related to later academic progress.

While referring to what are currently commonly known as stopouts, Eckland (1964a) noted that common methods of predicting four-year degree completion may not apply to students who drop out and return to college. More specifically, he explained, "The original predictive variables related to academic achievement and graduation in four years may not correlate in precisely the same manner with the return and later graduation of dropouts" (p. 60). Over a decade later, Kohen, Nestel, and Karmas (1978) also found that "it is unclear whether the factors that determine successful completion of the freshman year are the same as those that lead to success in subsequent undergraduate years" (p. 234).

Until the 1980s, Tinto's theoretical model of student departure was one of the few models that viewed dropping out of college within a temporal framework. Tinto (1975) articulated, "if one wishes to develop a theoretical model of dropout from college, one needs to seek to explain the longitudinal process of interactions that lead differing persons to varying forms of persistence and/or dropout behavior" (p. 93). In developing his model, Tinto (1975) argued that the interactions between the individual and the psychosocial environment should be viewed over a specific duration of time. According to Tinto’s (1975) model, "Given individual characteristics, prior experiences, and commitments, the model argues that it is the individual's integration into the academic and social systems of the college that most directly relates to his continuance in that college" (p. 96).

Heeding the advice of Tinto (1975), Kohen, Nestel, and Karmas (1978) published a study focused primarily on factors that affect the persistence of undergraduate students. For this study, they used a sample of males 14-24 years of age (when the study began) drawn from the National Longitudinal Surveys of Labor Force Experience (NLS) in 1966. In the original NLS study, the male students were interviewed annually through 1971, biennially in 1973 and 1975 by telephone, and face-to-face in 1976. However, only the data through 1970 were available for the analysis conducted by Kohen et al. (1978). They concluded that the importance of measured individual pre-college characteristics varies as students advance through academic levels (e.g., freshman, sophomore, junior, senior). Kohen et al. found that:

Pre-college characteristics such as socioeconomic status, race, age, and the

> respondent's marital status exhibited no significant net relationship with dropping out at any stage. The effect of having pursued a college preparatory program in high school is relevant only to completion of the freshman year. The net importance of precollege measured ability declines, while working inhibits persistence in college; this impediment appears to be greatest for those who work between half- and full-time. (p. 249)

Similar to the findings of Kohen, Nestel, and Karmas (1978), in an article published in the same year, Pantages and Creedon (1978) noted that throughout studies of college attrition from 1950-1975 the most significant single predictors of college attrition or persistence seem to be high school GPA, high school class rank, and scholastic aptitude. But this effect changes once a student has enrolled and completed at least a semester of college, and "first semester grades are an accurate predictor of attrition when grades are low" (p. 93). In addition, they found that while several studies indicated that students consistently rank finances high in their reasons for dropping out, other studies revealed that students who drop out of college for financial reasons often reenroll in college, signifying that financial factors may affect attrition and persistence more so than degree completion per se.

The 1990s saw an influx of research focusing specifically on retention and persistence. St. John, Andrieu, Oescher, and Starkey (1994) used the 1987 National Postsecondary Student Aid Study (NPSAS-87) to compare "alternative approaches for assessing the influence of student aid on within-year persistence by traditional college-aged students enrolled in four-year colleges" (p. 455). Instead of defining persistence as continuous enrollment from academic year to year, this study defined persistence as "reenrollment for the spring semester after being enrolled in the fall semester" (p. 458). The total sample for the NPSAS-87 was approximately 47,000 undergraduate, graduate, and professional students. St. John et al. (1994) used a subset of this sample of 16,221 traditional-aged college students enrolled at four-year colleges and universities for their study. Contrary to findings of prior research that considered year-to-year persistence, results from this study indicated a negative association between parents' education and within-year persistence. In addition, their definition of persistence yielded another finding inconsistent with previous research. When considering the within-year effects, "the amount of loan and work awarded was significant and negatively associated with persistence, while the amount of grant awarded was not significant" (p. 471). This finding was contrary to the prior work of Porter (1989) who found that "students who received grants in their first year of study were more likely to remain enrolled than students without grants" (p. v). According to Adelman (2006):

> The common belief that students do not persist after their first academic year of enrollment in higher education is false. Instead, he insisted that about 90% of traditional age beginning students turn up somewhere (maybe not the first school attended) at some time (may not be in the fall term) during the subsequent calendar academic year (which is measured as July 1 through June 30). (p. xx)

In line with this assertion, while analyzing factors related to timely degree completion, DesJardins, Ahlburg, and McCall (2002) analyzed persisters as two distinct groups: a) students who did not persist at all (dropouts), and b) students who persisted after temporary withdrawal (stopouts). From a sample of 3,070 students who matriculated at one Midwestern research university as freshmen in the fall of 1991, they found distinctly different persistence patterns between dropouts and stopouts. Within the total sample, 41% of students graduated (88% of graduates without an incident of stopping out), 60% of stopouts did not return within the 19-term window of observation, and 40% of stopouts eventual returned. DesJardins, Ahlburg, and McCall (2002) found that:

> Compared to the entering cohort, stopouts are more likely to be male, from underrepresented minority groups, from the Twin Cities metropolitan area, be enrolled in General College, have lower first-term GPAs and higher loan amounts in year one, have lower ACT scores and high-school rank percentiles, and indicate a need for assistance on all of the "help" variables included in the study. (p. 564)

In an effort to help improve research on student success, the American Federation of Teachers (AFT) advises researchers to better utilize national longitudinal data sets such as the Beginning Postsecondary Students Longitudinal Study: 1996-2001 (BPS: 1996/2001) that tracked postsecondary students between the years of 1995-2001. The AFT assumes that studies like this are valuable because they might yield more reliable results because they often account for students who transfer between institutions and/or temporarily stop out at some point in their academic careers. "To sum up, there are persistence problems in higher education, although raw college graduation numbers give us a wrong impression of their nature and magnitude" (AFT, 2003, p. 6).

Time to Degree Completion. Closely related to persistence, temporal dimensions of degree completion have caught the attention of many researchers over the past couple of decades. In a review of college transcripts of participants in the Center for Education Statistics (CES) National Longitudinal Survey of the High School class of 1972 (NLS-72), Hill and Owings (1986) highlighted, "according to the Center for Education

Statistics (CES), less than half of the students who earned a bachelor's degree follow a 'traditional' path to degree completion" (p. 2). Of the 4,440 graduates within the study who received a bachelor's degree by 1984, only 49% earned their degrees within four years. Seventy-five percent earned their degrees within five years, and 24% of students took longer than five years to graduate.

Willett and Singer (1991) published the article *From Whether to When: New Methods for Studying Student Departure and Teacher Attrition*. Much of their intellectual curiosity was fueled by an increasing number of college students taking longer than four years to graduate. According to data from the National Center for Educational Statistics, less than one-third of the 1990 national cohort of new freshmen entering college had graduated within four years. Consequently, Willett and Singer (1991) argued that framing research studies of student departure around when students graduated would provide for more powerful and informative analysis than the typical studies examining simply whether a student graduates. Drawing upon examples from literature on student dropout and graduation, they introduced and applied the principles of survival analysis, a statistical method commonly used in research in the academic disciplines of economics and sociology. With reference to student departure, the foundation of this argument was that student academic careers could be disrupted throughout college. They encouraged researchers to identify the factors associated with dropout and graduation: a) whether (and when) students drop out and why; and b) whether (and when) students graduate and why.

Illustrating how researchers attempting to explore such questions have had to implement "strategic fix-ups" in the absence of survival analysis techniques, Willett and

Singer (1991) noted that Barger and Hall (1965) attempted to study the timing of dropouts by collapsing their sample into two groups: students who dropped out before the end of the 10th week of the first semester and those who quit after the 10th week of the first semester. Willett and Singer (1991) asserted that, “survival analysis is a powerful way of answering all of these questions at the same time" (p. 427). DesJardins, Ahlbrug, and McCall (2002) used a type of survival analysis, called an event history model, to determine "whether the independent variables (associated with degree completion) have effects that are different over the course of a student's academic career" (p. 563).

DesJardins, McCall, Ahlburg, and Moye (2002) found that time-varying statistical models allowed them to "observe the relationship between the regressors and graduation and the direction that these relationships take over time" (p. 95). In a replication study of data pulled from Adelman's (1999) *Answers in the Toolbox Study*, DesJardins et al. (2002) found interesting changes in results after employing a time-varying coefficient (TVC) statistical model. For example, the results from Adelman's background model indicated a negative relationship between being male and bachelor's degree completion, but when the TVC approach was used by DesJardins et al. (2002):

> This effect actually changed over time. The flexible model results indicate that the baseline estimate is initially negative, but the trend is positive as time passes. In year four, male students are less likely to graduate than female students, but as time passes, this effect actually reverses. (p. 95)

Accountability in Agency Relationships

While allowing for increased autonomy, states have also increased the levels at which higher education institutions are held accountable for performance. Federal reporting requirements related to student and institutional performance is coupled with federal financial assistance. Federal financial assistance for postsecondary students dates back to a set of domestic programs put forth by President Lyndon B. Johnson known as the “Great Society.” As one of the new major spending programs, the Higher Education Act (HEA) of 1965 was enacted to increase both federal funding of universities and federal student aid in the form of scholarships, grants, low-interest loans, and work-study. This newfound financial assistance to students and institutions brought increased educational opportunity to students with limited financial access. Along with this funding came stringent reporting requirements. One such requirement comes from the Title IV – *Student Assistance* section of the HEA: the requirement that all institutions that participate or are applicants for participation in any federal financial assistance program authorized by Title IV of the HEA complete Integrated Postsecondary Education Data System (IPEDS) surveys. The completion of such surveys is mandated by Section 487 [20 USC 1094] (a) (17). Section 487 (a) (17) states, “the institution will complete surveys conducted as a part of the 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.”

According to Roska (2010), institutions have come under “increasing scrutiny since the Federal Student Right to Know and Campus Security Act of 1991 (SRK) mandated that institutions publish their graduation rates” (p. 1). As a requirement for disclosure and reporting under the SRK, Planty, Hussar, Snyder, Kena, Kewal-Ramani, Kemp, Bianco, and Dinkes (2009) explain that degree completion rates are calculated exclusively as:

> The total number of completers within the specified time to degree attainment (four, five, and six years) divided by the revised cohort minus any allowable exclusions (allowable exclusions include those students who had died or were permanently disabled; those who had left school to serve in the armed forces; those who had left to serve foreign aid service of the federal government such as the Peace Corps; and those who had left to serve on official church missions). (p. 54)

A limitation and major criticism of the degree completion rates as they are calculated for the U.S. Department of Education is that "only a subset of admitted freshmen are counted" (Adelman, 2006; Gold & Albert, 2006; as cited in NCES, 2006, p. v). According to IPEDS, degree completion data of nearly 30% of postsecondary students were not taken into account when determining the degree completion rates for 2004. Several populations of students excluded from official degree completion rate statistics include: first-time full-time freshmen who were matriculated during any academic term other than fall term, part-time students, transfer students, and students who take longer than six years to graduate.

Findings from a 2003 report published by the AFT indicate, "focusing on the college graduation rate confuses two separate issues—the issue of dropping out of college (persistence) and the issue of simply taking a long time to get a degree (time-to-degree)" (p. 5). Echoing this point, Adelman (2006) adds:

> The core question is not about basic "access" to higher education. It is not about persistence to the second term or the second year following postsecondary entry.

It is about completion of academic credentials—the culmination of opportunity, guidance, choice, effort, and commitment. (p. xv)

Archibald and Feldman (2008) claim that, "concerns about using raw graduation rates as an objective standard for comparing universities are not new" (p. 81). Around the 1950s, many studies on attrition focused on transitions from high school to college, and from college to graduate/professional schools, even though, as Iffert (1958) suggested, “more than a third of students who actually enter college will probably never obtain the baccalaureate degree” (as cited in Astin, 1964, p. 219). Summerskill (1962) observed that the "attrition rate had been variously defined as the percentage of students lost to a particular division within a college, lost to the college as a whole, or lost to higher education as a whole" (as cited in Pantages & Creedon, 1978, p. 4). Summerskill declared that a landmark study on retention and withdrawal of college students conducted by Iffert (1958) was the beginning of a trend in attrition research aimed at providing more categories of college dropouts. Iffert used ten categories in classifying different types of dropouts and non-dropouts. As argued by Savicki, Schumer, and Stamfield (1970, as cited in Pantages & Creedon, 1978), these finer discriminations among categories may yield better results and clearer interpretations of those results.

In the majority of methodological approaches to study college student attrition during the mid-20th century, "the criteria of success or failure are grades, early attrition, or graduation at some point during the four years immediately following the student’s matriculation in college" (Eckland, 1964a, p. 60). These narrowly focused approaches failed to account for the fact that students often drop out of college temporarily and return later to complete their academic degrees. Eckland (1964a) pointed out that a temporary disruption in academic progress posed great problems in predicting degree completion, because "a variety of factors may intervene between dropout and return to college" (p. 60).

In review of a 1962 ten-year follow-up study of males born in 1934 who enrolled as freshmen at the University of Illinois in September of 1952, Eckland (1964a) noted that, "evidence on the basis of an investigation that traced the academic careers of Illinois freshmen for 10 years support the conclusion that the associations of several independent variables with college attrition are not stable" (p. 72). Eckland (1964a) realized that many students fail to graduate from the college they first entered, but that did not mean that they never graduated. The temporary stopping out of students, whether it be due to transferring to another institution or temporally taking time off from college, creates various challenges in prediction studies because “the power of an item to predict ultimate graduation is annulled completely when allowances are made for the college dropouts who came back” (p. 72). Eckland (1964a) found that this instability of predictive items is caused by temporary disruptions of academic progress by students, so that:

> Predictive items and self-reported reasons that are associated with early attrition may fail to predict the return and graduation of the dropout, while other items not associated with early dropping out appear to be significantly correlated with late careers. (p. 72)

In a comparison of national four-year graduation rates and re-calculated graduation rates for students who drop out and reenroll in college, Eckland (1964b) found significant increases in graduation rates after accounting for students who drop out and reenroll. Before accounting for dropouts, Eckland (1964b) found that 49.7% of students graduate after varying periods of continuous enrollment, but only 36.5% graduate within four years. After including dropouts in his analysis, approximately 70% of all students were shown to have eventually graduated from some institution. Eckland (1964a) outlined four types of dropout that should be considered when conducting research on college attrition:

> 1) low achievers, or freshmen who failed, or nearly failed, their first semester in college by not receiving a "C" grade average or better, 2) early dropouts, or students who left the university (or college to which they transferred) during the first school year and did not immediately re-enroll at an institution of higher education the following term (excluding summer sessions), 3) all dropouts, or all students who left the University (or college to which they transferred) at any time before attaining a degree and did not immediately reenroll at any institution of higher education the following term (excluding summer sessions), and 4) permanent dropouts, or all dropouts whose graduation appears unlikely (they either did not return to college, or, if returned, were not "potential graduates"). (p. 63)

According to Pantages and Creedon (1978), findings of Eckland (1964b) have been supported by other researchers (e.g., Trent & Ruyle, 1965). Jex and Merrill (1962), in another ten-year study, estimated that approximately 60% of the students who drop out would eventually reenroll at the same or another institution and graduate. Johansson and Rossmann (1973) estimated that “80% of the dropouts will reenroll and 60% of them will graduate" (p. 55). Pantages and Creedon (1978) concurred that this finding introduced yet another significant problem in attrition research: "what exactly is attrition and what is a dropout"? (p. 51). Criticizing existing literature on postsecondary attrition, Spady (1970) decided to examine migration patterns of college students and institutional impacts on the attrition process. Before the year 1970, there were two widely accepted operational definitions of the college dropout: 1) any student who leaves a college at which they are registered; and 2) any student who never receives a degree at any point in time (Spady, 1970). Spady (1970) found that:

> The first definition proved to be methodologically convenient, but it fails to provide a broad enough perspective on the actual rates of retention pertinent to the system of higher education as a whole. The second definition requires the mobilization of immense data gathering and follow-up resources, which are further complicated by the elements of time, inter-institutional mobility, and the social stigma associated with the failure to persevere academically. (p. 68)

Astin (1972) joined critics of the literature on the college dropout and argued, "Since most empirical studies of dropouts have been carried out either at single institutions or in individual states, their findings may give a very misleading picture of the national scene" (p. 8). This critique was consistent with Summerskill's (1962) earlier findings from a review of 35 different studies of student attrition conducted between 1913 and 1962. Results from Summerskill’s study indicated that the "median loss of students in four years was 50%, and that the attrition rate had not changed appreciably between 1920 and 1962" (as cited in Bean, 1980, p. 155). Astin went on to articulate several serious defects of such studies, such as incomplete sampling of institutions, inadequate student input data, or complete reliance on student responses to mailed follow-up questionnaires.

Casting a wider lens on student attrition, Astin (1972) conducted a study that focused on a national profile of college dropouts. The major focus of Astin's study was to examine several related issues concerning college dropouts, such as national dropout rate, varying dropout rates by institution, dropout versus non-dropout, institutional impacts, impact of ability, and impact of background characteristics. In an attempt to better understand these issues, Astin developed a 150-item student information form covering such background information as age, sex, race, religion, parental income and education, and high school achievements, which was administered to every first-time full-time freshman entering a sample of 217 different institutions in the fall of 1966. In the fall of 1967, he randomly selected approximately 250 students from each of the institutions to gather academic information on student performance from institutional representatives, totaling 6,289 students from two-year colleges and 45,432 from four-year colleges and universities. In the fall of 1970 and the winter of 1970-71, representatives from the institutions were asked to answer four separate questions pertaining to the same sample of students from the 1967 follow-up:

> 1) Had the student obtained any degree by the time of the follow-up in fall 1970; 2) When was the student last enrolled for credit toward a degree; 3) Was his transcript ever sent to another academic institution; and 4) What was his cumulative grade point average? (Astin, 1972, p. 4)

Results from Astin's study revealed that persistence rates were substantially higher in the United States than what was published in the Newman Report (1971), which suggested that about one-third of students will complete a four-year degree. Summarizing the results, he explained that the national dropout rate for four-year colleges and universities was 50% and decreasing, as students were taking longer than four years to complete their degrees.

In the most widely cited study on the dropout process, Tinto (1975) noted that despite extensive literature on the dropout process, there are still many unknowns about this phenomenon. In reviewing many studies prior to 1975, Tinto suggested that future researchers work towards rectifying two major shortcomings: "inadequate attention given to the questions of definition and to the development of theoretical models that seek to explain, not simply to describe, the processes that bring individuals to leave institutions of higher education" (Tinto, 1975, p. 89). In more detail, Tinto (1975) explained that the failure to utilize precise definitions and categorizations of dropouts has led to contradictory findings throughout the related literature. Tinto (1975) noted that, "failure to separate permanent dropout from temporary dropout and/or transfer behaviors has often led institutional and state planners to overestimate substantially the extent of dropout from higher education" (p. 90).

In a review of studies of college attrition between the years of 1950-1975, Pantages and Creedon (1978) came to the conclusion that "the most meaningful research on attrition is provided by studies that cover a period of more than four years and that use precise operational definitions of dropout and non-dropout" (p. 92). The absence of these precise operational definitions negatively affects research study findings by increasing the ambiguity of outcomes. Pantages and Creedon (1978) found that only about 40% of students who enter college in the United States actually complete their degrees within four years, with an additional 10% who will eventually graduate at some point after those four years. Of the 50% of students who dropped out of college, 40% will eventually reenroll at another institution, and 20% of these students will eventually graduate. “This means that of the estimated 7.6 million undergraduate students enrolled in the U.S. in 1971, roughly 2.3 million students will drop out of higher education completely” (p. 49).

Such a finding was consistent with the work of Iffert (1958), Little (1959), and Summerskill (1962) who also found after examining 35 attrition studies conducted over a 40-year period that “the percentage of students lost to a college over a four year period has not changed significantly in four decades. The median loss reported by these studies was 50%, and the median graduating class four years later was 37%” (as cited in Pantages & Creedon, 1978, p. 55). These findings were somewhat consistent with those of Panos and Astin (1968), whose data showed that "within an American Council of Education national sample of 127,212 freshmen at 248 four-year colleges in 1961, 65% of the respondents to a follow-up questionnaire had already received four years of schooling" (Spady, 1970, p. 67). However, they found it impossible to accurately determine the proportion of graduates from this group, because their criterion did not differentiate between those who had graduated at the four-year mark and those who were still enrolled.

Relating to Astin's (1972) aforementioned fourth measure (received the bachelor’s degree, was still enrolled for work toward the degree, or had transcripts sent to another institution) designed to determine retention or dropout status, a decade later Tinto (1982) urged scholars to develop models to better track student inter-institutional movement. Tinto (1982) suggested that:

> This method would allow researchers to assess comparative interactive effects of differing institutional and system attributes upon the decisions of individuals to

> persist at a given institution, to transfer within a state to other institutions of varying kinds, to transfer out-of-state, or to leave higher education altogether. (p. 690)

Just as Tinto (1975) criticized imprecise definitions of dropout used throughout the student attrition literature, Kohen, Nestel, and Karmas (1978) found that this literature lacked utilization of multivariate statistical techniques. Tinto argued that the use of such techniques would enable researchers to draw more confident inferences about the independent effects of a multitude of factors said to correlate with dropping out of college. Kohen et al. (1978), focused on the co-varying effects of external factors independent of the student and institution (e.g., the state of the labor market, etc.). For example, Kohen et al. (1978) alluded to the idea that state labor markets can also have an impact on a student's decision to persist or drop out in such a way that lucrative professional opportunities could draw students away from college and limited professional opportunities could serve as an extrinsic motivator to persist. Kohen et al. (1978) found that:

> An important methodological conclusion is that findings from previous theoretical and empirical work on dropping out of college must be viewed with caution. By ignoring the inter-temporal nature of undergraduate education and by inadequately controlling for inter-correlated explanatory factors, previous research has drawn and perpetuated several erroneous inferences. (p. 250)

Reviewing the 1980 national survey of 28,000 high school seniors, more commonly known as the High School and Beyond (HSB) study, Porter (1989) highlighted several different definitions of student persistence. In the study, the term persistence was used to describe the flow of students through college over a six-year period, instead of over a four-year period. Here, four different categories of persistence were identified: “completers (those who completed a bachelor's degree), persisters (those who were continuously enrolled), stopouts (those who left and returned), and dropouts (those who left and did not return)” (p. iv). Porter (1989) found that:

> Among the students attending a four-year college or university, some 73% enrolled fulltime in fall 1980; the remainder started at a less-than-four-year institution, entered part time, or delayed entry for at least one semester. After six years, 40% of the students had completed a bachelor’s degree, while 44% had dropped out. However, if we look only at the students who began on the traditional entry path, the completion rate increases to 46% and the dropout rate falls to about 42%. (p. 10)

Until the early 1990s “most of the studies of persistence and attainment in postsecondary education were based on institutional data that focused on the issue of student retention at that institution” (Berkner, Cuccaro, & McCormick, 1996, p. 4). In a five-year follow-up longitudinal study of the 1990 BPS Longitudinal Study, Berkner, Cuccaro, and McCormick (1996) interviewed a sample of students at the end of their first year in 1990, in the spring of 1992, and in the spring of 1994. In this longitudinal study, they found substantial differences between institutional rates of retention and overall persistence among new freshmen. From the perspective of “first institution attended,” the five-year graduation rate was 37%, but from the perspective of the individual student, the five-year graduation rate was 50%.

Extending the idea of persisters and dropouts, Volkwein and Lorang (1996) identified an entirely new category of students: extenders. This study defined extenders as full-time undergraduate students who take longer than normal to graduate. The advantage of this approach is that it allowed for the assessment of students who were continuously enrolled (persisters) and took longer than normal to graduate, and also for the assessment of students who were continuously enrolled, but for fewer than 15 credits (defined here as a full credit load). A transcript analysis of 64 first-time full-time fall 1998 admitted freshmen who took five years to graduate revealed:

> 1) the most apparent reason for students to take longer than four years to graduate was that they attempted fewer than 15 credits a semester; 2) nearly every student did successfully complete one or more semesters with more than 15 credits; 3) for many students, pre- and post-matriculation credits earned elsewhere are an important factor in completing their program requirements for graduation; 4) credit accumulation beyond the 120 required for graduation was a significant factor for one student in five; 5) 16 students took longer to graduate because they withdrew for one or two semesters and returned; and 6) academic performance was at least a temporary problem for nearly one out of every five graduates. (Volkwein & Lorang, 1996, p. 52)

Data from the BPS Longitudinal Study 1996-2001 showed that 60.8% of postsecondary students in the U.S. who attended a public four-year institution graduated within six years, and 17.8% were still enrolled. To illustrate the difference between degree completion and degree production rates, the National Education Association (NEA, 2004) analyzed data from the BPS 1996-2001 Data Analysis System (BPS:

9/6/01). In reviewing the data, NEA found that there are significant differences between institutional six-year graduation rates (proportion of students who graduate from the college or university at which they started), and system six-year graduation rates (combination of those who graduate from their first school plus those who graduated from any subsequent college or university). The NEA's (2004) findings suggest that "about 51% of the 1995-1996 freshmen cohort that started at a four-year college or university graduated from the institution at which they started, but another 8% graduated from somewhere else within six years for a total of about 59% (p. 4). The NEA (2004) concluded in a higher education update that their "review of the evidence suggests that, by itself, this measure [graduation rates] is incomplete and can be misleading" (p. 1).

Highlighting factors that relate to institutional degree completion, Astin (2005) asserts that, "an institution's degree completion rate is primarily a reflection of its entering student characteristics, and differences among institutions in their degree completion rates are primarily attributable to differences among their student bodies at the time of entry" (p. 7). Criticizing requirements of the Federal Student Right-to-Know and Campus Security Act (SRK) of 1991, NOTE: this is spelled out earlier; does it need to be spelled out again? Astin (1997) stated that, "indeed, more than half of the variance in institutional retention rates can be attributed directly to differences in the kinds of students who initially enroll, rather than to any differential institutional effect" (p. 648). This belief is consistent with the NEA's (2004) claim that, "the links between institutional characteristics and student graduation are weaker than those between student characteristics and college completion" (p. 2). Astin's (1997) critique was aimed at the use of the retention/degree completion rate as a measure of institutional quality, suggesting that published rates might mislead people into assuming that, "Institutions with high retention rates are presumably doing a better job retaining their students than are institutions with lower rates" (p. 648).

Adelman's (2006) study *Paths to Degree Completion from High School through College* made headlines across the U.S. This study was unique because it explored and compared pre-matriculation and post-matriculation factors related to degree completion. This study was a follow-up to a previous study based on data from the High School and Beyond/Sophomore U.S. Department of Education national grade-cohort longitudinal study which "followed a national sample of 10th graders from 1980 to 1992 in surveys and to September 1993 on postsecondary transcripts" (Adelman, 2006, p. 4). According to the findings from this study, even though students demonstrated persistence through their academic career, the completion of fewer than 20 credits by the end of their first calendar year negatively impacted degree completion; demographic characteristics such as gender and race/ethnicity were not significantly associated with degree completion; and change of major did not have any influence on degree attainment after accounting for students who transferred from two-year institutions into four-year institutions.

The NEA (2004) findings are consistent with those of Jones-White, Radcliffe, Huesman, and Kellogg (2008), who found that institutional six-year graduation rates at one Midwestern research university were substantially lower than degree attainment rates of national cohorts of students. The data sample they used consisted of 15,496 students who enrolled as first-time degree-seeking freshmen at the study institution during the 1999 through 2001 fall semesters. To track the students over the course of six years, they utilized "central records" and the student tracker service from the National Student

Clearinghouse (NSC), which keeps accounts of approximately 91% of enrollment across the United States. To measure degree completion, they used three different definitions to account for various pathways to this accomplishment: "1) baccalaureate degree from home institution; 2) baccalaureate degree from other institution; and 3) associate degree/certificate award from other institution" (Jones-White, Radcliffe, Huesman, & Kellogg, 2008, p. 4). Their findings indicated that roughly 61.5% of students in the sample earned a degree from the institution where they first enrolled six years earlier, 7.5% earned a baccalaureate degree from another institution, and 2.3% of students earned an associate's degree or certificate from another institution. In addition, 1.6% of students in the sample were enrolled after six years at the institution where they initially enrolled after high school, 2.6% were enrolled at the six-year mark, and 11.8% of the students were still enrolled an another institution at or after the six-year mark. The unique role of two-year schools in supporting eventual degree completion bears further examination.

In a comparison of the California Community College (CCC), California State University (CSU), and University of California (UC) systems, Offenstein and Shulock (2009) found that the community college system had the largest role to play; their findings suggest that:

> The community college system is the only segment that awards pre-baccalaureate certificates and associate degrees; 70% of students receiving associates or bachelor's degrees from the state's public colleges are either CCC students or UC/CSU students who transferred from the CCC. (p. 7)

However, because of the strict IPEDS reporting requirements, students who transferred from a CCC institution to a UC/CSU institution did not count in the calculation of graduation rates. Because of these rigid reporting constraints, an ever-growing population of what Adelman (2006) calls "swirling" students are inaccurately counted as dropouts. Data compiled from Peter and Forrest-Cataldi (2005) indicate the following results for the 1995-96 beginning postsecondary students at public four-year institutions: 38.9% attended more than one institution, 12.4% sometimes simultaneously enrolled in more than one institution, and 27% transferred to another institution at least once. Adelman (2006) contends, "With all this change, we still measure something called college graduation rates with anachronistic formulas that do not track students through increasingly complex paths to degrees" (p. xvi).

Production of Bachelor's Degrees within States**.** According to data collected in *Measuring Up 2008: The National Report Card on Higher Education*, since the early 1990s, 43 states improved or stayed the same on the key indicator of percentage of 18-24-year-olds enrolled in college, while seven states declined. On the key indicator of completing a bachelor's degree, 48 states improved or stayed the same, while two states declined. Despite the fact that the nation as a whole has experienced gains in post-secondary enrollment rates of young adults, degrees conferred, and 6-year graduation rates, these gains vary greatly by state. For example, in 1991 the difference between the states with the highest (Rhode Island: 41.6%) and lowest (Alaska: 18.8%) percentages of 18-24-year-olds enrolled in college was 22.8%. In 2009, Rhode Island still enrolled the highest percentage of young adults at 52.8% and Alaska enrolled the lowest with 18.6%; over this time period, the difference increased to 34.2% (National Center for Higher Education Management Systems).

With respect to state differences in six-year graduation rates for all Title IV four-year institutions, for the fall 1991 beginning cohort Rhode Island had the highest six-year rate of college student degree completion at 72.4%, and Alaska had the lowest at 18.9%, a difference of 53.5% across these two states. For the fall 2008 cohort, Massachusetts had the highest six-year graduation rate of 69.1%, and Alaska had the lowest of 22.1%, a difference of 47% (National Center for Higher Education Management Systems). Although there is voluminous literature on correlates of institutional graduation rates, there is less research on institutional and state-level correlates of degree productivity at the bachelor's level. Advisor says "here make a specific reference to the need for agency."

Much of past research on the impacts of federal and state policies on higher education has focused primarily on issues related to the sorting of students within higher education. In analyzing this previous research, Perna and Titus (2004) found that four kinds of state public policies may influence the sorting process: "1) direct appropriations to higher education institutions, 2) financial aid to students, 3) tuition, and 4) policies related to academic preparation at the elementary and secondary school levels" (p. 502). Similarly, Hauptman (2001) identified three different aspects of a state's financial context that may influence the distribution of enrollments into higher education: "1) appropriations to higher education, 2) tuition policy, and 3) student financial aid" (as cited in Roska, 2010, p. 7).

While the aforementioned studies may help to shed light on questions related to student choice of enrollment, Bound and Turner (2007) argue that such analyses on demand-side factors assume that "colleges and universities adjust to supply fully with changes in demand" (p. 878). At the base of their argument is the notion that the supply of higher education to varying levels of student demand is not perfectly elastic. In economic terms, Winston (1999) put forth the idea that certain characteristics of non-profit organizations, such as peer effects with customer-input technology and financial hierarchies of universities and colleges, impact the ways in which higher education firms and markets adjust to student demand and degree production. In a lengthy summary on the awkward economics of higher education, Winston (1999) explains:

> The firms in higher education appear to display the following characteristics: they have donative as well as commercial revenues so that costs can and do exceed sales revenues by a great deal, subsidizing their customers; there are very different levels of donative revenues among different institutions; those donative revenues are fixed in the short run for private schools but typically expand with enrollment in public schools, which has influenced schools' incentives to restrict or expand enrollment; firms use a production technology in which an important input, student quality, can be purchased only from their customers; firms control who they sell to by using their donative resources to generate an excess demand that allows them to select among potential customers for student quality; higher student quality feeds back to increase demand, hence student quality; and schools will adjust the production technology they use for education in response to how they are positioned by their donative revenues. (p. 27)

Using Winston's (1999) economic ideas as a backdrop, Bound and Turner (2007) found that the interplay between donative and commercial revenues on the actual educational production costs paid by consumers, adjustments in enrollment demand are unlikely to be financially counterbalanced by non-tuition revenue. “For this reason, public investment in higher education plays a crucial role in determining the degrees produced and the supply of college educated workers to the labor market” (Bound & Turner, 2007, p. 878). As a byproduct of federal financial assistance directly to students, students are afforded the luxury of choice. More specifically, because federal need-based aid was aimed at providing students with more choices for enrollment:

> The price of college was therefore included in the federal need analysis formula, which is used to determine the expected family contribution (EFC) and the amount of federal need-based aid a student may receive, so that aid programs could address choice as well as access. (Institute for Higher Education Policy, 2002, p. 2)

Analyzing the impacts of financial resources on degree attainment, Bound and Turner (2007) assert, “Changes in the funding for public colleges and universities have a large impact on both the quantity and the quality of college graduates in the country” (p. 880). Their research findings suggest, “A 10% state-specific increase in the size of the college age population leads to a 4% decline in the fraction attaining a BA” (p. 895).

Analyzing how public tuition prices and financial aid expenditures in the 50 states relate to undergraduate enrollment rates (1976-1994), Heller (1999) found, “Increases in tuition lead to declines in public enrollment, and decreases in state grant spending lead to declines in enrollment, with the largest effect occurring among community college students” (p. 82). Addressing issues related to the distribution of enrollments in two- versus four-year institutions, Roska (2010) found evidence of sorting into two-year institutions as a result of financial aid policies, especially in states such as California where “students are more likely to begin their education in community colleges simply because of the spaces available in two- versus four-year institutions” (p. 5). Hypothesizing that the size of the community college sector may lead to differential sorting of students into two- versus four-year colleges, Roska (2010) drew from a sample of 1,052 public and private colleges and universities and included approximately 25,000 respondents. Utilizing logistic regression models, results from Roska’s (2010) study suggest, “The presence of community colleges facilitates sorting of students into higher education in a way that is associated with higher degree completion at public four-year institutions” (p. 14).

Because the actual cost of education to students is usually subsidized by public funding within states, relatively large cohorts of students entering higher education within a state can create a “crowding out” effect in which both students and institutions struggle. Absent complete per capita adjustments in state-level subsidies, these large cohorts drain educational resources available per student in aggregate. To this effect, Bound and Turner (2007) further explain, “When an increase in student cohort populations is not accompanied by a proportionate increase in resources, large cohorts are essentially “crowded out” of the higher education sector” (p. 879), impacting both the quantity of degrees produced and the quality of college graduates.

To begin their empirical analysis, Bound and Turner (2007) estimated “the elasticity of college completion, defined as then log of BA degrees awarded, with respect to cohort size, defined as the size of the population age 18 within the state four years earlier” (p. 885). An initial finding of this study suggests that there is a strong negative association between cohort sizes and completion rates within a state for a given year. As a result, these researchers questioned: “Whether the reductions in college completion rates among large cohorts are caused by declines in the college preparedness of large cohorts on the demand side of the higher education market or limitations in the adjustment of colleges and universities” (Bound & Turner, 2007). They hypothesized that “limited adjustment among colleges and universities on the supply-side of the higher education market is the primary cause of the relative reduction in attainment among large cohorts” (p. 879).

To test their “cohort crowding” hypothesis, Bound and Turner (2007) introduced an inverse demand function $T\left(\frac{L}{n}, \frac{n}{pop}\right)$, where L is the total non-tuition revenue and n is enrollment. Following this model, they believed that “much about the behavior of colleges and universities can be inferred from the non-distribution constraint, which applies to both public and private non-profit institutions of higher education and require that there be no residual shareholders” (Bound & Turner, 2007, p. 882). The non-distribution constraint is “$nT\left(\frac{L}{n}, \frac{n}{pop}\right) - nc(q) + L = 0$, where $c(q)$ reflects per-student costs as a function of quality (or resources), with c’$(q) > 0$ and total costs of $n\ c(q)$. It follows that the per-student costs of the quality of education provided is simply equal to tuition plus the per student subsidy (L/n)” (Bound & Turner, 2007, p. 882). Results from Bound and Turner’s (2007) results show:

> The elasticity of college completion at all institutions with respect to cohort size is significantly less than one, varying from .71 to .62 depending on the period of observation. In addition, the estimate for the effect of cohort size at age 18 on the number of degrees awarded by public institutions is broadly similar to the

estimate (.59 versus .62) over the period for which this distinction is possible. (p. 885)

Additional findings suggest that there are substantial cohort crowding effects on college completion rates, and consequently on college degree attainment rates. Their estimates suggest, “A 10% increase in the size of the college age population leads to a 4% decline in the fraction attaining a bachelor’s degree” within states (Bound & Turner, 2007, p. 895). In addition, they found no evidence to support the notion that growth in out-of-state enrollments or expansions of private college enrollment are able to absorb the effects of increased demand for higher education on degree attainment at public colleges. Bound and Turner (2007) conclude with a warning that “The impending collision of large cohorts and limited public resources in higher education is not just a predicament for colleges and universities, but a potential crisis in economic growth for decades to come if the flow of college-educated workers to the labor force is further curtailed” (p. 896).

In a similar study, Berger and Kostal (2002) illustrated how shifts in the financing of higher education, and competition for limited state resources, negatively impact student enrollments in higher education. To better understand how the shifting of the financial burden of financing higher education shifted from the state government to students and families, Berger and Kostal (2002) argued that empirical evidence from supply and demand-side effects of this shift must be considered. In their study, Berger and Kostal (2002) pointed to the need to “pay particular attention to the extent to which differing financial resources, most notably tuition and state and local appropriations, influence the enrollment rate in public higher education in the United States” (p. 102). The study used data collected from the Digest of Education Statistics and various samples obtained by the US Bureau of the Census to compile a sample inclusive of 48 states for a period from 1990 to 1995. Seeking to explain determinants of public higher education enrollment rates across states, Berger and Kostal (2002) estimated an econometric demand and supply model while simultaneously determining tuition fees and enrollments for public education" (p. 104). Based on the model, results from the study indicated:

> With regard to demand for public higher education, tuition proves to be the significant variable: as tuition increases the enrollment rate decreases. On the supply side, the enrollment rate is influenced positively by available funds (except tuition) and the relative size of the higher education sector within a certain state and negatively by the scope of autonomy of colleges and universities. (p. 109)

To help combat suboptimal degree completion rates, the U.S. Department of Education (DOE, 2011) suggests that states consider adopting funding formulas that reward institutions for degree completion, and move away from formulas that "reward institutions based on student enrollment" (p. 6). According to the DOE (2011), "Institutions of higher education are rewarded for turnover, as large freshman and remedial-level courses tend to cost less per pupil to deliver than smaller, more advanced level courses required for completion" (p. 6). States that have revised their funding formulas to consider degree completion include: Washington, Ohio, Indiana, Tennessee, and Texas. Funding formula revisions included considerations of performance measures of enrollment and institutional achievement measured against levels of and improvement in:

1) General outcome indicators: numbers and percentages of certificates and degrees conferred; 2) subgroup outcome indicators: general outcome

> indicators to Pell Grant recipients, adult students, minority students, and students who enter with low skills, as well as levels and progress in closing attainment gaps; 3) high-need subject outcome indicators: general outcome indicators in priority fields such as mathematics, science, engineering, and nursing; 4) progress indicators: number and percentage of students who transfer successfully, transition successfully from developmental to college-level course enrollment, and complete their certificate or degree programs on time. (Department of Education, 2011, p. 6)

Focusing more on the impact of the distribution of higher education enrollments on student outcomes, Roska (2010) pays close attention to the relative distribution of enrollments in two- versus four-year institutions within a state, and the existence of state-wide transfer articulation policies. After reviewing data from the National Center for Education Statistics (2007), which indicate approximately 70% of students in California's public education system attend community colleges, and less than 15% of public education students in Alaska and South Dakota attend these institutions, Roska (2010) looks more deeply into "understanding how the reliance on community colleges versus four-year institutions to provide higher education may be related to student outcomes" (p. 3).

In this study, Roska (2010) analyzed data from the Postsecondary Education Transcript Study (PETS) to perform two sets of analyses. The first set examined the probability of entry into a two- versus four-year public institution, and the second set was designed to estimate the likelihood of bachelor's degree completion. For each set of analyses, Roska (2010) presented two models: "the first model only controls for the key state-level variable of interest while the second model controls for other aspects of the state environment" (p. 8). Results from the first set of analyses confirmed that there is a negative relationship between the size of the community college sector and probability of entry into a four-year institution. More specifically, Roska (2010) explained: "in states with larger community college sectors, smaller proportions of students enter public four-year institutions" (p. 9).

Once confirming the relationship between the relative size of the community college sector within a state and student transfer enrollment patterns into four-year institutions, Roska (2010) moved on to the second set of analyses and asked "whether this sorting is associated with bachelor's degree completion" (p. 11). At the onset, Roska (2010) noted that results from this set of analyses seemed counter intuitive. While results from the first set of analyses suggest that the "larger the relative size of the community college sector, the lower the probability of entry into four-year institutions," results from the second set of analyses suggests that the "higher the probability of entry into four-year institutions, the lower the likelihood of degree completion" (p. 11). Elaborating on these findings, Roska (2010) further explains:

> The results suggest that there is a positive relationship between the size of the community college sector and bachelor's degree attainment at public four-year institutions: the larger the proportion of students attending community colleges in a state, the higher the probability of bachelor's degree attainment at public four-year institutions. This appears to be a product of student sorting: the presence of community colleges facilitates sorting of students into higher education in a way

that is associated with higher degree completion at public four-year institutions. (p. 14)

College student retention and graduation research literature is replete with extensive student-focused research on the relationships between student characteristics and persistence, time-to-degree, and degree completion. Throughout such studies, Titus (2009a) identifies three prominent student-focused conceptual frameworks that come to the fore: “Tinto’s (1987) integration theory, Bean’s (1990) student attrition model, and Astin’s (1984) notion of student involvement” (p. 8). While such frameworks have enhanced our understanding of the relationship between the student and the institution regarding degree completion, there is still limited research that helps to provide insight into the “problem of providing higher education in a more effective manner that enables existing resources to be used to meet increasing demand for education” (Abbott, 2003, p. 89).

Data Envelopment Analysis

Literature on the measurement of higher education institutional degree completion and degree production rates suggests that a more nuanced and accurate performance measure is required to effectively measure graduation rates and degree production across universities in the United States. One such performance measure was introduced in the 1997 *U.S. News and World Report, America’s Best Colleges*. Eventually called “graduation rate performance” Archibald and Feldman (2008) explain, “Gradation rate performance is calculated using the residuals from a regression equation in which the graduation rate is regressed on variables measuring entering student quality and expenditures per student” (p. 81). However, Archibald and Feldman (2008) argue that, “regression analysis may not be the best tool to assess the graduation rate performance of a college or university” (p. 81). As an alternative to using regression analysis to assess graduation rates, Archibald and Feldman (2008) contend that, “graduation rates should be compared to best practice measured by a production frontier” (p. 81). The use of a production frontier also allows for an assessment of the goals of states to increase baccalaureate degree production, and the reality of the limitations posed by the scarcity of resources and/or efficient utilization of resources by higher education institutions.

Emerging from the discipline of economics, production frontiers (also known as production possibility frontiers) illustrate the maximum output(s) that can be produced in an economy/environment at any given time, considering the input(s) or resources available. The intention of a production frontier is to estimate the maximum possible production (output) given a set of inputs, as opposed to average production given a set of inputs. The two most common non-parametric analytical strategies for estimating production frontiers are stochastic frontier analysis (SFA) and data envelopment analysis (DEA). While both analytic strategies estimate a production frontier, SFA is best suited for studies with a single input or predetermined weighted average of multiple inputs, and DEA offers the advantage of considering multiple inputs and outputs without predetermining weighted averages in the analysis. In addition, DEA differs from SFA because of the utilization of linear programming procedures which “offer more accurate estimates of relative efficiency, marginal input or output values and target levels” (Thanassoulis, 1993, p. 1130).

The term DEA was coined by Charnes, Cooper, and Rhodes (1978) and introduced as a “proposed measure of the efficiency of any decision making unit (DMU), obtained as the maximum ratio of weighted outputs to weighted inputs subject to the condition that the similar ratios for every DMU be less than or equal to unity" (p. 430). The terms "decision making unit" and "higher education institution" are used interchangeably in this study.

Compared to statistical parametric approaches, Johnes (2006) explains:

> DEA uses the input and output of the data themselves to compute, using linear programming methods, the production possibility frontier. The efficiency of each unit is measured as the ratio of weighted output to weighted input, where the weights used are not assigned a priori, but are calculated by the technique itself so as to reflect the unit this is most efficient relative to all others in the dataset. (p. 274)

Comparing DEA and regression analysis (RA), Thanassoulis (1993) concluded:

> DEA offers on the whole, more accurate estimates of efficiencies, marginal values and targets. The reason for this is, in general, because DEA is a boundary method basing estimates on efficiency rather than average performance. One further advantage of DEA is that its estimates or marginal values and target levels are not affected by correlations and multicollinearity between inputs or outputs. RA on the other hand is less prone to give extreme inaccuracies of estimates at the individual level, because RA estimates are based on the full set of observations. (p. 1143)

To explain differences between DEA and regression (RA) analyses, Bowlin, Charnes, Cooper, and Sherman (1985) note, "DEA uses "n" optimizations, one on each observation, to arrive at a piecewise linear surface, whereas regression approaches use only one optimization to arrive at a single smooth regression over all observations" (p. 114). Assessing the performance of 15 hypothetical hospitals, Bowlin, Charnes, Cooper, and Sherman (1985) found DEA preferable to ordinary least squares regression models because it allowed for the identification of the sources of inefficiencies by highlighting which resources were over/under utilized in each hospital.

Assessing performance measurement of hospitals, Banker, Conrad, and Strauss (1986) compared DEA and translog parametric function analytic strategies to test for the presence of technical efficiency (i.e., effectiveness of utilizing inputs to produce outputs considering a decision making unit's current size based on input values) and scale efficiency (i.e., effectiveness of utilizing inputs to produce outputs if a decision making unit was operating at the most productive size in relation to other decision making units in a comparative sample). One notable difference between the two analytical strategies was that DEA allowed for the estimation of most productive scale size (i.e., an estimation of optimal input values in order to produce actual output values) and returns to scale (i.e., an estimation of changes in output values resulting from a proportional change in all input values), while translog parametric functions could provide only estimates for returns to scale.

In addition, DEA allows for the estimation of technical and scale efficiency without the constraint of assuming no allocative inefficiency, whereas the translog parametric approach requires the assumption of no allocative inefficiency. While both analytic strategies performed similarly when illustrating marginal rates of transformation of outputs, there were differences in characterizations of efficiency estimates and return to scale. In the concluding remarks of their study, Banker, Conrad, and Strauss (1986) noted:

> Both models find the production of hospital care for children to be more resource intensive than the production of care for adults or the elderly. However, the technical efficiency estimates from the translog model do not appear to be as closely related to the degree of capacity utilization of individual hospitals as the corresponding DEA estimates. This could be because the assumption of no allocative inefficiency in the translog model may not be valid. (p. 42)

Internationally, the data envelopment analysis (DEA) methodology has been applied to studies of decision-making units (DMUs) within the context of higher education. Applied to higher education, DEA has been used as an analytical framework in university studies in Australia (Abott & Doucouliagos, 2003), Canada (McMillan & Datta, 1998), China (Ng & Li, 2000), Spain (Pina & Torres, 1995), and the UK (Johnes, 2006). Depending on the focus of the production activity being assessed, many DEA studies compare activities among universities and relatively fewer compare DMUs (e.g., academic departments) within the same higher education institution.

Focusing on the efficient utilization of public funding, Katharaki and Katharakis (2010) used the quantitative method of data envelopment analysis to estimate the efficiency 20 public higher education institutions in Greece. In Greece, “higher education is structured into two main types of institutions: universities and technological education institutions (which belong to the non-university sector). Greek universities offer both teaching and research, and offer bachelors, masters and doctorate courses” (Katharaki & Katharakis, 2010, p. 116). While it would be challenging to map the Greek higher education structure onto the Carnegie 2005 classifications of U.S. higher education institutions, the Greek universities would loosely map to Carnegie 15, 16, and 17 classifications based on the fact that universities in this category similarly offer bachelors, masters, and doctoral degree programs.

When assessing degree production efficiency of research universities, DEA is appealing because it allows for comparisons of baccalaureate degree production efficiency of particular institutions to the best performing institutions within a given homogeneous set, instead of comparing a particular institution to the average performance of institutions within a given set. To compare particular higher education institutions (also referred to as a DMU in DEA literature) to best performing institutions, Kumar and Gulati (2008) explain that:

> DEA identifies 'peer' DMUs for an individual DMU and then estimates the efficiency of the DMU by comparing its performance with that of the best practice DMUs chosen from its peers. Note that the idea here of best practice is not some theoretical and possibly unattainable concept, but the DMU(s) performing best amongst its peers, which is assigned an efficiency score of one. (p. 42)

In this study, the DEA linear programming procedure designed to "convert multiple incommensurable inputs and outputs of each DMU into a scalar measure of operational efficiency, relative to its competing DMUs" (Kumar & Gulati, 2008, p. 42), assigns a score of one to efficient research universities and a score of less than one for relatively inefficient research universities. Research universities with an efficiency score of one appear on the production efficiency frontier and 'envelope' the other institutions, thus data envelopment analysis. Assigned values of less than one indicate that a linear combination of other research universities from the sample could produce the same vector of outputs using a smaller vector of inputs.

Research Questions

Apart from an extensive array of existing student-focused models aimed at assessing factors that affect graduation rates and degree attainment, agency theory in conjunction with data envelopment analysis offers a fresh perspective for understanding efficient utilization of resources by including economic models that focus on the productivity of higher education institutions in the context of undergraduate degree production. The principal-agent model applied to agency relationships in higher education assumes goal conflict between the baccalaureate degree production needs of the state, and the need for increase graduation rates for higher education institutions. Data envelopment analysis helps to assess the efficiency of resource utilization across higher education institutions and between the goals of baccalaureate degree production and graduation rate efficiency.

Focusing on ways in which higher education institutions efficiently utilize resources (inputs) for baccalaureate degree production and graduation rate efficiency (outputs) will allow researchers to approach questions of comparative institutional performance, productivity, and efficiency. Archibald and Feldman (2008) argue that this conceptual shift away from a narrow focus on student success is important because, “It is a fallacy to think that every college or university should aim for a 100% graduation rate. And, despite the best efforts of the institution, a 100% graduation rate is neither likely nor socially optimal” (p. 81). As Moe (1984) explains, “The logic of the principal-agent model immediately leads us to the theoretical issues at the heart of the contractual paradigm: issues of hierarchical control in the context of information asymmetry and conflict of interest" (p. 757).

As stated by the U.S. Department of Education (2011), "Given the fiscal realities facing states, it is critical to understand the relationship between spending and results as students move through the education system and into the workforce" (p. 12). Utilizing Agency Theory as a heuristic framework and data envelopment analysis (DEA) as a statistical method, this study adds to the literature set and aids policy discussions on two fronts: 1) to better allow policy makers to identify relatively inefficient universities and highlight areas for future improvement and; 2) to provide policy makers with an alternative methodology for assessing performance of universities, with the aim of facilitating more informed decision making when allocating scarce public resources. With these goals in mind, the following research questions are posed:

1. On average, are research universities more or less effective at efficiently utilizing resources to maximize baccalaureate degree production or to increase graduation rate efficiency?
2. For inefficient research universities, on average, is overall technical inefficiency due to poor resource utilization or failure to operate at the most productive scale size?

CHAPTER THREE: METHODOLOGY

Analytic Strategy

Similar to a methodological approach by Agasisti and Johnes (2009), this study uses a multi-stage output-oriented DEA methodology to: 1) employ a Charnes, Cooper, and Rhodes (1978) (CCR) model under the constant return to scale (CRS) assumption to calculate measures of global technical efficiency (GTE); 2) employ a Banker, Charnes, and Cooper (1984) (BCC) model under the variable return to scale (VRS) assumption to calculate measures of local pure technical efficiency (LPTE); and 3) compare CRS and VRS efficiency scores of an institution to check for scale efficiencies (SE). Each stage in the DEA methodology was used to assess resource utilization for public and private non-profit Carnegie 15 (very high research activity) and 16 (high research activity) research universities.

In addition to efficiency scores, Coelli, Prasada Rao, O'Donnell, and Battese (2005) recommend that values of non-zero slacks should be reported along with technical efficiency scores (LPTE and GTE) in order to provide a more accurate indication of efficiency for an institution in the DEA analysis. Slacks represent the difference between observed inputs/outputs of a research university and the calculated target inputs/outputs needed for a university to be considered efficient. Slacks only exist for research universities that are identified as inefficient (i.e., research universities with efficiency score less than one) in any particular CCR-CRS or BCC-VRS model because they represent the proportion of inefficiency for a particular output of a research university needed to push that university to the efficiency frontier.

Measurement of Global Technical Efficiency

According to Cooper, Seiford, and Tone (2007), the CCR model under the CRS assumption, "postulates that the radial expansion and reduction of all observed decision making units (DMUs) and their nonnegative combinations are possible and hence the CCR-CRS score is called global technical efficiency" (p. 152). The CCR-CRS model assumes, "there is no significant relationship between the scale of operations and efficiency" (Avkiran, 2001, p. 66). Defining productivity as P, the DEA CCR model is expressed mathematically as:

$$P = \sum_{i=1}^{n} w_i y_i \, / \sum_{j=1}^{m} d_{j x_j}$$

where $y_i$is the i^{th}output produced, x_j is the j^{th} input used, w_i is the relative importance of output y_i, and d_j is the relative importance of input x_j. Following an algorithm proposed by Charnes, Cooper, and Rhodes (1978) to compute the productivity by obtaining weights that maximize the productivity for each institution, the efficiency of a given institution *k*, which uses *m* inputs to produce *s* outputs, relative to *n* -1 other institutions, is calculated as:

$$max \emptyset_k + \varepsilon \left(\sum_{r=1}^{s} s_r + \sum_{i=1}^{m} s_i \right)$$

s.t.

$$\emptyset_k y_{rk} - \sum_{j=1}^{n} \lambda_j \, y_{rj} + s_r = 0, r = 1, \ldots, s$$

$$x_{ik} - \sum_{r=1}^{n} \lambda_j \, x_{ij} - s_i = 0, i = 1, \ldots, m$$

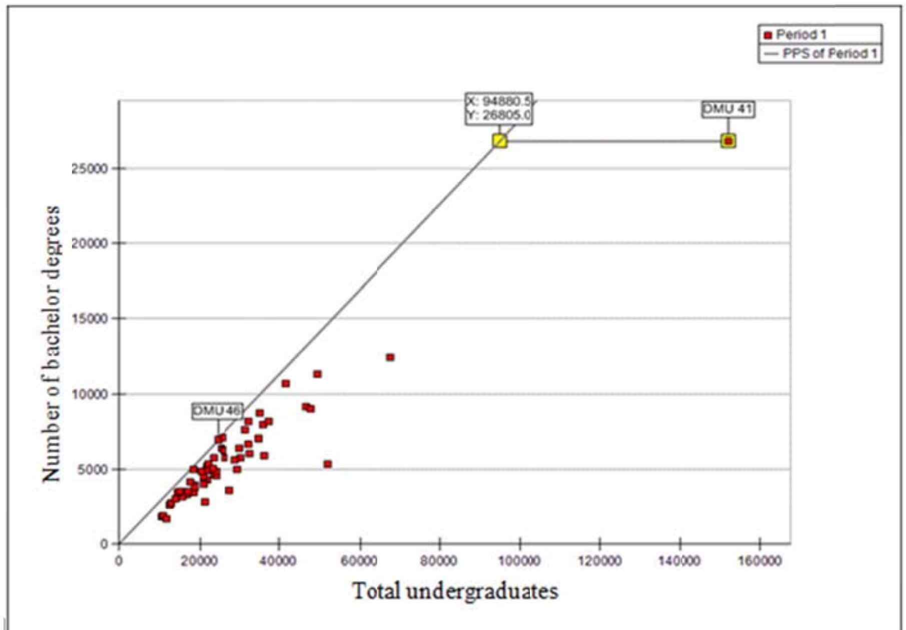
$$\lambda_j, s_r, s_i \geq 0 \quad \forall_j = 1, \ldots, n \quad r = 1, \ldots, s \quad i = 1, \ldots, m$$

where y_{rk} and x_{ik} are the amounts of output *r* and input *i* used by institution *k*, respectively, and s_r and s_j are the output and input slacks (i.e., the difference between an inefficient institution's estimated efficiency target and its actual input value), respectively (Agasisti & Johnes, 2009, p. 63). The result of the algorithm is a set of efficiency scores, where the technical efficiency of *k* is computed by the ratio $1/\emptyset_k$. The efficiency scores are based on the definition of an efficient frontier composed of observed and virtual producers: the research universities for which the efficiency score is equal to one are considered efficient, while the remaining research universities have a score less than one.

According to Kumar and Gulati (2008), "the technical efficiency measure corresponding to the CRS assumption represents overall technical efficiency (also known as global technical efficiency); which measures inefficiencies due to the input/output configuration and as well as the size of operations" (p. 43). To illustrate this concept, a hypothetical single input/single output-oriented CCR-CRS model was created for Carnegie 15 public research universities in Figure 1. As shown in Figure 1, the University of California – Berkeley is considered to have global technical efficiency because it has a GTE score of one. This institution alone comprises the reference point of all other inefficient institutions. The resource utilization process (i.e., utilization of 24,636 undergraduate students to produce 6,960 bachelor's degrees) for the University of California – Berkeley is not characterized by any waste in inputs and displays a corresponding slack value of zero. On the other end of the spectrum, the University of Texas – Austin is shown as the least efficient institution in Figure 2, because it is the institution farthest from the production frontier (i.e., it has the lowest GTE score of 0.62).

According to this example, the number of degrees produced for the University of Texas – Austin should increase its production of baccalaureate degrees by 12,158 or roughly 83 percent (as indicated by slack value of -12,158.4) in order to have a GTE score of one.

Figure 1
Single Input/output CCR Production Frontier for Public Carnegie 15 Research Universities



	GTE Score	input x1	output y1	target y1	Slack
University of California – Berkeley (DMU 46)	1	24636	6960	6960	0
University of Texas – Austin (DMU 41)	.62	152274	26805	14646.62	-12158.4

Measurements of Local Pure Technical Efficiency

Critiquing the Charnes, Cooper, and Rhodes (1978) model under the assumption of constant return to scale (CRS), Coelli (1996) notes that "imperfect competition, constraints on finance, etc. may cause a decision making unit (i.e., research university) to be not operating at optimal scale" (p. 17). The variable return to scale (VRS) model has an additional constraint not present in the CCR-CRS model, mathematically expressed as:

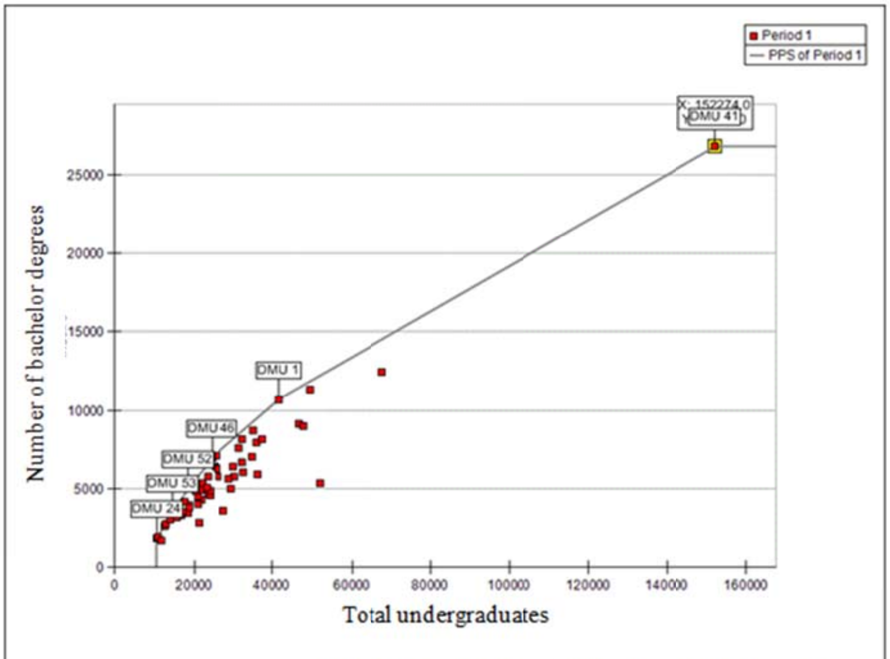
$$\sum_{j=1}^{n} \lambda_j = 1$$

Cooper, Seiford, and Tone (2007) explain that the BCC model under the VRS assumption assumes that "convex combinations of the observed DMUs form the production possibility set and the BCC-VRS score is called local pure technical efficiency" (p. 152). In essence, the "rise in inputs is expected to result in a disproportionate rise in outputs" (Avkiran, 2001, p. 67).

According to Kumar and Gulati (2008), "the technical efficiency measure corresponding to the VRS assumption represents local pure technical efficiency (LPTE), which measures inefficiencies due to only managerial underperformance" as opposed to a CRS model which estimates a score of global technical efficiency (GTE) which measures "inefficiencies due to the input/output configuration as well as the size of operations" (Kumar & Gulati, 2008, p. 43). To graphically illustrate the concept of a BCC-VRS model, a hypothetical single input (total undergraduates)/ output (total bachelor's degrees awarded) model was created for Carnegie 15 (very high research activity) public research universities (n = 60) in Figure 2. As shown in Figure 2, Arizona State University, Montana State University, University of California – Berkeley, University of California – Santa Barbara, University of California – Santa Cruz, and the University of Texas – Austin are said to have pure technical efficiency because they are most efficiently utilizing the total number of undergraduate students for baccalaureate degree production.

Compared to Figure 1, the constraint of assumed input/output proportionality is not included in the BCC-VRS model graphically illustrated in Figure 2. For example, the University of Texas – Austin appears on the efficiency frontier in Figure 2 due to the absence of the constraint of assumed input /output proportionality (i.e., number of degrees produced should increase at proportionately the same rate as increases in the total number of undergraduates). In addition, Kumar and Gulati (2008) explain:

Figure 2
Single Input/output BCC Production Frontier for Public Carnegie 15 Research Universities



	LPTE Score	input x1	output y1	target y1	slack
Montana State University (DMU 24)	1	10491	1809	1809	0
University of California – Santa Cruz (DMU 53)	1	14403	3450	3450	0
University of California – Santa Barbara (DMU 52)	1	18415	4977	4977	0
University of California – Berkeley (DMU 46)	1	24636	6960	6360	0
Arizona State University – Tempe (DMU 1)	1	41626	10706	10706	0
University of Texas – Austin (DMU 41)	1	152274	26805	26805	0

> It is significant to note here that the efficiency scores of banks (in this case research universities) rise on allowing VRS because BCC model forms a convex hull of intersecting planes which envelops the data points more tightly than CRS conical hull and provides efficiency scores which are greater than or equal to those obtained using the CCR model. (p. 57)

Measurement of Scale Efficiencies

In this study, both CRS global technical efficiency (GTE) and VRS local pure technical efficiency (LPTE) scores were computed for public four-year and above and private four-year and above Carnegie 15 (very high research activity) and 16 (high research activity) research universities. As Kumar and Gulati (2008) explain:

> The technical efficiency measure corresponding to the CRS assumption represents GTE which measures inefficiencies due to the input/output configuration as well as the size of operations. The efficiency measure corresponding to the VRS assumption represents LPTE which measures inefficiencies due only to managerial underperformance. (p. 43)

The relationship between GTE and LPTE provides a measure of scale efficiency (SE) (SE = GTE/LPTE). Thus, the GTE of a research university is equal to its LPTE if and only if the university is operating at its most productive scale size. In essence, a university can only have a GTE score of one if and only if it also has corresponding LPTE and SE scores of one. SE scores are valuable because they provide information regarding the primary source of inefficiency. For example, the University of Texas – Austin did not appear on the efficiency frontier in Figure 1 (having GTE score < 1) but it did in Figure 2 (having LPTE score = one). Because the University of Texas – Austin acquired a status of “global technical inefficiency” (GTE < 1) and “local pure technical efficiency (LPTE score = 1) it can be inferred that the source of inefficiency was inappropriate scale size.

Population and Sample

This study utilizes the data envelopment analysis as an analytical strategy to examine efficiency of resource utilization for research universities vis-a-vis baccalaureate degree production and graduation rate efficiency for the academic year 2007-08. Because the data were retrieved from the Delta Cost Project IPEDS publicly available database, which covers the academic years 1987-88 through 2007-2008 (at the time the date was retrieved), I chose to utilize the most recent academic year (2007-2008) available in the data set at the time the data were extracted from the database. The Delta Cost Project database includes 551 variables on institutional characteristics, finances, enrollment, completions, tuition and fees, staffing, and student financial aid for more than 6,000 higher education institutions in the U.S.

The population of interest in this study was U.S. public four-year or above and private non-profit four-year or above higher education research universities (as defined by the Carnegie 2005 classifications) who receive at least a portion of their revenue from state appropriations, grants and contracts. For the academic year 2007-2008, over 42% of all bachelor's degrees granted were granted from Carnegie 15 (very high research activity) (e.g., Arizona State University, University of California Berkeley, and University of Minnesota – Twin Cities) of and 16 (high research activity) (e.g., University of North Dakota, University of Memphis, and University of Nevada – Las Vegas) research universities. In addition, over 60% of total funding from state and local appropriations, grants, and contracts were allocated to Carnegie 15 and 16 universities. Of the 32 Carnegie 2005 classifications, only three classifications characterize universities as research universities (15, 16, and 17), two of which were included in this study. Carnegie 2005 classifications include all colleges and universities in the U.S. that are degree-granting and accredited by an accrediting agency recognized by the U.S. Secretary of Education. In total, there are 32 different Carnegie 2005 classifications.

According to Dyson, Allen, Camanho, Podinovski, Sarrico, and Shale (2001), "DEA makes a series of homogeneity assumptions about the units under assessment. In general, the units are understood to be similar in a number of ways" (p. 247). In order to avoid violating this assumption, public four-year or above research universities were clustered into distinct groups divided by sector (i.e., public and private non-profit) and research activity (i.e., very high and high): 1) public Carnegie 15 – research universities with very high research activity (n = 60) and public Carnegie 16 – research universities with high research activity (n = 66); and 2) private non-profit Carnegie 15 – research universities with very high research activity (n = 31) and private non-profit Carnegie 16 – research universities with high research activity (n = 25).

Variable Selection

In their review of international literature focused on the evaluation of efficiency of resource utilization for universities via data envelopment analysis, Katharaki and Katharakis (2010) found that, "the primary concern which emerges from this literature centers on the selection and definition of appropriate 'input' and 'output' sets" (p. 116). Common categories for inputs and outputs include:

> number of academic and non-academic staff, number of undergraduate and postgraduate students, expenditures on all non-labor inputs, expenditures on library and computing; while the following are defined as outputs: number of

graduates, number of research projects, publications' index and other similar data. (Katharaki & Katherakis, 2010, p. 116)

While there are often convincing reasons for a researcher to include or exclude variables of interest into or from their studies, Katharaki and Katharakis (2010) note that, "researchers conclude, that data availability, combined with the aim of the study, are the most significant determining factors in the final selection of the input-output set" (p. 116).

Following general recommendations for input/out data selection for DEA models from Cooper, Seiford, and Tone (2007), the following four guidelines were considered during the variable selection process:

1) Numerical data are available for each input and output, with the data assumed to be positive for all institutions; 2) the items (inputs, outputs, and choice of institutions) should reflect an analyst's or manager's interest in the components that will enter into the relative efficiency evaluations of the institutions; 3) in principle, smaller input amounts are preferable and larger output amounts are preferable so the efficiency scores should reflect these principles; and 4) the measurement units of the different inputs and outputs need not be congruent. Some may involve number of persons, or areas of floor space, money expended, etc. (p. 22)

Table 10 highlights variables used in prior studies utilizing DEA that influenced the final selection of input and output variables used in this study. Based on a review of studies listed in Table 10 and the availability of data from the Delta Cost Project database, the following five inputs were included in this study: total education and general expenditures (based on research from Flegg, Allen, Field, & Thurlow, 2004; Madden, Savage, & Kemp, 1997); total number of undergraduate students (based on research from Flegg et al., 2004); total number of administrative staff (based on research from Worthington and Lee, 2008; Flegg et al., 2004; Abbott & Doucouliagos, 2003; Avkiran, 2001; Madden, Savage & Kemp, 1997); total number of faculty (based on research from Worthington & Lee, 2008; Flegg et al., 2004; Abbott & Doucouliagos, 2003; Avkiran, 2001; Madden, Savage, & Kemp, 1997).

Considering the financial challenges of the recent U.S. economic recession and the continuing rapid increase of higher education tuition, one additional input (revenue from state and local appropriations, grants and contracts) was also included in this study. The decision to include revenue from state and local appropriations, grants and contracts was based on the importance of highlighting institutions that have found effective strategies for efficiently utilizing state funding. According to the State Higher Education Executive Officers (2010):

> Support for higher education involves a substantial financial commitment by state and local governments. Twenty-five years ago, in 1985, state and local governments invested $29.1 billion (in current dollars) in direct support for the operations of public and independent higher education institutions. By 2010, state and local support for higher education reached $88.5 billion. (p. 17)

However, “public funding is becoming increasingly diluted, particularly as competition increases from other recipients of public funds (such as healthcare)” (Katharakis & Katharakis, 2010, p. 116).

Table 10

Variables Used in Various DEA Studies of Higher Education Institutions

Authors	Sample	Methodology	Input variables	Output variables
Worthington & Lee(2008)	35 Australian universities 1998-2003	DEA: Malmquist index	FTE academic staff, FTE non-academic staff, non-labor expenditure, undergraduate student load, postgraduate student load	Numbers of undergraduate awards, numbers of postgraduate awards, number of doctorate awards, publications, research income
Flegg, Allen, Field, & Thurlow (2004)	45 British universities 1980/81 - 1992/93	DEA: Technical efficiency	Number of staff, number of undergraduate students, number of postgraduate students, aggregate departmental expenditure	Income from research and consultancy, number of undergraduate degrees awarded, number of postgraduate degrees awarded
Abbott & Doucouliagos (2003)	36 Australian universities 1995	DEA: Technical efficiency	FTE academic staff, non-academic staff, expenditures on all non-labor inputs, value of non-current assets to approximate existing capital stock	EFTS enrollments, research quantum
Avkiran (2001)	36 Australian universities 1995	VRS DEA: overall performance model	FTE academic staff, non-academic staff	Undergraduate enrollments, postgraduate enrollments, research quantum
McMillan & Datta (1998)	45 Canadian universities 1992-1993	Cost efficiency	Number of faculties, total expenditures	Undergraduate teaching, graduate teaching, research income
Athanassopoulos & Shale (1997)				
Madden, Savage, & Kemp (1997)	24 Australian university economic departments, 1987/1991	DEA	Expenditures on library and computing, number of staff	

SOURCE: Katharaki & Katharakis (2010)

The output total number of baccalaureate degrees granted was included in this study based on a review of studies from Worthington and Lee (2008), Flegg, Allen, Field, and Thurlow (2004), and Adelman (2006) who stated:

> The core question is not about basis “access” to higher education. It is not about

> persistence to the second term or the second year following postsecondary entry. It is about completion of academic credentials – the culmination of opportunity, guidance, choice, effort, and commitment. (p. xv)

One additional output (number of students graduating within 150 percent of normal time) was also included in this study. This additional output was included in the study for a few reasons: 1) to highlight differences in institutional performance between graduation rates (the percentage of a cohort of first-time full-time degree seeking students who graduate within 150 percent of "normal time" as determined by an institution's curriculum standards); 2) 150 percent of normal time is the maximum time allowed that an undergraduate degree seeking student is eligible to receive federal financial aid; and most importantly 3) to assess whether or not institutions are more or less efficient at utilizing resources to increase graduation rates as opposed to the total number of baccalaureate degrees produced (Titus, 2009a). The input/output set was influenced by the availability of data for institutions in the Delta Cost Project database for the academic year 2007-2008.

Combined, there are a total of seven variables (i.e., five inputs and two outputs) included in this study. Each of the seven variables followed a coding scheme outlined in the Delta Cost Project data dictionary. In essence, the code for each variable represents an abbreviated alphanumeric string designed to reflect the essence of the code definition. Because the Delta Cost Project database contains over 551 variables on institutional characteristics, finances, enrollment, completions, tuition and fees, staffing, and student financial aid, the coding scheme from the IPEDS glossary and data dictionary where not altered. In many cases, several variables and definitions in the database were similar.

Because of this, I chose to use the original variable names and definitions in order to avoid unnecessary confusion when referring back to the original database. Table 11 outlines the coding of each of the five input and two output variables and their associated definitions from the IPEDS glossary and data dictionary.

Table 11
Definition of Input and Output Variables Included in the Study

Variables	Definition- From IPEDS glossary and Data Dictionary unless variable is calculated
Financial Resource Inputs	
eandg01:	Total education and general expenditures includes all core operating expenditures, including sponsored research, but excluding auxiliary enterprises. This variable was originally reported in IPEDS, but for recent years it is calculated by summing expenditures on instruction, research, public service, academic support, student services, institutional support, operations and maintenance, and scholarships and fellowships.
state09:	The total amount of revenue coming from state and local appropriations, grants, and contracts.
Human Resource Inputs	
total_undergraduates:	The total number of undergraduate students.
total_executive_admin_managerial_w_other_professionals:	A primary function or occupational activity category used to classify persons employed for the primary purpose of performing academic support, student service, and institutional support, whose assignments would require either a baccalaureate degree or higher or experience of such kind and amount as to provide a comparable background.
total_faculty_all:	Persons identified by the institution as such and typically those whose initial assignments are made for the purpose of conducting instruction, research or public service as a principal activity (or activities). They may hold academic rank titles of professor, associate professor, assistant professor, instructor, lecturer or the equivalent of any of those academic ranks. Faculty may also include the chancellor/president, provost, vice provosts, deans, directors or the equivalent, as well as associate deans, assistant deans and executive officers of academic departments (chairpersons, heads or the equivalent) if their principal activity is instruction combined with research and/or public service. The designation as "faculty" is separate from the activities to which they may be currently assigned. For example, a newly appointed president of an institution may also be appointed as a faculty member. Graduate, instruction, and research assistants are not included in this category.
Outputs	
Bachelordegrees:	Total number of awards conferred (baccalaureate or equivalent degree, as determined by the Secretary, U.S. Department of Education) that normally require at least 4 but not more than 5 years of full-time equivalent college-level work. This includes all bachelor's degrees conferred in a 5-year cooperative (work-study) program. A cooperative plan provides for alternate class attendance and employment in business, industry, or government; thus, it allows students to combine actual work experience with their college studies. Also includes bachelor's degrees in which the normal 4 years of work are completed in 3 years.
grad_rate_150_n4yr:	Number of full-time, first-time, bachelor's degree-seeking undergraduate students graduating within 150 percent of normal time at four-year institutions

Data Source: Delta Cost Project IPEDS database

Input Variables

STATE09. The variable STATE09 represents the portion of an institution's revenue from state or local government agencies for training programs or similar activities that are either received or reimbursable under contract or grant. Revenues received by the institution through acts of a state legislative body (except grants and contracts) or by a governmental entity below the state level are included in this metric. For state appropriations, funds are for meeting current operating expenses, not for specific projects or programs. Education district taxes include all taxes revenues assessed directly by an institution or on behalf of an institution when the institution will receive the exact amount collected. These revenues also include similar revenues that result from actions of local governments or citizens (such as through referendum) that result in receipt by the institution of revenues based on collections of other taxes or resources (sales taxes, gambling taxes, etc.).

Research by Bound and Turner (2007) suggests:

> Because consumers pay only a fraction of the cost of production, changes in demand are unlikely to be accommodated fully by colleges and universities with commensurate increases in non-tuition revenue. For this reason, public investment in higher education plays a crucial role in determining the degrees produced and the supply of college-educated workers to the labor market. (p. 877)

EANDG01. The variable EANDG01represents total university education and general expenditures including core operating and sponsored research, excluding auxiliary services. Instead of considering educational expenditures as an output to be maximized or minimized, total university education and general expenditures are used as inputs to measure how universities utilize such inputs to maximize production of bachelor's degrees. Investigating the inefficient utilization of funding allocations to academic departments, Madden, Savage, and Kemp (1997) used data envelopment analysis to analyze the effects of the "Dawkins" plan on economics departments within Australian higher education institutions.

In 1987 the "Dawkins plan effectively transferred resources from established universities to the former colleges of advanced education" (Madden, Savage, & Kemp, 1997, p. 153). In their study they found:

> In allocating funds to academic departments, policy makers are more interested in how departments utilize inputs to produce multiple outputs. Mean inefficiency scores for the sample reveal substantial reductions in inefficiency and suggest an overall productivity improvement across all economics departments in the period following the policy reforms. (p. 157)

TOTAL_UNDERGRADUATES. The variable TOTAL_UNDERGRADUATES represents an institution's total number of full-time and part-time undergraduate students. As a key measure for state funding and degree production, the total number of undergraduate students is directly correlated with the number of baccalaureate degrees produced.

TOTAL_EXECUTIVE_ADMIN_MANAGERIAL_W_OTHER_PROFESSIONALS. The variable TOTAL_EXECUTIVE_ADMIN_MANAGERIAL_W_OTHER_PROFESSIONALS represents an institution's total number of staff whose primary function is for the purpose of performing academic support, student service, and institutional support, whose assignments would require either a baccalaureate degree or higher experience. This input variable was included in addition to the input variable representing the total number of faculty for an institution as a means to assess whether or not an institution's total number of academic support staff affects an institution's efficiency score. As costs for the delivery of higher education continue to rise, institutional operating expenses are a key statistic taken into consideration by states and local governments who are trying provide sufficient funding for higher education institutions.

TOTAL_FACULTY_ALL. The variable TOTAL_FACULTY_ALL represents the total number of staff identified as faculty whose initial assignments are made for the purpose of conducting instruction, research or public service as a principal activity. Studies from Archibald and Feldman (2008), and Winston (1999) suggest that this measure of institutional effort may have an effect on graduation rates. Winston (1999) found, "The greater the percentage of full-time faculty and the higher the cost per undergraduate student, the higher will be the institution's graduation rate" (p. 20)

Output Variables

BACHELORDEGREES. The variable BACHELORDEGREES reflects the total number of bachelor degree completions by an institution. According to Flegg, Allen, Field, and Thurlow (2004), "The number of undergraduate degrees awarded is clearly an important measure of the output of any university" (p. 235). Various studies (Johnes, 2006; Titus, 2009(a); Titus, 2009(b); Agasisti & Johnes, 2009; Abbott & Doucouliagos, 2003; Lingenfelter, 2007) have also referred to the production of bachelor's degrees as a desired output for higher education institutions.

GRAD_RATE_150_N4YR. The variable GRAD_RATE_150_N4YR reflects the number of full-time, first-time, bachelor's degree seeking undergraduate students graduating within 150 percent of normal time at four-year institutions. The federal definition for "normal time" can be a bit misleading because it actually refers to the average number of credits required for degree completion for the majority of undergraduate students at an institution. In most cases, the average number of credits required for degree completion at four-year institutions on a semester based academic calendar is 120 credits. Thus, a student graduating within 150 percent of normal time must do so within 120 to 180 credits. A degree completion rate related to 150 percent of normal time was selected instead of a four- or six-year degree completion rate because it better reflected financial/federal financial support for higher education by way of the threshold of student financial aid eligibility.

A comparison of the statistical profiles of universities included in this study can be found in Table 12. During the process of excluding higher education institutions from the data set, numerous inconsistencies of data collection/reporting for public four-year and above and private non-profit four-year or above institutions were apparent, which might serve as an indication of asymmetric information in the agency relationship between states and institutions. This inconsistency of data collection/reporting was the determining factor in the number of universities that were included in this study. To deal with missing data, a simple listwise deletion approach was utilized. If the statistical methodology of this study was regression based with the goal of inference, other deletion approaches (i.e., pairwise deletion) or data substitution approaches (e.g., maximum likelihood or multiple imputation) would have been considered.

Table 12

Statistical Profiles of Institutions Included in Sample (2007-08)

	Public (Carnegie 15[a])		Public (Carnegie 16[b])	
Variables	Mean	StdDev	Mean	StdDev
Outputs:				
BACHELORDEGREES	5734.18	3583.82	3050.64	1698.84
GRAD_RATE_150_n4YR	3133.58	1747.29	1320.02	745.40
Inputs:				
EANDG01	11668.15	8100.85	3742.07	1559.22
STATE09***	4943.88	3676.37	1686.13	793.39
TOTAL_UNDERGRADUATES	27902.62	19749.48	16963.74	7725.22
TOTAL_EXECUTIVE_ADMIN_MANAGERIAL_ W_OTHER_PROFESSIONALS	4010.43	3154.22	1181.83	691.97
TOTAL_FACULTY_ALL	5977.97	3701.91	2249.79	921.94

	Private non-profit (Carnegie 15[a])		Private non-profit (Carnegie 16[b])	
Variables	Mean	StdDev	Mean	StdDev
Outputs:				
BACHELORDEGREES	1848.29	1087.22	1624.16	1404.54
GRAD_RATE_150_n4YR	1451.16	701.46	1056.6	688.41
EANDG01*	13092.09	8234.24	3325.12	2299.62
STATE09*	345.81	572.11	76.57	74.29
TOTAL_UNDERGRADUATES	7694.48	4482.07	7863.8	6491.01
TOTAL_EXECUTIVE_ADMIN_MANAGERIAL _W_OTHER_PROFESSIONALS	3404.58	2087.28	948.6	672.21
TOTAL_FACULTY_ALL	4119.39	2314.68	1569.44	849.28

a - Carnegie 15 = Research Universities (very high activity); b - Carnegie 16 = Research Universities (high research activity); *Actual dollar amounts were divided by 100000; Data Source: Delta Cost Project (IPEDS)

Research Hypotheses

Hypothesis One: On average, public and/or private non-profit Carnegie 15 or 16 research universities are more efficient at utilizing resources for maximizing bachelor degree production than for increasing graduation rate efficiency.

The overall effectiveness of universities to produce college-educated workers has been questioned by scholars, journalists, and policy decision makers for more than the past quarter century. According to Carnevale and Rose (2011), “The United States has been under producing college-going workers since 1980. Supply has failed to keep pace with growing demand, and as a result, income inequality has grown precipitously” (p. 1).

Agency theory provides an additional lens through which the relationships between states and higher educational institutions can be analyzed in the context of graduation rate efficiency versus bachelor's degree completion rates. Through this politically tinted lens, "Organizations are viewed as collectives of self-interested people with partially conflicting goals" (Eisenhardt, 1988, p. 492). For instance, if the goal of the state is to increase to the total number baccalaureate degrees awarded, but the goal of a particular university is to increase graduation rates, and these two goals are in conflict with each other, data from the DEA models would reflect an LPTE score equal to one for the model including output (GRAD_RATE_150_n4YR) and an LPTE score less than one for the model including output (BACHELORDEGREES) for a particular research university. The aforementioned means that the research university in question has acquired a status of "local pure technical efficiency" in regards to efficiently utilizing inputs to increase graduation rates (as evidence by having LPTE score = 1), but it has not acquired the status of "local pure technical efficiency" in regards to efficiently utilizing inputs to increase the total number of baccalaureate degrees awarded (as evidenced by having LPTE < 1).

To test hypothesis one, BCC-VRS efficiency scores were computed for four homogeneous sets of public and private non-profit Carnegie 15 and 16 research universities: 1) public Carnegie 15 research universities, 2) public Carnegie 16 research universities, 3) private non-profit Carnegie 15 research universities, and 4) private non-profit Carnegie 16 research universities. A DEA BCC-VRS model was chosen because "the efficiency measure corresponding to the VRS assumption represents local pure technical efficiency (LPTE), which measures inefficiencies due to only managerial underperformance" (Kumar & Gulati, 2008, p. 43). In other words, LPTE scores corresponding with the VRS assumption reflect the impact (positive or negative) of institutional managerial decisions regarding resource utilization (inputs) on baccalaureate degree production and/or graduation rate efficiency (outputs).

To determine the first set of BCC-VRS efficiency scores for each of the four homogeneous sets of research universities corresponding to baccalaureate degree production, all five input variables (EANDG01, STATE09, TOTAL_UNDERGRADUATES, TOTAL_EXECUTIVE_ADMIN_MANAGERIAL_W_OTHER_PROFESSIONALS, and TOTAL_FACULTY) and only the output BACHELORDEGREES was included in the DEA BCC-VRS model. To determine the second set of BCC-VRS efficiency scores for each of the four homogeneous sets of research universities corresponding to graduation rate efficiency, all five input variables (EANDG01, STATE09, TOTAL_UNDERGRADUATES, TOTAL_EXECUTIVE_ADMIN_MANAGERIAL_W_OTHER_PROFESSIONALS, and TOTAL_FACULTY) and only the output GRAD_RATE_150_n4YR was included in the DEA BCC-VRS model.

Testing Hypothesis One – Goal Conflict

The first hypothesis assessed the assumption of conflicting goals between states and higher education research universities, namely: 1) states would like higher education institutions to focus more on increasing baccalaureate degree production than graduation rate efficiency; and 2) research universities are more focused on increasing graduation rates than on increasing the total number of baccalaureate degrees produced. While the two goals may not be mutually exclusive, research from Jones and Kelly (2007) suggests:

> The U.S. will likely be unable to regain its place of primacy by 2025 if it solely relies on strategies focused on traditional-aged students. Attention will necessarily have to be directed at enhancing the education attainment levels of adults who have fallen into the cracks of the education system somewhere along the way” (p. vii).

To test hypothesis one, a BCC-VRS model was applied to four homogeneous sets of public and private non-profit Carnegie 15 and 16 research universities (PCRU-15s, n = 60), public Carnegie 16 research universities (PCRU-16s, n = 66), private Carnegie 15 research universities (PNCRU-15s, n = 31), and private Carnegie 16 research universities (PNCRU-16s, n = 25). Testing hypothesis one involves the estimation of BCC-VRS LPTE scores, efficiency slacks, and efficiency targets for each research university. While it is possible to utilize CRS and VRS models to calculate efficiency scores, there are different underlying assumptions of each model. Technical efficiency scores from the VRS model were preferred because “the efficiency measure corresponding to the VRS assumption represents local pure technical efficiency (LPTE), which measures inefficiencies due to only managerial underperformance” (Kumar & Gulati, 2008, p. 43). Efficiency slacks represent the difference between an observed input value of a research university and the calculated efficiency target input needed for that input to be considered technically efficient. Efficiency target values represent the estimated value needed for a particular research university input and/or output to be considered technically efficient.

To determine the first set of BCC-VRS efficiency scores, slacks, and targets corresponding to baccalaureate degree production, all five input variables (EANDG01, STATE09, TOTAL_UNDERGRADUATES, TOTAL_EXECUTIVE_ADMIN_MANAGERIAL_W_OTHER_PROFESSIONALS, and TOTAL_FACULTY) and only the output BACHELORDEGREES was included in the DEA BCC-VRS model. To determine the second set of BCC-VRS efficiency scores, slacks, and targets corresponding to graduation rate efficiency, all five input variables (EANDG01, STATE09, TOTAL_UNDERGRADUATES, TOTAL_EXECUTIVE_ADMIN_MANAGERIAL_W_OTHER_PROFESSIONALS, and TOTAL_FACULTY) and only the output GRAD_RATE_150_n4YR was included in the DEA BCC-VRS model. Hypothesis one, thus, was stated as follows:

- Hypothesis One: On average, public and/or private non-profit Carnegie 15 or 16 research universities are more efficient at utilizing resources for maximizing bachelor degree production than for increasing graduation rate efficiency.

Hypothesis Two: On average, managerial underperformance, rather than the input/output configuration and/or the size of operations, serves as the primary source of inefficiency for public and/or private non-profit Carnegie 15 or 16 research universities for baccalaureate degree production and/or graduation rate efficiency.

Determining the source of inefficiency for higher education institutions is often complicated and challenging due to the complexity of numerous and sometimes conflicting institutional goals. Considering the potential differences between public and private institutional goals and objectives, it is necessary to analyze whether or not the sources of inefficiencies are due to “the input/output configuration as well as the size of operations (as evidenced by having a global technical efficiency (GTE) score < 1), to the size of operations (as evidenced by having a scale efficiency (SE) score < 1), or to only managerial underperformance (as evidenced by having a local pure technical efficiency (LPTE) score < 1)” (Kumar & Gulati, 2008, p. 43). Assessing inefficiencies due to the size of a university’s size of operations is known in DEA as “scale inefficiency” (SE), which is a measured relationship between GTE (which measures inefficiencies due to managerial underperformance and inappropriate institution size) and LPTE (which measures inefficiencies due only to managerial underperformance) expressed mathematically as SE = GTE/LPTE. In cases where institutions have observed GTE scores less than one and LPTE scores equal to one “the inference can be made that the LPTE in these institutions is not caused by poor input utilization (i.e., managerial inefficiency), but rather by the operations of the institution’s inappropriate scale size” (Kumar & Gulati, 2008, p. 57).

While the efficiency scores of interest in hypothesis one were LPTE scores (because LPTE scores indicate managerial underperformance if < 1), GTE and SE scores provide additional information on whether or not poor resource utilization is due to failure of an institution to operate at the most productive scale size (as evidenced by having SE < 1) as well as managerial underperformance (as evidenced by having LPTE < 1). GTE scores measure combined inefficiency that is due to both LPTE and SE, while LPTE scores alone measure inefficiencies due to managerial underperformance devoid of the scale effects (i.e., scale efficiency or inefficiency).

To test this hypothesis, all five input variables (EANDG01, STATE09, TOTAL_UNDERGRADUATES, TOTAL_EXECUTIVE_ADMIN_MANAGERIAL_W_OTHER_PROFESSIONALS, and TOTAL_FACULTY) and two output variables (BACHELORDEGREES and GRAD_RATE_150_n4YR) were included in DEA BCC (under the VRS assumption), CCR (under the CRS assumption), and scale efficiency (SE) output-oriented models for four homogeneous sets of public and private non-profit Carnegie 15 and 16 research universities. In total, three separate DEA output oriented models (BCC-VRS, CCR-CRS, and SE) output oriented models were run separately for: 1) public Carnegie 15 research universities; 2) public Carnegie 16 research universities; 3) private non-profit Carnegie 15 research universities; and 4) private non-profit Carnegie 16 research universities. The results provided three separate efficiency scores for each of the four homogenous sets of research universities: 1) GTE scores calculated by a CCR-CRS output oriented model; 2) LPTE scores calculated by a BCC-VRS output oriented model; and 3) SE scores calculated by a SE output oriented model. Results from hypothesis two provide evidence as to whether or not the source of inefficiency for research universities is: 1) managerial underperformance (as evidenced by having LPTE < 1), and/or 2) inappropriate scale size (as evidenced by having GTE < 1).

Testing Hypothesis Two – Source of Inefficiency

In the first hypothesis, research universities were tested with the Banker, Charnes, and Cooper (1984) (BCC) model under the assumption of variable return to scale (VRS) devoid of the scale effects with the goal of focusing on inefficiencies directly resulting from managerial underperformance in utilization of research university resources. According to Kumar and Gulati (2008):

> It is significant to note here that the efficiency scores of the DMUs rise on allowing VRS because the BCC model (i.e., a DEA model under the VRS assumption) forms a convex hull of intersecting planes which envelopes the data points more tightly than the CRS conical hull and provides efficiency scores which are greater than or equal to those obtained using the CCR model (i.e., a DEA model under the CRS assumption). (p. 57)

The second hypothesis addressed an assumption that managerial underperformance serves as the attributable source of inefficiency for public and/or private non-profit research universities. Employing a Charnes, Cooper, and Rhodes (1978) (CCR) under the assumption of constant return to scale (CRS) and scale efficiency (SE) models in addition to the BCC-VRS model allows for a more circumstantial assessment of technical efficiency for research universities. By doing so, results will indicate whether or not inefficiencies are due to poor resource utilization (i.e., local pure technical efficiency) and/or the failure for a research university to operate at the most productive scale size (i.e., scale efficiency). For inefficient research universities, the global technical inefficiency score (GTIE = 1 minus GTE) reflects the combined inefficiency that is due to both local pure technical inefficiency (LPTIE = 1 minus LPTE) and scale inefficiency (SIE = 1 minus SE). Comparing all three measures of inefficiency will allows for the assessment of how much of the observed technical inefficiency of an inefficient research university is due to managerial underperformance or due to the inappropriate size of operations. Research universities with, with GTE, LPTE and SE scores equal to one are said to be operating in the “most productive scale size” (Cooper, Seiford, & Tone, 2007, p. 152), are considered peers, and set an example of best operating practices for inefficient research universities to emulate.

To determine the first set of BCC-VRS, CCR-CRS, and SE efficiency scores corresponding to baccalaureate degree production, all five input variables (EANDG01, STATE09, TOTAL_UNDERGRADUATES, TOTAL_EXECUTIVE_ADMIN_MANAGERIAL_W_OTHER_PROFESSIONALS, and TOTAL_FACULTY) and only the output BACHELORDEGREES will be included in the DEA models. To determine the second set of BCC-VRS, CCR-CRS, and SE efficiency scores corresponding to graduation rate efficiency, all five input variables (EANDG01, STATE09, TOTAL_UNDERGRADUATES, TOTAL_EXECUTIVE_ADMIN_MANAGERIAL_W_OTHER_PROFESSIONALS, and TOTAL_FACULTY) and only the output GRAD_RATE_150_n4YR will be included in the DEA models. Hypothesis two, thus, was stated as follows:

- Hypothesis Two: On average, managerial underperformance serves as the primary source of inefficiency for public and/or private non-profit Carnegie 15 or 16 research universities for baccalaureate degree production and/or graduation rate efficiency.

CHAPTER FOUR: RESULTS

The purpose of this study is to analyze relative efficiencies of public and private non-profit four-year or above research universities using principal-agent theory as a heuristic framework and data envelopment analysis as an analytical strategy. Combined, principal-agent theory and data envelopment analysis allowed for a unique analysis of higher education research university resource utilization and goal conflict between state baccalaureate degree production goals and university graduation rate efficiency goals. In addition, date envelopment analysis also allowed for a more in-depth investigation of sources of resource utilization inefficiencies, albeit managerial underperformance or inappropriate scale size.

Measuring Relative Efficiencies of Research Universities Using DEA

In this section, efficiency scores obtained from the output-oriented Banker, Charnes, and Cooper (1984) (BCC) model under the variable return to scale (VRS) assumption, the Charnes, Cooper, and Rhodes (CCR) (1978) model under the constant return to scale (CRS) assumption, and scale efficiency (SE) models are discussed. Each of the data envelopment models are output-oriented with the goal of “maximizing outputs while using no more than the observed amount of any input” (Cooper, Seiford, & Tone, 2007, p. 58). A BCC-VRS model was employed in testing hypothesis one to measure local pure technical efficiency (LPTE) (i.e., inefficiencies due to managerial underperformance). To test hypothesis two, BCC-VRS, CCR-CRS, and SE models were employed. The additional CCR-CRS model was employed in testing hypothesis two to measure global technical efficiency (GTE) (i.e., inefficiencies due to managerial underperformance and inappropriate university size of operations). Finally, the SE model was employed to measure the productivity of the scale size of research universities.

Hypothesis One Results – Public Carnegie 15 Research Universities

Table 13 provides descriptive statistics derived from the BCC-VRS model for 60 public Carnegie 15 research universities with very high research activity (PCRU-15s) regarding baccalaureate degree production. Research universities with an LPTE score equal to one are considered most efficient amongst research universities in the analysis. The research universities with an LPTE score less than one are considered relatively inefficient. Of the 60 PCRU-15s, 12 (Arizona State University, Colorado State University, Florida State University, Montana State University, Pennsylvania State University, State University of New York – Albany, University of Texas – Austin, University of California – Berkeley, University of California – Riverside, University of California – Santa Barbara, University of California – Santa Cruz, and University of Colorado – Boulder) were found to have local pure technical efficiency since they had a LPTE score equal to one. The technically efficient PCRU-15s together define the efficient frontier. The resource utilization process in these research universities is functioning well. In essence, the baccalaureate degree production process of these research universities is not characterized by any waste of inputs. In DEA terminology, these research universities are considered peers and set an example of best operating practices for inefficient research universities to emulate. Efficiency scores corresponding to baccalaureate degree production for all PCRU-15s can be found in Appendix A.

The average of LPTE scores for 60 PCRU-15s was 0.86. This suggests that the average PCRU-15, if producing its baccalaureate degrees on the efficient frontier instead of its current baccalaureate degree production, would need to utilize only 86 percent of its measured resources (inputs). The magnitude of local pure technical inefficiency (LPTIE) for PCRU-15s is 14.22 percent. This suggests that, by adopting best operating practice, PCRU-15s can, on average, reduce their inputs of current year total of education and general expenditures, revenue from state and local appropriations, total number of undergraduate students, total number of executive and managerial employees, and total number of faculty by at least 14.22 percent and still produce the same level of baccalaureate degrees. However, the potential reduction in resource utilization and output maximization varies among PCRU-15s. Considering output maximization, PCRU-15s have the potential of producing 1.16 times (i.e., 1/0.86) more baccalaureate degrees from the same level of inputs.

Table 13

Descriptive Statistics of LPTE Scores for Public Carnegie 15 Research Universities: Baccalaureate Degree Production

Statistics	All Universities	Efficient Universities	Inefficient Universities
N	60	12	48
Average LPTE	0.86	1	0.82
Average LPTIE (%)	14.22	0	17.77
SD of LPTE	12.91	0	0.12
Minimum	49.04	1	0.49
Lower Quartile (25th percentile)	78.78	1	0.77
Median	87.6	1	0.84
Upper Quartile (75th percentile)	96.75	1	0.92
Maximum	1.00	1	0.99

Notes: LPTE = Local pure technical efficiency; SD = Standard deviation; LPTIE = Local pure technical inefficiency (=1-LPTE)*100)

Table 14 provides values of inputs and output slacks derived from the BCC-VRS model corresponding to baccalaureate degree production for 60 PCRU-15s. The potential improvement shows areas of improvement in input-output activity needed to put an inefficient PCRU-15 onto the efficiency frontier. Considering overall input and output inefficiencies (i.e., all non-zero input and output values) for all PCRU-15s, on average, revenue from state and local appropriations, total education and general expenditures, total number of undergraduate students, total number of executive and managerial employees, and total number of faculty needs to be reduced by 30.85, 26.51, 10.80, 34.20, and 28.19 percent, respectively, and baccalaureate degree production needs to be increased by 24.84 percent to project all the inefficient PCRU-15s onto the efficient frontier.

Individual scores for PCRU-15s can be found in Appendix B. For interpreting the contents of Appendix B, consider the case of the least efficient PCRU-15 Wayne State University (LPTE score = 0.49). To move onto the efficient frontier corresponding to baccalaureate degree production, Wayne State University needs to use 12.73 percent less revenue from state and local appropriations, reduce its total education and general expenditures by 9.04 percent, cut the number of total number of executive administrative managerial employees by 1.48 percent, and increase baccalaureate degree production by 105.54 percent.

Table 14
Average Input Reduction (%) and Output Addition (%) Slacks for Public Carnegie 15 Research Universities: Baccalaureate Degree Production

	Slack % (input reduction)					Slack % (output addition)
Statistics	x1	x2	x3	x4	x5	y1
Average	-12.75	-17.72	-0.64	-16.39	-14.26	27.90
SD	17.27	15.87	2.76	19.68	16.38	25.18
Minimum	-60.70	-55.64	-15.56	-73.78	-72.64	0.00
Lower Quartile (25th percentile)	-17.89	-28.16	0.00	-28.14	-23.73	12.42
Median	-4.53	-14.85	0.00	-10.76	-9.23	22.14
Upper Quartile (75th percentile)	0.00	-5.04	0.00	0.00	0.00	36.72
Maximum	0.00	0.00	0.00	0.00	0.00	134.16

Notes: x1 =state09_div100000, x2 =eandg01_div100000, x3 =total_undergraduates, x4 =total_executive_admin_managerial_w_other_professionals, x5 =total_faculty_all, y1 =BACHELORDEGREES; y2 =GRAD_RATE_150_n4YR

Table 15 provides descriptive statistics derived from the BCC-VRS model for 60 public Carnegie 15 research universities (PCRU-15s) corresponding with graduation rate efficiency. Research universities with an LPTE score equal to one are considered most efficient amongst research universities in the analysis. The research universities with an LPTE score less than one are considered relatively inefficient. Of the 60 PCRU-15s, 14 (Florida State University, Indiana University – Bloomington, Montana State University, Pennsylvania State University, State University of New York – Albany, Texas A & M University, University of Texas – Austin, University of California – Riverside, University of California – Santa Barbara, University of California – Santa Cruz, University of Colorado – Boulder, University of Delaware, University of Michigan – Ann Arbor, and University of Virginia) were found to have local pure technical efficiency since they had a LPTE score equal to one. The technically efficient PCRU-15s together define the best practice or efficient frontier. The resource utilization process in these research universities is functioning well. In essence, the graduation rate efficiency process of these research universities is not characterized by any waste of inputs. In DEA terminology, these research universities are considered peers and set an example of best operating practices for inefficient research universities to emulate. Efficiency scores for a PCRU-15s corresponding with graduation rate efficiency can be found in Appendix C.

The average of LPTE scores for 60 PCRU-15s was 0.77. This suggests that the average PCRU-15, if producing its baccalaureate degrees on the efficient frontier instead of its current graduation rate efficiency, would need to utilize only 77 percent of its measured resources (inputs). The magnitude of local pure technical inefficiency (LPTIE) for PCRU-15s is 22.65 percent. This suggests that, by adopting best operating practice, PCRU-15s can, on average, reduce their inputs of current year total of education and general expenditures, revenue from state and local appropriations, total number of undergraduate students, total number of executive and managerial employees, and total number of faculty by at least 22.65 percent and still produce the same level of baccalaureate degrees. However, the potential reduction in resource utilization and output maximization varies among PCRU-15s. Considering output maximization, PCRU-15s have the scope of increasing graduation rate efficiency 1.30 times (i.e., 1/0.77) from the same level of inputs.

Table 15
Descriptive Statistics of LPTE Scores for Public Carnegie 15 Research Universities: Graduation Rate Efficiency

Statistics	All Universities	Efficient Universities	Inefficient Universities
N	60	14	46
Average LPTE	0.77	1	0.07
Average LPTIE (%)	22.65	0	29.54
SD of LPTE	0.22	0	0.21
Minimum	0.18	1	0.18
Lower Quartile (25th percentile)	0.65	1	0.63
Median	0.80	1	0.74
Upper Quartile (75th percentile)	1.00	1	0.85
Maximum	1.00	1	1.00

Notes: LPTE = Local pure technical efficiency; SD = Standard deviation; LPTIE = Local pure technical inefficiency (=1-LPTE)*100)

Table 16 provides values of inputs and output slacks derived from the BCC-VRS model corresponding to graduation rate efficiency for 60 PCRU-15s. The potential improvement shows areas of improvement in input-output activity needed to put an inefficient PCRU-15 onto the efficiency frontier. Considering overall input and output inefficiencies (i.e., all non-zero input and output values) for all PCRU-15s, on average, revenue from state and local appropriations, total education and general expenditures, total number of undergraduate students, total number of executive and managerial employees, and total number of faculty needs to be reduced by 30.38, 12.97, 1.99, 12.54, and 12.59 percent, respectively, and graduation rate efficiency needs to be increased by 51.34 percent to project all the inefficient PCRU-15s onto the efficient frontier.

Table 16

Average Input Reduction (%) and Output Addition (%) Slacks for Public Carnegie 15 Research Universities: Graduation Rate Efficiency

	Slack % (input reduction)					Slack % (output addition)
Statistics	x1	x2	x3	x4	x5	y2
Average	-30.38	-12.97	-1.99	-12.54	-12.59	51.34
SD	26.60	18.20	6.20	19.98	16.23	91.60
Minimum	-79.42	-73.93	-29.88	-69.98	-62.96	0.00
Lower Quartile (25th percentile)	-52.32	-21.69	0.00	-20.08	-24.52	0.49
Median	-32.72	-2.38	0.00	0.00	-6.71	25.49
Upper Quartile (75th percentile)	0.00	0.00	0.00	0.00	0.00	54.15
Maximum	0.00	0.00	0.00	0.00	0.00	467.25

Notes: x1 =state09_div100000, x2 =eandg01_div100000, x3 =total_undergraduates, x4 =total_executive_admin_managerial_w_other_professionals, x5 =total_faculty_all, y1 =BACHELORDEGREES; y2 =GRAD_RATE_150_n4YR

Individual scores for PCRU-15s can be found in Appendix D. For interpreting the contents of Appendix D, consider the case of the least efficient PCRU-15 University of Colorado – Denver (LPTE score = 0.18). To move onto the efficient frontier corresponding to baccalaureate degree production, University of Colorado – Denver needs to reduce its total education and general expenditures by 48.91 percent, cut the number of total number of faculty by 62.96 percent, and increase graduation rate efficiency by 467.25 percent.

Hypothesis One Results – Public Carnegie 16 Research Universities

Table 17 provides descriptive statistics derived from the BCC-VRS model for 66 public Carnegie 16 research universities with high research activity (PCRU-16s) corresponding with baccalaureate degree production. Research universities with an LPTE score equal to one are considered most efficient amongst research universities in the analysis. The research universities with an LPTE score less than one are considered relatively inefficient. Of the 66 PCRU-16s, four (Colorado School of Mines, Northern

Illinois University, San Diego State University, and State University of New York – College of Environmental Science and Forestry) were found to have local pure technical efficiency since they had a LPTE score equal to one. The technically efficient PCRU-16s together define the best practice or efficient frontier. The resource utilization process in these research universities is functioning well. In essence, the baccalaureate degree production process of these research universities is not characterized by any waste of inputs. In DEA terminology, these research universities are considered peers and set an example of best operating practices for inefficient research universities to emulate. Efficiency scores for a PCRU-16s corresponding with baccalaureate degree completion can be found in Appendix E.

Table 17

Descriptive Statistics of LPTE Scores for Public Carnegie 16 Research Universities: Baccalaureate Degree Production

Statistics	All Universities	Efficient Universities	Inefficient Universities
N	66	4	62
Average LPTE	0.55	1	0.53
Average LPTIE (%)	44.54	0	47.41
SD of LPTE	26.2	0	26.41
Minimum	0.15	1	0.15
Lower Quartile (25th percentile)	0.41	1	0.41
Median	0.49	1	0.48
Upper Quartile (75th percentile)	0.65	1	0.59
Maximum	1.00	1	0.99

Notes: LPTE = Local pure technical efficiency; SD = Standard deviation; LPTIE = Local pure technical inefficiency (=1-LPTE)*100)

The average of LPTE scores for 66 PCRU-16s was 0.55. This suggests that the average PCRU-16, if producing its baccalaureate degrees on the efficient frontier instead of its current baccalaureate degree production, would need to utilize only 55 percent of its measured resources (inputs). The magnitude of local pure technical inefficiency (LPTIE) for PCRU-16s is 44.54 percent. This suggests that, by adopting best operating practice, PCRU-16s can, on average, reduce their inputs of current year total of education and general expenditures, revenue from state and local appropriations, total number of undergraduate students, total number of executive and managerial employees, and total number of faculty by at least 44.54 percent and still produce the same level of baccalaureate degrees. However, the potential reduction in resource utilization and output maximization varies between PCRU-16s. Considering output maximization, PCRU-16s have the scope of producing 1.82 times (i.e., 1/0.55) more baccalaureate degrees from the same level of inputs.

Table 18 provides values of inputs and output slacks derived from the BCC-VRS model corresponding to baccalaureate degree production for 66 PCRU-16s. The potential improvement shows areas of improvement in input-output activity needed to put an inefficient PCRU-16 onto the efficiency frontier. Considering overall input and output inefficiencies (i.e., all non-zero input and output values) for all PCRU-16s, on average, revenue from state and local appropriations, total education and general expenditures, total number of undergraduate students, total number of executive and managerial employees, and total number of faculty needs to be reduced by 13.87, 28.36, 18.20, 22.05, and 17.37 percent, respectively, and baccalaureate degree production needs to be increased by 103.86 percent to project all the inefficient PCRU-16s onto the efficient frontier.

Individual scores for PCRU-16s can be found in Appendix F. For interpreting the contents of Appendix F, consider the case of the least efficient PCRU-16 University of Alaska – Fairbanks (LPTE score = 0.15). To move onto the efficient frontier corresponding to baccalaureate degree production, the University of Alaska – Fairbanks needs to use 52.5 percent less revenue from state and local appropriations, reduce its total education and general expenditures by 40.73 percent, reduce the total number of undergraduate students by 26.8 percent, cut the number of total number of executive and managerial employees by 1.85 percent, cut the total number faculty by 15.69 percent, and increase baccalaureate degree production by 566.12 percent.

Table 18
Average Input Reduction (%) and Output Addition (%) Slacks for Public Carnegie 16 Research Universities: Baccalaureate Degree Production

	Slack % (input reduction)					Slack % (output addition)
Statistics	x1	x2	x3	x4	x5	y1
Average	-13.87	-28.36	-18.20	-22.05	-17.37	103.86
SD	15.82	15.99	18.18	20.65	15.09	80.62
Minimum	-52.50	-62.73	-55.72	-71.71	-53.27	0.00
Lower Quartile (25th percentile)	-27.70	-40.95	-31.14	-35.90	-29.51	52.96
Median	-6.87	-28.79	-12.66	-17.33	-16.12	105.57
Upper Quartile (75th percentile)	0.00	-17.56	0.00	0.00	-0.43	143.54
Maximum	0.00	0.00	0.00	0.00	0.00	566.12

Notes: x1 =state09_div100000, x2 =eandg01_div100000, x3 =total_undergraduates, x4 =total_executive_admin_managerial_w_other_professionals, x5 =total_faculty_all, y1 =BACHELORDEGREES; y2 =GRAD_RATE_150_n4YR

Table 19 provides descriptive statistics derived from the BCC-VRS model for 66 public Carnegie 16 research universities (PCRU-16s) corresponding with graduation rate efficiency. Research universities with an LPTE score equal to one are considered most efficient amongst research universities in the analysis. The research universities with an LPTE score of less than one are considered relatively inefficient. Of the 66 PCRU-16s, eight (College of William and Mary, Colorado School of Mines, Jackson State University, Miami University – Oxford, Northern Carolina A & T State University, State University of New York – College of Environmental Science and Forestry, University of Central Florida, and Western Michigan University) were found to have local pure technical efficiency since they had a LPTE score equal to one. The technically efficient PCRU-16s together define the best practice or efficient frontier. The resource utilization process in these research universities is functioning well. In essence, the graduation rate efficiency process of these research universities is not characterized by any waste of inputs. In DEA terminology, these research universities are considered peers and set an example of best operating practices for inefficient research universities to emulate. Efficiency scores for a PCRU-16s corresponding with graduation rate efficiency can be found in Appendix G.

Table 19
Descriptive Statistics of LPTE Scores for Public Carnegie 16 Research Universities: Graduation Rate Efficiency

Statistics	All Universities	Efficient Universities	Inefficient Universities
N	66	8	58
Average LPTE	0.59	1	0.54
Average LPTIE (%)	40.58	0	46.18
SD of LPTE	0.24	0	0.20
Minimum	0.11	1	0.11
Lower Quartile (25th percentile)	0.41	1	0.40
Median	0.53	1	0.50
Upper Quartile (75th percentile)	0.78	1	0.69
Maximum	1.00	1	0.97

Notes: LPTE = Local pure technical efficiency; SD = Standard deviation; LPTIE = Local pure technical inefficiency (=1-LPTE)*100)

The average of LPTE scores for 66 PCRU-16s was 0.59. This suggests that the average PCRU-16, if producing its baccalaureate degrees on the efficient frontier instead of its current baccalaureate degree production, would need to utilize only 59 percent of its measured resources (inputs). The magnitude of local pure technical inefficiency (LPTIE) for PCRU-16s is 40.58 percent. This suggests that, by adopting best operating practice, PCRU-16s can, on average, reduce their inputs of current year total of education and general expenditures, revenue from state and local appropriations, total number of undergraduate students, total number of executive and managerial employees, and total number of faculty by at least 40.58 percent and still produce the same level of baccalaureate degrees. However, the potential reduction in resource utilization and output maximization varies among PCRU-16s. Considering output maximization, PCRU-16s have the scope of increasing graduation rate efficiency 1.69 times (i.e., 1/0.59) from the same level of inputs.

Table 20 provides values of inputs and output slacks derived from the BCC-VRS model corresponding to graduation rate efficiency for 66 PCRU-16s. The potential improvement shows areas of improvement in input-output activity needed to put an inefficient PCRU-16 onto the efficiency frontier. Considering overall input and output inefficiencies (i.e., all non-zero input and output values) for all PCRU-16s, on average, revenue from state and local appropriations, total education and general expenditures, total number of undergraduate students, total number of executive and managerial employees, and total number of faculty needs to be reduced by 35.94, 15.90, 5.38, 17.90, and 10.72 percent, respectively, and graduation rate efficiency needs to be increased by 105.70 percent to project all the inefficient PCRU-16s onto the efficient frontier.

Table 20
Average Input Reduction (%) and Output Addition (%) Slacks for Public Carnegie 16 Research Universities: Graduation Rate Efficiency

	Slack % (input reduction)					Slack % (output addition)
Statistics	x1	x2	x3	x4	x5	y2
Average	-35.94	-15.90	-5.38	-17.90	-10.72	105.70
SD	24.77	16.17	10.20	19.71	12.56	119.97
Minimum	-70.90	-53.16	-36.32	-70.79	-44.06	0.00
Lower Quartile (25th percentile)	-58.88	-25.58	-5.12	-31.92	-18.24	28.93
Median	-39.58	-10.89	0.00	-11.88	-6.48	89.77
Upper Quartile (75th percentile)	-8.71	0.00	0.00	0.00	0.00	143.23
Maximum	0.00	0.00	0.00	0.00	0.00	806.52

Notes: x1 =state09_div100000, x2 =eandg01_div100000, x3 =total_undergraduates, x4 =total_executive_admin_managerial_w_other_professionals, x5 =total_faculty_all, y1 =BACHELORDEGREES; y2 =GRAD_RATE_150_n4YR

Individual scores for PCRU-16s can be found in Appendix H. For interpreting the contents of Appendix H, consider the case of the least efficient PCRU-16 University of Alaska – Fairbanks (LPTE score = 0.11). To move onto the efficient frontier corresponding to baccalaureate degree production, the University of Alaska – Fairbanks needs to use 59.49 percent less revenue from state and local appropriations, reduce its total education and general expenditures by 31.2 percent, reduce the total number of undergraduate students by 0.48 percent, cut the total number faculty by 6.86 percent, and increase graduation rate efficiency by 806.52 percent.

Hypothesis One Results – Private Non-profit Carnegie 15 Research Universities

Table 21 provides descriptive statistics derived from the BCC-VRS model for 31 private non-profit Carnegie 15 research universities with very high research activity (PNCRU-15s) corresponding with baccalaureate degree production. Research universities with an LPTE score equal to one are considered most efficient amongst research universities in the analysis. The private non-profit research universities with an LPTE score less than one are considered relatively inefficient. Of the 31 PNCRU-15s, 11 (Boston University, Brandeis University, Brown University, Massachusetts Institute of Technology, New York University, Rensselaer Polytechnic Institute, Rice University, Tufts University, Tulane University of Louisiana, University of Notre Dame, and University of Southern California) were found to have local pure technical efficiency since they had a LPTE score equal to one. The technically efficient PNCRU-15s together define the best practice or efficient frontier. The resource utilization process in these private non-profit research universities is functioning well. In essence, the baccalaureate degree production process of these private non-profit research universities is not characterized by any waste of inputs. In DEA terminology, these research universities are considered peers and set an example of best operating practices for inefficient research universities to emulate. Efficiency scores for a PNCRU-15s corresponding with baccalaureate degree completion can be found in Appendix I.

The average of LPTE scores for 31 PNCRU-15s was 0.91. This suggests that the average PNCRU-15, if producing its baccalaureate degrees on the efficient frontier instead of its current baccalaureate degree production, would need to utilize only 91 percent of its measured resources (inputs). The magnitude of local pure technical inefficiency (LPTIE) for PNCRU-15s is 8.65 percent. This suggests that, by adopting best operating practice, PNCRU-15s can, on average, reduce their inputs of current year total of education and general expenditures, revenue from state and local appropriations, total number of undergraduate students, total number of executive and managerial employees, and total number of faculty by at least 8.65 percent and still produce the same level of baccalaureate degrees. However, the potential reduction in resource utilization and output maximization varies among PNCRU-15s. Considering output maximization, PNCRU-15s have the scope of producing 1.10 times (i.e., 1/0.91) more baccalaureate degrees from the same level of inputs.

Table 21
Descriptive Statistics of LPTE Scores for Private Non-profit Carnegie 15 Research Universities: Baccalaureate Degree Production

Statistics	All Universities	Efficient Universities	Inefficient Universities
N	31	11	20
Average LPTE	0.91	1	0.87
Average LPTIE (%)	8.65	0	13.41
SD of LPTE	0.09	0	0.07
Minimum	0.68	1	0.68
Lower Quartile (25th percentile)	0.85	1	0.83
Median	0.93	1	0.87
Upper Quartile (75th percentile)	1.00	1	0.92
Maximum	1.00	1	0.97

Notes: LPTE = Local pure technical efficiency; SD = Standard deviation; LPTIE = Local pure technical inefficiency (=1-LPTE)*100)

Table 22 provides values of inputs and output slacks derived from the BCC-VRS model corresponding to baccalaureate degree production for 31 PNCRU-15s. The potential improvement shows areas of improvement in input-output activity needed to put an inefficient PNCRU-15 onto the efficiency frontier. Considering overall input and output inefficiencies (i.e., all non-zero input and output values) for all PNCRU-15s, on average, revenue from state and local appropriations, total education and general expenditures, total number of undergraduate students, total number of executive and managerial employees, and total number of faculty needs to be reduced by 24.40, 22.42, 0.01, 26.75, and 11.82 percent, respectively, and baccalaureate degree production needs to be increased by 10.55 percent to project all the inefficient PNCRU-15s onto the efficient frontier.

Table 22

Average Input Reduction (%) and Output Addition (%) Slacks for Private Non-profit Carnegie 15 Research Universities: Baccalaureate Degree Production

	Slack % (input reduction)					Slack % (output addition)
Statistics	x1	x2	x3	x4	x5	y1
Average	-24.40	-22.42	-0.01	-26.75	-11.82	10.55
SD	33.86	24.62	0.07	26.85	20.83	11.72
Minimum	-97.38	-78.17	-0.40	-77.97	-65.73	0.00
Lower Quartile (25th percentile)	-52.07	-36.08	0.00	-45.79	-16.49	0.00
Median	0.00	-13.84	0.00	-25.10	0.00	7.75
Upper Quartile (75th percentile)	0.00	0.00	0.00	0.00	0.00	17.86
Maximum	0.00	0.00	0.00	0.00	0.00	46.46

Notes: x1 =state09_div100000, x2 =eandg01_div100000, x3 =total_undergraduates, x4 =total_executive_admin_managerial_w_other_professionals, x5 =total_faculty_all, y1 =BACHELORDEGREES; y2 =GRAD_RATE_150_n4YR

Individual scores for PNCRU-15s can be found in Appendix J. For interpreting the contents of Appendix J, consider the case of the least efficient PCRU-16 Case Western Reserve University (LPTE score = 0.69). To move onto the efficient frontier corresponding to baccalaureate degree production, Case Western Reserve University needs to use 62.69 percent less revenue from state and local appropriations, reduce its total education and general expenditures by 9.46 percent, reduce the total number of executive and managerial employees by 42.98 percent, and increase baccalaureate degree production by 46.46 percent.

Table 23 provides descriptive statistics derived from the BCC-VRS model for 31 private non-profit Carnegie 15 research universities (PNCRU-15s) corresponding with graduation rate efficiency. Research universities with an LPTE score equal to one are considered most efficient amongst research universities in the analysis. The research universities with an LPTE score less than one are considered relatively inefficient. Of the 31 PNCRU-15s, 12 (Boston University, Brandeis University, Brown University, Cornell University, Dartmouth University, Duke University, Princeton University, Rensselaer Polytechnic Institute, Rice University, Stanford University, Tulane University of Louisiana, and University of Notre Dame) were found to have local pure technical efficiency since they had a LPTE score equal to one. The technically efficient PNCRU-15s together define the best practice or efficient frontier. The resource utilization process in these research universities is functioning well. In essence, the graduation rate efficiency process of these research universities is not characterized by any waste of inputs. In DEA terminology, these research universities are considered peers and set an example of best operating practices for inefficient research universities to emulate. Efficiency scores for a PNCRU-15s corresponding with graduation rate efficiency can be found in Appendix K.

The average of LPTE scores for 31 PNCRU-15s was 0.89. This suggests that the average PNCRU-15, if producing its baccalaureate degrees on the efficient frontier instead of its current baccalaureate degree production, would need to utilize only 89 percent of its measured resources (inputs). The magnitude of local pure technical inefficiency (LPTIE) for PNCRU-15s is 10.69 percent. This suggests that, by adopting best operating practice, PNCRU-15s can, on average, reduce their inputs of current year total of education and general expenditures, revenue from state and local appropriations, total number of undergraduate students, total number of executive and managerial employees, and total number of faculty by at least 10.69 percent and still produce the same level of baccalaureate degrees. However, the potential reduction in resource utilization and output maximization varies among PNCRU-15s. Considering output maximization, PNCRU-15s have the scope of increasing graduation efficiency 1.02 times (i.e., 1/0.89) from the same level of inputs.

Table 23

Descriptive Statistics of LPTE Scores for Private Non-profit Carnegie 15 Research Universities: Graduation Rate Efficiency

Statistics	All Universities	Efficient Universities	Inefficient Universities
N	31	12	19
Average LPTE	0.89	1	0.83
Average LPTIE (%)	10.69	0	17.44
SD of LPTE	0.12	0	0.10
Minimum	0.66	1	0.66
Lower Quartile (25th percentile)	0.76	1	0.75
Median	0.93	1	0.79
Upper Quartile (75th percentile)	1.00	1	0.90
Maximum	1.00	1	0.99

Notes: LPTE = Local pure technical efficiency; SD = Standard deviation; LPTIE = Local pure technical inefficiency (=1-LPTE)*100)

Table 24 provides values of inputs and output slacks derived from the BCC-VRS model corresponding to graduation rate efficiency for 31 PNCRU-15s. The potential improvement shows areas of improvement in input-output activity needed to put an inefficient PNCRU-15 onto the efficiency frontier. Considering overall input and output inefficiencies (i.e., all non-zero input and output values) for all PNCRU-15s, on average, revenue from state and local appropriations, total education and general expenditures, total number of undergraduate students, total number of executive and managerial employees, and total number of faculty needs to be reduced by 16.48, 17.69, 0.41, 13.20, and 22.86 percent, respectively, and graduation rate efficiency needs to be increased by 14.05 percent to project all the inefficient PNCRU-15s onto the efficient frontier.

Table 24

Average Input Reduction (%) and Output Addition (%) Slacks for Private Non-profit Carnegie 15 Research Universities: Graduation Rate Efficiency

	Slack % (input reduction)					Slack % (output addition)
Statistics	x1	x2	x3	x4	x5	y2
Average	-16.48	-17.69	-0.41	-13.20	-22.86	14.05
SD	27.20	24.52	2.18	20.80	23.91	16.39
Minimum	-97.38	-78.17	-12.16	-67.36	-81.30	0.00
Lower Quartile (25th percentile)	-36.09	-36.67	0.00	-21.35	-37.12	0.00
Median	0.00	0.00	0.00	0.00	-21.63	8.10
Upper Quartile (75th percentile)	0.00	0.00	0.00	0.00	0.00	30.94
Maximum	0.00	0.00	0.00	0.00	0.00	51.11

Notes: x1 =state09_div100000, x2 =eandg01_div100000, x3 =total_undergraduates, x4 =total_executive_admin_managerial_w_other_professionals, x5 =total_faculty_all, y1 =BACHELORDEGREES; y2 =GRAD_RATE_150_n4YR

Individual scores for PNCRU-15s can be found in Appendix L. For interpreting the contents of Appendix L, consider the case of the least efficient PCRU-16 Case Western Reserve University (LPTE score = 0.66). To move onto the efficient frontier corresponding to graduation rate efficiency, Case Western Reserve University needs to use 43.12 percent less revenue from state and local appropriations, reduce its total education and general expenditures by 3.7 percent, reduce the total number of executive and managerial employees by 32.13 percent, cut the total number of faculty by 34.98 percent, and increase graduation rate efficiency by 51.11 percent.

Hypothesis One Results – Private Non-profit Carnegie 16 Research Universities

Table 25 provides descriptive statistics derived from the BCC-VRS model for 25 private non-profit Carnegie 16 research universities with high research activity (PNCRU-16s) corresponding with baccalaureate degree production. Research universities with an LPTE score equal to one are considered most efficient amongst research universities in the analysis. The research universities with an LPTE score less than one are considered relatively inefficient. Of the 25 PNCRU-16s, eight (Boston College, Brigham Young

University, Clark Atlanta University, Clark University, Clarkson University, Fordham University, Howard University, and Polytechnic University) were found to have local pure technical efficiency since they had a LPTE score equal to one. The technically efficient PNCRU-16s together define the best practice or efficient frontier. The resource utilization process in these research universities is functioning well. In essence, the baccalaureate degree production process of these research universities is not characterized by any waste of inputs. In DEA terminology, these research universities are considered peers and set an example of best operating practices for inefficient research universities to emulate. Efficiency scores for a PNCRU-16s corresponding with baccalaureate degree completion can be found in Appendix M.

Table 25
Descriptive Statistics of LPTE Scores for Private Non-profit Carnegie 16 Research Universities: Baccalaureate Degree Production

Statistics	All Universities	Efficient Universities	Inefficient Universities
N	25	8	17
Average LPTE	0.91	1	0.87
Average LPTIE (%)	8.53	0	12.55
SD of LPTE	0.10	0	0.10
Minimum	0.62	1	0.62
Lower Quartile (25th percentile)	0.85	1	0.83
Median	0.95	1	0.91
Upper Quartile (75th percentile)	1.00	1	0.95
Maximum	1.00	1	0.99

Notes: LPTE = Local pure technical efficiency; SD = Standard deviation; LPTIE = Local pure technical inefficiency (=1-LPTE)*100)

The average of LPTE scores for 25 PNCRU-16s was 0.91. This suggests that the average PNCRU-16, if producing its baccalaureate degrees on the efficient frontier instead of its current baccalaureate degree production, would need to utilize only 91 percent of its measured resources (inputs). The magnitude of local pure technical inefficiency (LPTIE) for PNCRU-16s is 8.53 percent. This suggests that, by adopting best operating practice, PNCRU-16s can, on average, reduce their inputs of current year total of education and general expenditures, revenue from state and local appropriations, total number of undergraduate students, total number of executive and managerial employees, and total number of faculty by at least 8.53 percent and still produce the same level of baccalaureate degrees. However, the potential reduction in resource utilization and output maximization varies among PNCRU-16s. Considering output maximization, PNCRU-15s have the scope of producing 1.10 times (i.e., 1/0.91) more baccalaureate degrees from the same level of inputs.

Table 26 provides values of inputs and output slacks derived from the BCC-VRS model corresponding to baccalaureate degree production for 25 PNCRU-16s. The potential improvement shows areas of improvement in input-output activity needed to put an inefficient PNCRU-16 onto the efficiency frontier. Considering overall input and output inefficiencies (i.e., all non-zero input and output values) for all PNCRU-16s, on average, revenue from state and local appropriations, total education and general expenditures, total number of undergraduate students, total number of executive and managerial employees, and total number of faculty needs to be reduced by 16.67, 17.02, 0.00, 17.74, and 19.79 percent, respectively, and baccalaureate degree production needs to be increased by 10.82 percent to project all the inefficient PNCRU-16s onto the efficient frontier.

Individual scores for PNCRU-16s can be found in Appendix N. For interpreting the contents of Appendix N, consider the case of the least efficient PCRU-16 Case Saint Louis University (LPTE score = 0.62). To move onto the efficient frontier corresponding to baccalaureate degree production, Saint Louis University needs to use 10.76 percent less revenue from state and local appropriations, reduce the total number of executive and managerial employees by 32.1 percent, cut the total number of faculty by 35.18 percent, and increase baccalaureate degree production by 61 percent.

Table 26
Average Input Reduction (%) and Output Addition (%) Slacks for Private Non-profit Carnegie 16 Research Universities: Baccalaureate Degree Production

	Slack % (input reduction)					Slack % (output addition)
Statistics	x1	x2	x3	x4	x5	y1
Average	-16.67	-17.02	0.00	-17.74	-19.79	10.82
SD	26.82	21.86	0.00	23.07	20.10	14.43
Minimum	-84.27	-81.94	0.00	-74.11	-66.72	0.00
Lower Quartile (25th percentile)	-29.94	-27.67	0.00	-32.10	-30.66	0.00
Median	0.00	-13.74	0.00	0.00	-18.71	5.24
Upper Quartile (75th percentile)	0.00	0.00	0.00	0.00	0.00	17.96
Maximum	0.00	0.00	0.00	0.00	0.00	61.00

Notes: x1 =state09_div100000, x2 =eandg01_div100000, x3 =total_undergraduates, x4 =total_executive_admin_managerial_w_other_professionals, x5 =total_faculty_all, y1 =BACHELORDEGREES; y2 =GRAD_RATE_150_n4YR

Table 27 provides descriptive statistics derived from the BCC-VRS model for 25 private non-profit Carnegie 16 research universities (PNCRU-16s) corresponding with graduation rate efficiency. Research universities with an LPTE score equal to one are considered most efficient amongst research universities in the analysis. The research universities with an LPTE score less than one are considered relatively inefficient. Of the 25 PNCRU-16s, 12 (Baylor University, Boston College, Brigham Young University, Clark Atlanta University, Clark University, Clarkson University, Howard University, Lehigh University, Marquette University, Northeastern University, Polytechnic University, and Syracuse University) were found to have local pure technical efficiency since they had a LPTE score equal to one. The technically efficient PNCRU-16s together define the best practice or efficient frontier. The resource utilization process in these research universities is functioning well. In essence, the graduation rate efficiency process of these research universities is not characterized by any waste of inputs. In DEA terminology, these research universities are considered peers and set an example of best operating practices for inefficient private non-profit research universities to emulate.

Efficiency scores for a PNCRU-16s corresponding with baccalaureate degree completion can be found in Appendix O.

The average of LPTE scores for 25 PNCRU-16s was 0.86. This suggests that the average PNCRU-16, if producing its baccalaureate degrees on the efficient frontier instead of its current baccalaureate degree production, would need to utilize only 86 percent of its measured resources (inputs). The magnitude of local pure technical inefficiency (LPTIE) for PNCRU-16s is 13.53 percent. This suggests that, by adopting best operating practice, PNCRU-16s can, on average, reduce their inputs of current year total of education and general expenditures, revenue from state and local appropriations, total number of undergraduate students, total number of executive and managerial employees, and total number of faculty by at least 13.53 percent and still produce the same level of baccalaureate degrees. However, the potential reduction in resource utilization and output maximization varies among PNCRU-16s. Considering output maximization, PNCRU-15s have the scope of increasing graduation efficiency 1.16 times (i.e., 1/0.86) from the same level of inputs.

Table 27
Descriptive Statistics of LPTE Scores for Private Non-profit Carnegie 16 Research Universities: Graduation Rate Efficiency

Statistics	All Universities	Efficient Universities	Inefficient Universities
N	25	12	13
Average LPTE	0.86	1	0.74
Average LPTIE (%)	13.53	0	26.01
SD of LPTE	0.18	0	0.17
Minimum	0.45	1	0.45
Lower Quartile (25th percentile)	0.71	1	0.63
Median	0.98	1	0.71
Upper Quartile (75th percentile)	1.00	1	0.91
Maximum	1.00	1	0.98

Notes: LPTE = Local pure technical efficiency; SD = Standard deviation; LPTIE = Local pure technical inefficiency (=1-LPTE)*100)

Table 28 provides values of inputs and output slacks derived from the BCC-VRS model corresponding to graduation rate efficiency for 25 PNCRU-16s. The potential improvement shows areas of improvement in input-output activity needed to put an inefficient PNCRU-16 onto the efficiency frontier. Considering overall input and output inefficiencies (i.e., all non-zero input and output values) for all PNCRU-16s, on average, revenue from state and local appropriations, total education and general expenditures, total number of undergraduate students, total number of executive and managerial employees, and total number of faculty needs to be reduced by 5.45, 12.01, 0.31, 15.85, and 12.89 percent, respectively, and graduation rate efficiency needs to be increased by 22.19 percent in order to project all the inefficient PNCRU-16s onto the efficient frontier.

Table 28

Average Input Reduction (%) and Output Addition (%) Slacks for Private Non-profit Carnegie 16 Research Universities: Graduation Rate Efficiency

	Slack % (input reduction)					Slack % (output addition)
Statistics	x1	x2	x3	x4	x5	y2
Average	-5.45	-12.01	-0.31	-15.85	-12.89	22.19
SD	13.53	21.17	1.43	22.38	19.15	33.40
Minimum	-51.53	-75.16	-7.16	-74.50	-66.34	0.00
Lower Quartile (25th percentile)	0.00	-13.74	0.00	-29.69	-25.40	0.00
Median	0.00	0.00	0.00	0.00	0.00	2.30
Upper Quartile (75th percentile)	0.00	0.00	0.00	0.00	0.00	41.78
Maximum	0.00	0.00	0.00	0.00	0.00	122.01

Notes: x1 =state09_div100000, x2 =eandg01_div100000, x3 =total_undergraduates, x4 =total_executive_admin_managerial_w_other_professionals, x5 =total_faculty_all, y1 =BACHELORDEGREES; y2 =GRAD_RATE_150_n4YR

Individual scores for PNCRU-15s can be found in Appendix P. For interpreting the contents of Appendix P, consider the case of the least efficient PCRU-16 Illinois Institute of Technology (LPTE score = 0.45). To move onto the efficient frontier corresponding to graduation rate efficiency, Illinois Institute of Technology needs to use 29.06 percent less revenue from state and local appropriations, reduce its total education and general expenditures by 65.44 percent, reduce the total number of executive and managerial employees by 59.08 percent, cut the total number of faculty by 66.34 percent, and increase graduation rate efficiency by 122.01 percent.

Hypothesis Two Results – Public Carnegie 15 Research Universities

Table 29 provides descriptive statistics derived from the CCR-CRS, BCC-VRS, and SE models for 60 public Carnegie 15 research universities with high research activity (PCRU-15s) corresponding with baccalaureate degree production. According to LPTE and SE scores for PCRU-15s as a whole, GTIE is due to both managerial underperformance (i.e., poor input utilization) and failure to operate at the most productive scale size. The average LPTE score for 60 PCRU-15s is listed in Table 29 as 0.81, which implies that 14.22 percentage points (LPTIE) of about 19.45 percent of GTIE is due to local research university managerial decisions to not follow best practice management strategies and selecting incorrect input combinations. In addition, lower means and higher standard deviations of the LPTE scores compared to the SE scores indicate that a greater portion of GTIE (i.e., combined inefficiency due to managerial underperformance and inappropriate size of operations) is due to LPTIE (i.e., inefficiency due to managerial underperformance). Individual GTE, LPTE, and SE scores for PCRU-15s are listed in Appendix A.

Table 29
Descriptive Statistics of Efficiency Scores for Public Carnegie 15 Research Universities: Baccalaureate Degree Production

Statistics	GTE	LPTE	SE
N	60	60	60
Average efficiency	0.81	0.86	0.94
Average inefficiency (%)	19.45	14.22	5.76
SD of average efficiency	0.13	0.13	0.08
Minimum	0.43	0.49	0.65
Lower Quartile (25th percentile)	0.73	0.79	0.92
Median	0.82	0.88	0.98
Upper Quartile (75th percentile)	0.89	0.97	0.99
Maximum	1	1	1

Notes: GTE = global technical efficiency; LPTE = Local pure technical efficiency; SE = scale efficiency; SD = Standard deviation; Average inefficiency (%) = (1-average efficiency)*100)

As observed in Table 13, 12 of the 60 PCRU-15s (Arizona State University, Colorado State University, Florida State university, Montana State University, Pennsylvania State University, State University of New York – Albany, University of Texas – Austin, University of California – Berkeley, University of California – Riverside, University of California – Santa Barbara, University of California – Santa Cruz, and University of Colorado – Boulder) were found to have local pure technical efficiency since they acquired a LPTE score equal to one. In addition, five (Arizona State University, Florida State University, University of California – Berkeley, University of California – Santa Barbara, and University of Colorado – Boulder) of the 12 PCRU-15s which acquired a LPTE score equal to one were also found to have global technical efficiency since they also acquired a GTE score equal to one. The remaining eight of the 12 PCRU-15s which were found to be efficient under the VRS assumption (i.e., LPTE score equal to one) have not been found to be efficient under the CRS assumption (i.e., CRS score > one). In cases where a PCRU-15 acquires an LPTE score equal to one and a GTE score less than one, the inference can be made that the global technical inefficiency is not caused by managerial underperformance, but rather caused by the operations of the PCRU-15s with inappropriate scale size.

Forty-eight of the 60 PCRU-15s exhibited inefficiency due to managerial underperformance (i.e., having LPTE < 1) of varying magnitudes. In these PCRU-15s, GTIE stems from both LPTIE and SIE as indicated by the fact that these PCRU-15s have both LPTE and SE scores less than one. Out of these 48 PCRU-15s, 39 have a LPTE score less than the SE score. This phenomenon indicates that the inefficiency in resource utilization in these PCRU-15s is primarily attributed to inefficiency due to managerial underperformance rather than to scale inefficiency.

Table 30 provides descriptive statistics derived from the CCR, CRS, BCC-VRS, and SE models for 60 public Carnegie 15 research universities (PCRU-15s) corresponding with graduation rate efficiency. According to LPTE and SE scores for PCRU-15s as a whole, GTIE is due to both managerial underperformance (i.e., poor input utilization) and failure to operate at most productive scale size. The average LPTE score for 60 PCRU-15s is listed in Table 30 as 0.77, which implies that 22.65 percentage points (LPTIE) of about 28.47 percent of GTIE is due to local research university managerial decisions to not follow best practice management strategies and to select incorrect input combinations. In addition, lower means and higher standard deviations of the LPTE scores compared to the SE scores indicate that a greater portion of GTIE (i.e., combined inefficiency due to managerial underperformance and inappropriate size of operations) is due to LPTIE (i.e., inefficiency due to managerial underperformance). Individual GTE, LPTE, and SE scores for PCRU-15s are listed in Appendix B.

Table 30
Descriptive Statistics of Efficiency Scores for Public Carnegie 15 Research Universities: Graduation Rate Efficiency

Statistics	GTE	LPTE	SE
N	60	60	60
Average efficiency	0.72	0.77	0.92
Average inefficiency (%)	28.47	22.65	7.59
SD of average efficiency	0.22	0.22	0.12
Minimum	0.11	0.18	0.41
Lower Quartile (25th percentile)	0.62	0.65	0.91
Median	0.74	0.8	0.98
Upper Quartile (75th percentile)	0.86	1	1
Maximum	1	1	1

Notes: GTE = global technical efficiency; LPTE = Local pure technical efficiency; SE = scale efficiency; SD = Standard deviation; Average inefficiency (%) = (1-average efficiency)*100)

Forty-six of the 60 PCRU-15s exhibited inefficiency due to managerial underperformance (i.e., having LPTE < 1) of varying magnitudes. In these PCRU-15s, GTIE stems from both LPTIE and SIE as indicated by the fact that these PCRU-15s have both LPTE and SE scores less than one. Out of these 46 PCRU-15s, 42 have a LPTE score less than the SE score. This phenomenon indicates that the inefficiency in resource utilization in these PCRU-15s is primarily attributed to inefficiency due to managerial underperformance rather than to scale inefficiency.

As observed in Table 15, 14 of the 60 PCRU-15s (Florida State University, Indiana University – Bloomington, Montana State University, Pennsylvania State University, State University of New York – Albany, Texas A & M University, University of Texas – Austin, University of California – Riverside, University of California – Santa Barbara, University of California – Santa Cruz, University of Colorado – Boulder, University of Delaware, University of Michigan – Ann Arbor, and University of Virginia) have local pure technical efficiency since they acquired a LPTE score equal to one. In addition, seven (Florida State University, Indiana University – Bloomington, Texas A & M University, University of California – Santa Barbara, University of Colorado – Boulder, University of Delaware, and University of Virginia) of the 14 PCRU-15s which acquired a LPTE score equal to one were also found to have global technical efficiency since they also acquired a GTE score equal to one. The remaining seven of the 14 PCRU-15s which were found to be efficient under the VRS assumption (i.e., LPTE score equal to one) have not been found to be efficient under the CRS assumption (i.e., CRS score > one). In cases where a PCRU-15 acquires an LPTE score equal to one and a GTE score less than one, the inference can be made that the global technical inefficiency is not caused by managerial underperformance, but rather caused by the operations of the PCRU-15s with inappropriate scale size.

Hypothesis Two Results – Public Carnegie 16 Research Universities

Table 31 provides descriptive statistics derived from the CCR, CRS, BCC-VRS, and SE models for 66 public Carnegie 16 research universities (PCRU-16s) corresponding with baccalaureate degree production. According to LPTE and SE scores for PCRU-16s as a whole, GTIE is due to both managerial underperformance (i.e., poor input utilization) and failure to operate at most productive scale size. The average LPTE score for 66 PCRU-16s is listed in Table 31 as 0.55, which implies that 44.54 percentage points of about 52.59 percent of GTIE is due to local research university managerial decisions to not follow best practice management strategies and selecting incorrect input combinations. In addition, lower means and higher standard deviations of the LPTE scores compared to the SE scores indicate that a greater portion of GTIE (i.e., combined inefficiency due to managerial underperformance and inappropriate size of operations) is due to LPTIE (i.e., inefficiency due to managerial underperformance). Individual GTE, LPTE, and SE scores for PCRU-15s are listed in Appendix C.

Table 31
Descriptive Statistics of Efficiency Scores for Public Carnegie 16 Research Universities: Baccalaureate Degree Production

Statistics	GTE	LPTE	SE
N	66	66	66
Average efficiency	0.47	0.55	0.88
Average inefficiency (%)	52.59	44.54	11.98
SD of average efficiency	0.16	0.2	0.14
Minimum	0.15	0.15	0.3
Lower Quartile (25th percentile)	0.39	0.41	0.85
Median	0.43	0.49	0.93
Upper Quartile (75th percentile)	0.52	0.65	0.97
Maximum	1	1	1

Notes: GTE = global technical efficiency; LPTE = Local pure technical efficiency; SE = scale efficiency; SD = Standard deviation; Average inefficiency (%) = (1-average efficiency)*100)

Sixty-two of the 66 PCRU-16s exhibited inefficiency due to managerial underperformance (i.e., having LPTE < 1) of varying magnitudes. In these PCRU-16s, GTIE stems from both LPTIE and SIE as indicated by the fact that these PCRU-16s have both LPTE and SE scores less than one. Out of these 62 PCRU-16s, 57 have a LPTE score less than the SE score. This phenomenon indicates that the inefficiency in resource utilization in these PCRU-16s is primarily attributed to inefficiency due to managerial underperformance rather than to scale inefficiency.

As observed in Table 17, four of the 66 PCRU-16s (Colorado School of Mines, Northern Illinois University, San Diego State University, and State University of New York – College of Environmental Science and Forestry) have local pure technical efficiency since they acquired a LPTE score equal to one. In addition, two (Northern Illinois University and San Diego State University) of the four PCRU-16s which acquired a LPTE score equal to one were also found to have global technical efficiency since they also acquired a GTE score equal to one. The remaining three of the four PCRU-16s which were found to be efficient under the VRS assumption (i.e., LPTE score equal to one) have not been found to be efficient under the CRS assumption (i.e., CRS score > one). In cases where a PCRU-16 acquires an LPTE score equal to one and a GTE score less than one, the inference can be made that the global technical inefficiency is not caused by managerial underperformance, but rather caused by the operations of the PCRU-16s with inappropriate scale size.

Table 32 provides descriptive statistics derived from the CCR, CRS, BCC-VRS, and SE models for 66 public Carnegie 16 research universities (PCRU-16s) corresponding with graduation rate efficiency. According to LPTE and SE scores for PCRU-16s as a whole, GTIE is due to both managerial underperformance (i.e., poor input utilization) and failure to operate at most productive scale size. The average LPTE score for 66 PCRU-16s is listed in Table 32 as 0.59, which implies that 40.58 percentage points of about 46.8 percent of GTIE is due to local research university managerial decisions to not follow best practice management strategies and selecting incorrect input combinations. In addition, lower mean and higher standard deviation of the LPTE scores compared to the SE scores indicate that a greater portion of GTIE (i.e., combined inefficiency due to managerial underperformance and inappropriate size of operations) is due to LPTIE (i.e., inefficiency due to managerial underperformance). Individual GTE, LPTE, and SE scores for PCRU-16s are listed in Appendix D.

Table 32
Descriptive Statistics of Efficiency Scores for Public Carnegie 16 Research Universities: Graduation Rate Efficiency

Statistics	GTE	LPTE	SE
N	66	66	66
Average efficiency	0.53	0.59	0.91
Average inefficiency (%)	46.8	40.58	9.36
SD of average efficiency	0.21	0.24	0.1
Minimum	0.09	0.11	0.45
Lower Quartile (25th percentile)	0.39	0.41	0.87
Median	0.48	0.53	0.93
Upper Quartile (75th percentile)	0.69	0.78	0.98
Maximum	1	1	1

Notes: GTE = global technical efficiency; LPTE = Local pure technical efficiency; SE = scale efficiency; SD = Standard deviation; Average inefficiency (%) = (1-average efficiency)*100)

Fifty-eight of the 66 PCRU-16s exhibited inefficiency due to managerial underperformance (i.e., having LPTE < 1) of varying magnitudes. In these PCRU-16s, GTIE stems from both LPTIE and SIE as indicated by the fact that these PCRU-16s have both LPTE and SE scores less than one. Out of these 58 PCRU-16s, 55 have a LPTE score less than the SE score. This phenomenon indicates that the inefficiency in resource utilization in these PCRU-16s is primarily attributed to inefficiency due to managerial underperformance rather than to scale inefficiency.

As observed in Table 19, eight of the 66 PCRU-16s (College of William and Mary, Colorado School of Mines, Jackson State University, Miami University – Oxford, Northern Carolina A & T State University, State University of New York – College of Environmental Science and Forestry, University of Central Florida, and Western Michigan University) have local pure technical efficiency since they acquired a LPTE score equal to one. In addition, three (College of William and Mary, Miami University – Oxford, and Western Michigan University) of the eight PCRU-16s which acquired a LPTE score equal to one also have global technical efficiency since they also acquired a GTE score equal to one. The remaining five of the eight PCRU-16s which were found to be efficient under the VRS assumption (i.e., LPTE score equal to one) have not been found to be efficient under the CRS assumption (i.e., CRS score > one). In cases where a PCRU-16 acquires an LPTE score equal to one and a GTE score less than one, the inference can be made that the global technical inefficiency is not caused by managerial underperformance, but rather caused by the operations of the PCRU-16s with inappropriate scale size.

Hypothesis Two Results – Private Non-profit Carnegie 15 Research Universities

Table 33 provides descriptive statistics derived from the CCR, CRS, BCC-VRS, and SE models for 31 private non-profit Carnegie 15 research universities (PNCRU-15s) corresponding with baccalaureate degree production. According to LPTE and SE scores for PNCRU-15s as a whole, GTIE is due to both managerial underperformance (i.e., poor input utilization) and failure to operate at most productive scale size. The average LPTE score for 31 PNCRU-15s is listed in Table 33 as 0.91, which implies that 8.65 percentage points of about 9.48 percent of GTIE is due to local research university managerial decisions to not follow best practice management strategies and selecting incorrect input combinations. In addition, lower mean and higher standard deviation of the LPTE scores compared to the SE scores indicate that a greater portion of GTIE (i.e., combined inefficiency due to managerial underperformance and inappropriate size of operations) is due to LPTIE (i.e., inefficiency due to managerial underperformance). Individual GTE, LPTE, and SE scores for PNCRU-15s are listed in Appendix E.

Table 33
Descriptive Statistics of Efficiency Scores for Private Non-profit Carnegie 15 Research Universities: Baccalaureate Degree Production

Statistics	GTE	LPTE	SE
N	31	31	31
Average efficiency	0.91	0.91	0.99
Average inefficiency (%)	9.48	8.65	0.96
SD of average efficiency	0.09	0.09	0.02
Minimum	0.67	0.68	0.92
Lower Quartile (25th percentile)	0.85	0.85	1
Median	0.92	0.93	1
Upper Quartile (75th percentile)	1	1	1
Maximum	1	1	1

Notes: GTE = global technical efficiency; LPTE = Local pure technical efficiency; SE = scale efficiency; SD = Standard deviation; Average inefficiency (%) = (1-average efficiency)*100)

Twenty of the 31 PNCRU-15s exhibited inefficiency due to managerial underperformance (i.e., having LPTE < 1) of varying magnitudes. In these PNCRU-15s, GTIE stems from both LPTIE and SIE as indicated by the fact that these PNCRU-15s have both LPTE and SE scores less than one. Out of these 20 PNCRU-15s, all 20 have a LPTE score less than the SE score. This phenomenon indicates that the inefficiency in resource utilization in these PNCRU-15s is primarily attributed to inefficiency due to managerial underperformance rather than to scale inefficiency.

As observed in Table 21, 11 of the 31 PNCRU-15s (Boston University, Brandeis University, Brown University, Massachusetts Institute of Technology, New York University, Rensselaer Polytechnic Institute, Rice University, Tufts University, Tulane University of Louisiana, University of Notre Dame, and University of Southern California) were found to have local pure technical efficiency since they acquired a LPTE score equal to one. In addition, 10 of the 11 PNCRU-15s which acquired a LPTE score equal to one also have global technical efficiency since they also acquired a GTE score equal to one. The remaining one (New York University) of 11 PNCRU-15s which was found to be efficient under the VRS assumption (i.e., LPTE score equal to one) had not been found to be efficient under the CRS assumption (i.e., CRS score > one). In cases where a PNCRU-15 acquires an LPTE score equal to one and a GTE score less than one, the inference can be made that the global technical inefficiency is not caused by managerial underperformance, but rather caused by the operations of the PNCRU-15s with inappropriate scale size.

Table 34 provides descriptive statistics derived from the CCR, CRS, BCC-VRS, and SE models for 31 private non-profit Carnegie 15 research universities (PNCRU-15s) corresponding with graduation rate efficiency. According to LPTE and SE scores for PNCRU-15s as a whole, GTIE is due to both managerial underperformance (i.e., poor input utilization) and failure to operate at most productive scale size. The average LPTE score for 31 PNCRU-15s is listed in Table 34 as 0.89, which implies that 10.69 percentage points of about 14.32 percent of GTIE is due to local research university managerial decisions to not follow best practice management strategies and selecting incorrect input combinations. In addition, lower means and higher standard deviations of the LPTE scores compared to the SE scores indicate that a greater portion of GTIE (i.e., combined inefficiency due to managerial underperformance and inappropriate size of operations) is due to LPTIE (i.e., inefficiency due to managerial underperformance). Individual GTE, LPTE, and SE scores for PNCRU-15s are listed in Appendix F.

Nineteen of the 31 PNCRU-15s exhibited inefficiency due to managerial underperformance (i.e., having LPTE < 1) of varying magnitudes. In these PNCRU-15s, GTIE stems from both LPTIE and SIE as indicated by the fact that these PNCRU-15s have both LPTE and SE scores less than one. Out of these 19 PNCRU-15s, 14 have a LPTE score less than the SE score. This phenomenon indicates that the inefficiency in resource utilization in these PNCRU-15s is primarily attributed to inefficiency due to managerial underperformance rather than to scale inefficiency.

Table 34
Descriptive Statistics of Efficiency Scores for Private Non-profit Carnegie 15 Research Universities: Graduation Rate Efficiency

Statistics	GTE	LPTE	SE
N	31	31	31
Average efficiency	0.86	0.89	0.96
Average inefficiency (%)	14.32	10.69	4.31
SD of average efficiency	0.14	0.12	0.06
Minimum	0.58	0.66	0.76
Lower Quartile (25th percentile)	0.73	0.76	0.93
Median	0.89	0.93	0.98
Upper Quartile (75th percentile)	0.99	1	1
Maximum	1	1	1

Notes: GTE = global technical efficiency; LPTE = Local pure technical efficiency; SE = scale efficiency; SD = Standard deviation; Average inefficiency (%) = (1-average efficiency)*100)

As observed in Table 23, 12 of the 31 PNCRU-15s (Boston University, Brandeis University, Brown University, Cornell University, Dartmouth University, Duke University, Princeton University, Rensselaer Polytechnic Institute, Rice University, Stanford University, Tulane University of Louisiana, and University of Notre Dame) have local pure technical efficiency since they acquired a LPTE score equal to one. In addition, six (Boston University, Brandeis University, Dartmouth College, Duke University, Tulane University of Louisiana, and University of Notre Dame) of the 12 PNCRU-15s which acquired a LPTE score equal to one were also found to have global technical efficiency since they also acquired a GTE score equal to one. The remaining six of the 12 PNCRU-15s which were found to be efficient under the VRS assumption (i.e., LPTE score equal to one) had not been found to be efficient under the CRS assumption (i.e., CRS score > one). In cases where a PNCRU-15 acquires an LPTE score equal to one and a GTE score less than one, the inference can be made that the global technical inefficiency is not caused by managerial underperformance, but rather caused by the operations of the PNCRU-15s with inappropriate scale size.

Hypothesis Two Results – Private Non-profit Carnegie 16 Research Universities

Table 35 provides descriptive statistics derived from the CCR, CRS, BCC-VRS, and SE models for 25 private non-profit Carnegie 16 research universities (PNCRU-16s) corresponding with baccalaureate degree production. According to LPTE and SE scores for PNCRU-16s as a whole, GTIE is due to both managerial underperformance (i.e., poor input utilization) and failure to operate at most productive scale size. The average LPTE score for 25 PNCRU-16s is listed in Table 35 as 0.91, which implies that 8.53 percentage points of about 12.34 percent of GTIE is due to local research university managerial decisions to not follow best practice management strategies and selecting incorrect input combinations. In addition, lower mean and higher standard deviation of the LPTE scores compared to the SE scores indicate that a greater portion of GTIE (i.e., combined inefficiency due to managerial underperformance and inappropriate size of operations) is due to LPTIE (i.e., inefficiency due to managerial underperformance). Individual GTE, LPTE, and SE scores for PNCRU-16s are listed in Appendix G.

Seventeen of the 25 PNCRU-16s exhibited inefficiency due to managerial underperformance (i.e., having LPTE < 1) of varying magnitudes. In these PNCRU-16s, GTIE stems from both LPTIE and SIE as indicated by the fact that these PNCRU-16s have both LPTE and SE scores less than one. Out of these 17 PNCRU-16s, 16 have a LPTE score less than the SE score. This phenomenon indicates that the inefficiency in resource utilization in these PNCRU-15s is primarily attributed to inefficiency due to managerial underperformance rather than to scale inefficiency.

Table 35
Descriptive Statistics of Efficiency Scores for Private Non-profit Carnegie 16 Research Universities: Baccalaureate Degree Production

Statistics	GTE	LPTE	SE
N	25	25	25
Average efficiency	0.88	0.91	0.96
Average inefficiency (%)	12.34	8.53	4.04
SD of average efficiency	0.11	0.1	0.06
Minimum	0.62	0.62	0.72
Lower Quartile (25th percentile)	0.8	0.85	0.95
Median	0.9	0.95	0.99
Upper Quartile (75th percentile)	0.97	1	1
Maximum	1	1	1

Notes: GTE = global technical efficiency; LPTE = Local pure technical efficiency; SE = scale efficiency; SD = Standard deviation; Average inefficiency (%) = (1-average efficiency)*100)

As observed in Table 25, eight of the 25 PNCRU-16s (Boston College, Brigham Young University, Clark Atlanta University, Clark University, Clarkson University, Fordham University, Howard University, and Polytechnic University) have local pure technical efficiency since they acquired a LPTE score equal to one. In addition, four (Boston College, Brigham Young University, Clarkson University, and Fordham University) of the eight PNCRU-16s which acquired a LPTE score equal to one were also found to have global technical efficiency since they also acquired a GTE score equal to one. The remaining four of the eight PNCRU-15s which were found to be efficient under the VRS assumption (i.e., LPTE score equal to one) had not been found to be efficient under the CRS assumption (i.e., CRS score > one). In cases where a PNCRU-16 acquires an LPTE score equal to one and a GTE score less than one, the inference can be made that the global technical inefficiency is not caused by managerial underperformance, but rather caused by the operations of the PNCRU-16s with inappropriate scale size.

Table 36 provides descriptive statistics derived from the CCR, CRS, BCC-VRS, and SE models for 25 private non-profit Carnegie 16 research universities (PNCRU-16s) corresponding with graduation rate efficiency. According to LPTE and SE scores for PNCRU-16s as a whole, GTIE is due to both managerial underperformance (i.e., poor input utilization) and failure to operate at most productive scale size. The average LPTE score for 25 PNCRU-16s is listed in Table 36 as 0.86, which implies that 13.53 percentage points of about 18.35 percent of GTIE is due to local research university managerial decisions to not follow best practice management strategies and selecting incorrect input combinations. In addition, lower mean and higher standard deviation of the LPTE scores compared to the SE scores indicate that a greater portion of GTIE (i.e., combined inefficiency due to managerial underperformance and inappropriate size of operations) is due to LPTIE (i.e., inefficiency due to managerial underperformance). Individual GTE, LPTE, and SE scores for PNCRU-15s are listed in Appendix H.

Thirteen of the 25 PNCRU-16s exhibited inefficiency due to managerial underperformance (i.e., having LPTE < 1) of varying magnitudes. In these PNCRU-16s, GTIE stems from both LPTIE and SIE as indicated by the fact that these PNCRU-16s have both LPTE and SE scores less than one. Out of these 13 PNCRU-16s, all 13 have a

LPTE score less than the SE score. This phenomenon indicates that the inefficiency in resource utilization in these PNCRU-16s is primarily attributed to inefficiency due to managerial underperformance rather than to scale inefficiency.

Table 36
Descriptive Statistics of Efficiency Scores for Private Non-profit Carnegie 16 Research Universities: Graduation Rate Efficiency

Statistics	GTE	LPTE	SE
N	25	25	25
Average efficiency	0.82	0.86	0.94
Average inefficiency (%)	18.35	13.53	5.64
SD of average efficiency	0.19	0.18	0.08
Minimum	0.44	0.45	0.72
Lower Quartile (25th percentile)	0.66	0.71	0.91
Median	0.87	0.98	0.98
Upper Quartile (75th percentile)	1	1	1
Maximum	1	1	1

Notes: GTE = global technical efficiency; LPTE = Local pure technical efficiency; SE = scale efficiency; SD = Standard deviation; Average inefficiency (%) = (1-average efficiency)*100)

As observed in Table 27, 12 of the 25 PNCRU-16s (Baylor University, Boston College, Brigham Young University, Clark Atlanta University, Clark University, Clarkson University, Howard University, Lehigh University, Marquette University, Northeastern University, Polytechnic University, and Syracuse University) have local pure technical efficiency since they acquired a LPTE score equal to one. In addition, seven (Baylor University, Boston College, Clark Atlanta University, Clark University, Clarkson University, Howard University, and Lehigh University) of the 12 PNCRU-16s which acquired a LPTE score equal to one were also found to have global technical efficiency since they also acquired a GTE score equal to one. The remaining five of the 12 PNCRU-15s which were found to be efficient under the VRS assumption (i.e., LPTE score equal to one) had not been found to be efficient under the CRS assumption (i.e., CRS score > one). In cases where a PNCRU-16 acquires an LPTE score equal to one and a GTE score less than one, the inference can be made that the global technical inefficiency is not caused by managerial underperformance, but rather caused by the operations of the PNCRU-16s with inappropriate scale size.

CHAPTER 5: DISCUSSION, CONCLUSIONS, AND IMPLICATIONS

As higher education institutions in the U.S. continue to face mounting pressures for more efficient utilization of public-sector resources, a confluence of factors have steered the attention of the higher education community in the U.S. toward an increasing demand for baccalaureate degree attainment. Lingenfelter (2007) notes that such a demand for increased degree attainment in higher education may be due to the perspective that, "unprecedented political, social, and ecological demands on a global scale now confront humanity" (p. 2).

Agency relationships between states and higher education institutions can be described from the three aforementioned perspectives highlighted by Lingenfelter (2007): political, social, and ecological. From the political perspective, "The predominant mode for governance of universities has seemingly shifted from control and regulation to supervision and enforcement of the self-regulative capabilities of the universities" (Kivisto, 2007, p. 1). In addition, the Institute for Higher Education Policy (2006) highlights that, "The imperative is to increase production, quality, and affordability all across the educational pipeline without a substantial new infusion of public revenues" (p. 3). From the social perspective, Katharaki and Katharakis (2010) point out that, "public funding is becoming increasingly diluted, particularly as competition increases from other public funds such as healthcare" (p. 115). From an ecological perspective, degree attainment fits into a chain of successes that help individuals to achieve a more productive and healthful life. In what some refer to as the "information age" or the "knowledge economy," it is becoming clear that individuals must become more educated in order to compete intellectually and financially in an interconnected global environment.

In comparison to educational attainment in other countries, Jones notes (2007), “As other countries show consistent decade-to-decade progress in enhancing the education levels of their adult populations, the U.S. has been stuck at essentially the same level for 30 years” (p. vi). However, clear pathways for higher education institutions to collectively increase baccalaureate degree attainment remain unclear.

This study was designed to examine resource utilization vis a vis global, local pure technical, and scale efficiency scores of public and private non-profit Carnegie 15 (very high research activity) and Carnegie 16 (high research activity) research universities across the U.S. for the academic year 2007-08. Utilizing Agency Theory as a heuristic framework and data envelopment analysis (DEA) as an analytic strategy, results from this study shed light on three key areas of limited higher education research: 1) efficiency of efforts to increase degree production versus graduation rates; 2) efficiency of utilization of resources (education and general expenditures, total revenue from the state and local appropriations, total number of undergraduate student, total number of academic support staff, and total number of faculty); and 3) sources of inefficient resource utilization.

Baccalaureate Degree Production versus Graduation Rate Efficiency

Hypothesis one was designed to assess whether or not, on average, the magnitude of local pure technical efficiency (LPTE) (i.e., inefficiencies directly resulting from managerial decision making) scores for research universities were greater when resource utilization was measured against maximization of baccalaureate degree production, or when resource utilization was measured against maximization of graduation rate efficiency.

Within the context of agency theory, this hypothesis helped to examine goal conflict between educational goals of states (i.e., baccalaureate degree production) and those of research universities (i.e., graduation rate efficiency). Comparing resource utilization of these two goals separately allowed for a comparison of managerial underperformance of research universities in relation to goals of maximizing baccalaureate degree production and increases in graduation rate efficiency. Utilizing data envelopment analysis to assess managerial decision making of research universities (i.e., local pure technical efficiency), allows for better assessment of what Kivisto (2007) refers to as a, “shift in government-university relationships from control and regulation to supervision and enforcement of the self-regulative capabilities of the universities (p. 1).

As observed in Table 37, the results for public Carnegie 15 research universities (PCRU-15s), on average, show that resource utilization is better when measured against baccalaureate degree production than against graduation rate efficiency as indicated by LPTIE scores for all public Carnegie 15 research universities (PCRU-15s) corresponding with baccalaureate degree production (LPTIE % = 14.22) and graduation rate efficiency (LPTIE % = 22.65). The results for public Carnegie 16 research universities (PCRU-16s), on average, show that resource utilization is better when measured against graduation rate efficiency than against baccalaureate degree production as indicated by LPTIE scores for public Carnegie 16 research universities (PCRU-16s) corresponding with baccalaureate degree production (LPTIE % = 44.54) and graduation rate efficiency (LPTIE % = 40.58).

Table 37

Summary of Results from Hypothesis One: Local Pure Technical Efficiency

	Baccalaureate Degree Production			Graduation Rate Efficiency		
Carnegie Classification	LPTE Efficient (%)	Average LPTE	Average LPTIE (%)	LPTE Efficient (%)	Average LPTE	Average LPTIE (%)
Public						
Carnegie 15	20	0.86	14.22	23.33	0.77	22.65
Carnegie 16	6	0.55	44.54	12	0.59	40.58
Private						
Carnegie 15	35	0.91	8.65	39	0.89	10.69
Carnegie 16	32	0.91	8.53	48	0.86	13.53

Notes: LPTE = Local pure technical efficiency; LPTIE = Local pure technical inefficiency (=1-LPTE)*100)

Comparing the magnitude of LPTIE scores for private non-profit Carnegie 15 research universities (PNCRU-15s) corresponding with baccalaureate degree production (LPTIE %= 8.65) and graduation rate efficiency (LPTIE %= 10.69), results indicate that managerial decisions for PNCRU-15s, on average, are such that resource utilization is better when measured against baccalaureate degree production than against graduation rate efficiency. Consistent with private non-profit Carnegie 15 research universities, the magnitude of LPTIE scores for private non-profit Carnegie 16 research universities (PNCRU-16s) corresponding with baccalaureate degree production (LPTIE %= 8.53) and graduation rate efficiency (LPTIE %= 13.53), results indicate that managerial decisions for PNCRU-16s, on average, are such that resource utilization is better when measured against baccalaureate degree production than against graduation rate efficiency.

Of the four types of research universities, only PCRU-16s (i.e., public Carnegie research universities with high research activity) exhibited managerial decision making behavior that was more favorable to graduation rate efficiency than for baccalaureate degree production. While all research universities have room for improvement in terms of managerial decisions to better utilize resources to reduce input utilization and maximize outputs, on average, managerial decisions of PNCRU-16s (i.e., private non-profit Carnegie research universities with high research activity) were best aligned with baccalaureate degree production. In addition, of all of the sets of Carnegie public and private research universities, on average, managerial decisions of PNCRU-15s (i.e., private non-profit Carnegie research universities with very high research activity) were best aligned with graduation rate efficiency.

Areas for Efficiency Improvement

In addition to assessment of managerial decision making of research universities, data envelopment analysis also allows for analyses of targeted areas for improvement. Considering changes in levels of autonomy and self-regulative capabilities of universities that "have been characterized by delegation and a shift from hierarchical, authority-based governance structures to contractual, exchange-base governance structures" (Kavisto, 2007, p. 1), states must determine not only appropriate levels of financial support for higher education but also the degree to which such financial support impacts degree attainment. By utilizing data envelopment analysis to estimate targeted areas for improvement for research universities, results of this study call attention to the complex nature of resource utilization and the impacts of scale effects. In essence, increases in state financial support for higher education institutions may not always translate to a proportional increase in desired outcomes (e.g., increased degree production). Thus, increasing state funding for research universities or increasing faculty to improve faculty to student ratio, may not equate to improvements in baccalaureate degree production or graduation rates.

As presented in Table 38, measures of efficiency slacks (i.e., the difference between an observed input value of a research university and the calculated efficiency target input needed for that input to be considered technically efficient) indicate considerable differences in areas for performance improvements across public and private non-profit Carnegie 15 (very high research activity) and Carnegie 16 (high research activity) research universities. Measures of efficiency slacks and targets indicate that public Carnegie 15 research universities have more room for improvement when attempting to increase graduation rate efficiency (slack output addition % = 51.34) than for maximizing baccalaureate degree production (slack output addition % = 27.90). Comparing resource utilization among public Carnegie 15 research universities when measured against baccalaureate degree production, total undergraduate students was the most efficiently utilized resource and the total number of executive, and managerial administrative staff was the least efficiently utilized resource. When measured against graduation rate efficiency, total undergraduate students was the most efficiently utilized resource and revenue from state and local appropriations was the least efficiently utilized resource.

Measures of efficiency slacks and targets indicate that public Carnegie 16 research universities have slightly more room for improvement when attempting to increase graduation rate efficiency (slack output addition % = 105.70) than for maximizing baccalaureate degree production (slack output addition % = 103.86). Comparing resource utilization among public Carnegie 16 research universities when measured against baccalaureate degree production, revenue from state and local appropriations was the most efficiently utilized resource, and total education and general expenditures was the least efficiently utilized resource. When measured against graduation rate efficiency, total undergraduate students is the most efficiently utilized resource, and revenue from state and local appropriations is the least efficiently utilized resource.

Table 38

Summary of Results from Hypothesis One: Slacks

Carnegie Classification	Slack % (input reduction) x1	x2	x3	x4	x5	Slack % (output addition) y1/y2
Public						
Carnegie 15: baccalaureate degree production	-12.75	-17.72	-0.64	-16.39	-14.26	27.90
Carnegie 15: graduation rate efficiency	-30.4	-13	-1.99	-12.5	-12.6	51.34
Carnegie 16: baccalaureate degree production	-13.87	-28.36	-18.20	-22.05	-17.37	103.86
Carnegie 16: graduation rate efficiency	-35.94	-15.90	-5.38	-17.90	-10.72	105.70
Private Non-profit						
Carnegie 15: baccalaureate degree production	-24.40	-22.42	-0.01	-26.75	-11.82	10.55
Carnegie 15: graduation rate efficiency	-16.48	-17.69	-0.41	-13.20	-22.86	14.05
Carnegie 16: baccalaureate degree production	-16.67	-17.02	0.00	-17.74	-19.79	10.82
Carnegie 16: graduation rate efficiency	-5.45	-12.01	-0.31	-15.85	-12.89	22.19

Notes: x1 =state09_div100000, x2 =eandg01_div100000, x3 =total_undergraduates, x4 =total_executive_admin_managerial_w_other_professionals, x5 =total_faculty_all, y1 =BACHELORDEGREES; y2 =GRAD_RATE_150_n4YR

Measures of efficiency slacks and targets indicate that private non-profit Carnegie 15 research universities have more room for improvement when attempting to increase graduation rate efficiency (slack output addition % = 14.05) than for maximizing baccalaureate degree production (slack output addition % = 10.55). Comparing resource utilization among private non-profit Carnegie 15 research universities when measured against baccalaureate degree completion, total undergraduate students was the most efficiently utilized resource, and total executive and managerial administrative staff was the least efficiently utilized resource. When measured against graduation rate efficiency, total undergraduate students was the most efficiently utilized resource, and total faculty was the least efficiently utilized resource.

Measures of efficiency slacks and targets indicate that private non-profit Carnegie 16 research universities have more room for improvement when attempting to increase graduation rate efficiency (slack output addition % = 22.19) than for maximizing baccalaureate degree production (slack output addition % = 10.82). Comparing resource utilization among private non-profit Carnegie 16 research universities when measured against baccalaureate degree production, total undergraduate students was the most efficiently utilized resources, and total faculty was the least efficiently utilized resource. When measured against graduate rate efficiency, total undergraduate students was the most efficiently utilized resource, and total executive and managerial administrative staff was the least efficiently utilized resource.

Source of Inefficiencies

While scholars have speculated about various reasons higher education institutions might be operating inefficiently, very few studies have investigated the potential source of inefficiency, whether it is the end result of poor managerial decisions to efficiently utilize resources (i.e., local pure technical inefficiency), or failure to operate at the most productive scale size (i.e., scale inefficiency). To better understand the potential source of inefficiency a Banker, Charnes, and Cooper (1984) model under the variable return to scale assumption was used to measure managerial underperformance for research universities (i.e., local pure technical inefficiency), and a Charnes, Cooper, and Rodes (1978) model under the constant return to scale assumption was used to measure total inefficiency (i.e., global technical efficiency) due to both managerial underperformance and failure to operate a most productive scale size. The resulting efficiency scores were global technical efficiency (GTE), local pure technical efficiency (LPTE), and scale efficiency (SE). In addition, a measure of the magnitude of inefficiency (i.e., (1 – average efficiency score) * 100) was calculated and used to explain differences and input utilization and output maximization. According to the GTE, LPTE, and SE scores for all Carnegie 15 (very high research activity) and 16 (high research activity) public and private non-profit research universities scores listed in Table 39, overall technical inefficiency for all sets of research universities is primarily attributed to managerial decisions rather than failure to operate at most productive scale size except for private non-profit Carnegie 15 research universities (as indicated by LPTE > GTE efficiency scores).

Table 39

Summary of Results from Hypothesis Two: Efficiency Scores

Carnegie Classification	GTE	LPTE	SE
Public			
Carnegie 15 Average: baccalaureate degree production	0.81	0.86	0.94
Carnegie 15 Average: graduation rate efficiency	0.72	0.77	0.92
Carnegie 16 Average: baccalaureate degree production	0.47	0.55	0.88
Carnegie 16 Average: graduation rate efficiency	0.53	0.59	0.91
Private Non-profit			
Carnegie 15 Average: baccalaureate degree production	0.91	0.91	0.99
Carnegie 15 Average: graduation rate efficiency	0.86	0.86	0.96
Carnegie 16 Average: baccalaureate degree production	0.88	0.91	0.96
Carnegie 16 Average: graduation rate efficiency	0.82	0.86	0.94

Notes: GTE = global technical efficiency; LPTE = Local pure technical efficiency; SE = scale efficiency

Delimitations

While the institutional selection process used for this study included both public and private four-year and above research universities, the population of interest was not inclusive of all of the various Carnegie classifications of higher education institutions. Using the Carnegie 2005 classifications to categorize a homogenous set of universities, this study included only data on research universities classified as Carnegie 15 (very high research activities) and 16 (high research activity) for the year 2007/08. This study was focused on universities with identified “research” missions, as opposed to those with technical, liberal arts, or comprehensive missions.

While this study did capture cohorts of first-time full-time students based on the output variable GRAD_RATE_150_n4YR, and all undergraduate student based on output variable BACHELORDEGREES, it did not include input variables indicative of the degree to which an institution served unique populations of students. That is to say there was not an input variable that captured data on the percentage of first-time full-time students or part-time students attending a particular university. Such nuances of higher education institutional configuration were excluded because managerial decisions to serve unique populations of students, meet specific needs of constituents, and/or better align institutional operations with institutional mission, are all ultimately still unique managerial decisions that can be managed locally. However, complex issues related to the process of choosing a desirable mix of inputs and outputs in data envelopment analysis models deserve further study. By and large, there is no consensus on what constitutes key performance inputs or outputs across research universities.

Limitations of the Study

As with many analytical strategies, the research design for this study comes with its limitations. While data envelopment analysis (DEA) allows for the assessment of relative efficiencies of universities with varying incommensurate inputs and outputs, there are a couple of issues and assumptions identified by Dyson (2001) that are worth noting. The first issue is related to homogeneity assumptions. In essence, DEA assumes, “the units are assumed to be undertaking similar activities and producing comparable products or services so that a common set of outputs can be defined” (p. 247), and “there is an unwritten assumption that the units are operating in similar environments, since the external environment generally impacts upon the overall performance of units” (p. 247). While this study attempted to avoid violating homogeneity assumptions by selecting 2005 Carnegie classifications as a predetermined grouping variable, further investigation into the rigor of Carnegie classification assignment is warranted.

Second, the selection of the input and output set is a less-than-empirical process. Best stated by Robbins, Davis, Davis, Lauver, Langley, and Carlstrom (2004) "Conceptual confusion occurs when defining college success and its determinants" (p. 261). One reason for ambiguity of relative contributions of factors related to student success is that “researchers have used a variety of theoretical and methodological approaches to examine the problem" (Perna, 2006, p. 100). For this study, at the suggestion of Katharaki and Katharakis (2010), “The indicators best suited to gauge the performance of a university should be problem-oriented and policy relevant” (p. 117). In addition, Katharaki and Katharakis (2010) also suggest that performance indicators regarding higher education should have the following characteristics, they should, “comply with the mission of the university, be specific, quantifiable and standardized, and be simple and consistent with the activities for that they will be a reference for a decision” (p. 117).

Policy Implications and Opportunities for Future Research

The long history of research on college student success includes a vast body of literature on retention and graduation rates vis a vis completion of the baccalaureate degree. For decades, most of that literature focused entirely on how student characteristics at entry (e.g., high school rank, standardized test scores, etc.) predict retention and graduation rates for institutions. Subsequently, more recent research has examined how student’s participation in certain activities (e.g., first-year experience) affects a students’ probability of completing a baccalaureate degree. In spite of several decades of research, statistics indicate that graduation rates have changed relatively little. Perhaps researchers are looking in the wrong places to help solve the graduation rate dilemma. An alternative approach is to step back from a study focused on student characteristics and institutional experiences to a study of the institutions themselves. That was the purpose for the research summarized in this dissertation.

The aim of this study was to utilize the principal-agent model as a heuristic framework and data envelopment analysis (DEA) as an analytical framework to examine relative inefficiencies of public and private non-profit four-year or above research universities in the United States. Results from various data envelopment output-oriented models were used to shed light on relative efficiencies of universities. In spite of reservations related to utilizing DEA as an assessment tool for higher education universities in the U.S., the results of this study help to better understand key ideas related to efficiency, utilization of resources, and alternative models for assessing universities across states.

Findings from this study point to a number of noteworthy policy implications and identify interesting areas for future empirical inquiry. The first finding is related to assessment of utilization resources measured against independent “desirable” outputs (i.e., baccalaureate degree production and graduation rate efficiency). Even if the assumption of Jones and Kelly (2007) that institutional measures to protect or increase graduation rates by limiting the enrollment of “non-traditional, high-risk students” (p. 5) is true, that does not translate to institutions making managerial decisions to reduce overall enrollment of baccalaureate students, nor does it mean that the mix of the undergraduate student body is a key area of improvement for research universities.

Another noteworthy opportunity for further research relates to the assignment of Carnegie classifications and the process through which these classifications are determined. How different are universities with “very high research activity” or “high research activity” classifications from universities with other Carnegie classifications? Should these institutions be measured differently? While there are several notable differences between Carnegie 15/16 public and private non-profit research universities, results were such that efficiency scores for public Carnegie 16 research universities appeared to be lower than all other sets of research universities.

Considering the claim from the Institute for Higher Education Policy (IHEP) (2006), “The imperative is to increase production, quality, and affordability all across the educational pipeline without a substantial new infusion of public revenues” (p. 3), it seems that the environment of higher education research is ripe with similar truisms that leave many of us admiring a plethora of truly exceptional but not necessarily unique problems. As with many organizations, the goal is to find ways to produce more of a better product with the resources available. When all managerial decisions have been made, as eloquently stated by Adelman (2006):

> The core question is not about basic “access” to higher education. It is not about persistence to the second term or the second year following postsecondary entry. It is about completion of academic credentials—the culmination of opportunity, guidance, choice, effort, and commitment. (p. xv)

Finally, this study suggests that DEA could serve as an analytic strategy for assessing accountability of U.S. higher educational institutions. DEA is shown to be a promising alternative for assessing resource utilization for the purpose of maximizing desired outputs during times of scare resources. Furthermore, consistent with findings from Katharaki and Katharakis (2010), “this analysis could be provided to policy and decision makers to highlight which universities are using resources efficiently, and which steps should be taken by inefficient universities in order to more effectively manage their resources” (p. 127).

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Appendix A: Overall GTE, LPTE, and SE scores for public Carnegie 15 research universities: Baccalaureate degree production

DMU	Name	GTE	GTIE (%)	LPTE	LPTIE (%)	SE	SIE (%)
DMU 1	Arizona State University at the Tempe Campus	1.00	0.00	1.00	0.00	1.00	0.00
DMU 7	Colorado State University	0.96	3.72	1.00	0.00	0.96	3.72
DMU 13	Florida State University	1.00	0.00	1.00	0.00	1.00	0.00
DMU 15	Georgia Institute of Technology-Main Campus	0.73	27.26	0.96	3.62	0.75	24.53
DMU 17	Indiana University-Bloomington	0.78	22.34	0.78	21.90	0.99	0.56
DMU 18	Iowa State University	0.79	20.82	0.79	20.57	1.00	0.32
DMU 20	Kansas State University	0.75	25.21	0.79	20.95	0.95	5.39
DMU 21	Louisiana State University and Agricultural & Mechanical College	0.73	27.26	0.73	26.63	0.99	0.86
DMU 23	Michigan State University	0.84	16.07	0.85	14.68	0.98	1.62
DMU 24	Montana State University	0.76	23.74	1.00	0.00	0.76	23.74
DMU 26	North Carolina State University at Raleigh	0.71	29.41	0.71	29.12	1.00	0.41
DMU 28	Ohio State University-Main Campus	0.72	27.99	0.80	20.20	0.90	9.76
DMU 29	Oregon State University	0.80	20.13	0.90	10.24	0.89	11.01
DMU 30	Pennsylvania State University-Main Campus	0.78	21.90	1.00	0.00	0.78	21.90
DMU 32	Purdue University-Main Campus	0.73	27.41	0.73	26.97	0.99	0.61
DMU 36	Stony Brook University	0.78	21.52	0.84	16.02	0.93	6.56
DMU 37	SUNY at Albany	0.86	14.05	1.00	0.00	0.86	14.05
DMU 38	SUNY at Buffalo	0.82	18.08	0.84	15.64	0.97	2.90
DMU 39	Texas A & M University	0.86	13.88	0.86	13.81	1.00	0.08
DMU 40	The University of Tennessee	0.61	38.57	0.63	37.35	0.98	1.94
DMU 41	The University of Texas at Austin	0.66	34.33	1.00	0.00	0.66	34.33
DMU 44	University of Alabama at Birmingham	0.64	36.45	0.98	1.55	0.65	35.45
DMU 45	University of Arizona	0.71	28.91	0.72	27.63	0.98	1.77
DMU 46	University of California-Berkeley	1.00	0.00	1.00	0.00	1.00	0.00
DMU 47	University of California-Davis	0.88	12.10	0.88	12.05	1.00	0.06
DMU 48	University of California-Irvine	0.89	11.43	0.89	10.54	0.99	1.00
DMU 49	University of California-Los Angeles	0.97	3.22	0.98	2.15	0.99	1.09
DMU 50	University of California-Riverside	0.91	8.65	1.00	0.00	0.91	8.65
DMU 51	University of California-San Diego	0.87	12.87	0.87	12.75	1.00	0.14
DMU 52	University of California-Santa Barbara	1.00	0.00	1.00	0.00	1.00	0.00
DMU 53	University of California-Santa Cruz	0.94	6.42	1.00	0.00	0.94	6.42
DMU 54	University of Cincinnati-Main Campus	0.53	46.98	0.53	46.57	0.99	0.77
DMU 55	University of Colorado at Boulder	1.00	0.00	1.00	0.00	1.00	0.00

DMU 56	University of Colorado Denver	0.57	43.10	0.76	24.28	0.75	24.85
DMU 57	University of Connecticut	0.82	18.17	0.82	17.78	1.00	0.47
DMU 58	University of Delaware	0.85	15.05	0.93	6.84	0.91	8.81
DMU 59	University of Florida	0.91	8.68	0.94	5.82	0.97	3.03
DMU 60	University of Georgia	0.93	7.42	0.94	5.93	0.98	1.58
DMU 61	University of Hawaii at Manoa	0.80	20.21	0.93	6.68	0.86	14.50
DMU 62	University of Illinois at Chicago	0.84	16.12	0.96	4.40	0.88	12.26
DMU 63	University of Iowa	0.79	21.45	0.79	21.13	1.00	0.42
DMU 64	University of Kansas	0.71	29.25	0.71	28.75	0.99	0.71
DMU 65	University of Kentucky	0.73	26.72	0.74	25.84	0.99	1.19
DMU 66	University of Maryland-College Park	0.90	9.88	0.92	8.11	0.98	1.92
DMU 68	University of Michigan-Ann Arbor	0.88	12.28	0.89	10.80	0.98	1.67
DMU 69	University of Minnesota-Twin Cities	0.74	26.46	0.77	23.11	0.96	4.36
DMU 70	University of Missouri-Columbia	0.73	26.54	0.81	19.35	0.91	8.91
DMU 71	University of Nebraska-Lincoln	0.69	31.09	0.69	30.91	1.00	0.25
DMU 72	University of New Mexico-Main Campus	0.43	57.29	0.49	50.57	0.86	13.61
DMU 73	University of North Carolina at Chapel Hill	0.83	16.62	0.88	11.68	0.94	5.60
DMU 76	University of Pittsburgh-Pittsburgh Campus	0.82	17.73	0.83	17.37	1.00	0.43
DMU 78	University of South Carolina-Columbia	0.78	22.37	0.79	21.48	0.99	1.13
DMU 79	University of South Florida	0.95	5.03	0.99	0.68	0.96	4.38
DMU 81	University of Utah	0.84	16.15	0.84	15.52	0.99	0.74
DMU 82	University of Virginia-Main Campus	0.88	12.27	0.95	4.88	0.92	7.77
DMU 83	University of Washington-Seattle Campus	0.92	7.52	0.95	4.88	0.97	2.77
DMU 84	University of Wisconsin-Madison	0.77	22.71	0.79	20.82	0.98	2.38
DMU 86	Virginia Polytechnic Institute and State University	0.85	15.37	0.85	14.66	0.99	0.83
DMU 87	Washington State University	0.90	9.53	0.91	8.91	0.99	0.69
DMU 89	Wayne State University	0.49	51.35	0.49	50.96	0.99	0.79

Notes: GTE =global technical efficiency, GTIE(%) =global technical inefficiency=(1-GTE)*100, LPTE =local pure technical efficiency, LPTIE(%) =local pure technical inefficiency=(1-LPTE)*100, SE =scale efficiency, SIE(%)= scale inefficiency=(1-SE)*100

Appendix B: Overall input/output slacks for public Carnegie 15 research universities: baccalaureate degree production

	Input Reduction					Output Addition
	Slack %					Slack %
Name	x1	x2	x3	x4	x5	y1
Arizona State University at the Tempe Campus	0	0	0	0	0	0
Colorado State University	0	-15.41	-13.68	-73.78	0	3.86
Florida State University	0	0	0	0	0	0
Georgia Institute of Technology-Main Campus	-14.63	-12.73	0	-20.85	-15.12	37.48
Indiana University-Bloomington	0	-6.08	0	-27.4	0	28.76
Iowa State University	-7.61	-5.32	0	0	-37.84	26.3
Kansas State University	0	0	0	-20.93	0	33.71
Louisiana State University and Agricultural & Mechanical College	-21.92	-13.08	0	-11.32	0	37.48
Michigan State University	0	-22.63	0	-29.05	0	19.14
Montana State University	0	-4.21	-5.92	-32.85	0	31.13
North Carolina State University at Raleigh	-39.97	-21.61	0	0	-15	41.66
Ohio State University-Main Campus	-5.3	-15.78	0	-21.27	0	38.87
Oregon State University	-18.28	-8.31	0	0	-16.2	25.2
Pennsylvania State University-Main Campus	0	-18.45	0	-43.36	0	28.05
Purdue University-Main Campus	0	-14.28	0	0	-33.21	37.77
Stony Brook University	-60.7	-34.99	0	0	-37.78	27.43
SUNY at Albany	-52.53	-19.99	0	0	-17.34	16.34
SUNY at Buffalo	-53.79	-26.29	0	0	-41.32	22.07
Texas A & M University	-36	-30.56	0	0	-3.35	16.11
The University of Tennessee	-39.58	-17.03	0	0	-18.46	62.78
The University of Texas at Austin	-16.49	-18.22	0	-21.54	0	52.29
University of Alabama at Birmingham	-40.28	-55.64	0	-43.77	0	57.35
University of Arizona	-8.99	-10.1	0	-40.21	0	40.66
University of California-Berkeley	0	0	0	0	0	0
University of California-Davis	-7.73	-8.65	0	0	-3.64	13.76
University of California-Irvine	0	-27.84	0	-21.99	-24.16	12.91
University of California-Los Angeles	-16.66	-33.49	0	-24.14	-10.49	3.33
University of California-Riverside	0	-3.35	0	0	-20.43	9.46
University of California-San Diego	0	-29.31	0	-30.7	-0.84	14.77
University of California-Santa Barbara	0	0	0	0	0	0
University of California-Santa Cruz	0	0	0	-17.79	0	6.86
University of Cincinnati-Main Campus	0	0	0	-22.4	-21.54	88.62
University of Colorado at Boulder	0	0	0	0	0	0
University of Colorado Denver	-5.85	-51.72	0	0	-72.64	75.74
University of Connecticut	-16.17	-5.41	0	0	-2.45	22.21
University of Delaware	0	-21.37	0	-13.71	0	17.71
University of Florida	-48.54	-23.28	0	0	-23.59	9.5
University of Georgia	-17.76	0	0	-10.2	-4.51	8.01

University of Hawaii at Manoa	-45.62	-34.39	0	0	-25.83	25.34
University of Illinois at Chicago	0	-29.1	0	-46.41	-32.58	19.22
University of Iowa	0	-11.35	0	-35.98	-13.81	27.32
University of Kansas	0	-8.2	0	-12.82	-19.11	41.35
University of Kentucky	-22.87	-20.79	0	-19.6	0	36.46
University of Maryland-College Park	-32.73	-26.05	0	0	-38.47	10.96
University of Michigan-Ann Arbor	0	-53.95	0	-57.41	-43.32	14
University of Minnesota-Twin Cities	-15	-17.33	0	0	-15.79	35.98
University of Missouri-Columbia	0	0	0	-32.29	-21.24	36.12
University of Nebraska-Lincoln	0	0	0	0	-7.32	45.11
University of New Mexico-Main Campus	-3.75	0	-3.13	-13.83	0	134.16
University of North Carolina at Chapel Hill	-34.4	-32.45	0	0	-15.53	19.94
University of Pittsburgh-Pittsburgh Campus	0	-53.56	0	-63.39	-35.94	21.55
University of South Carolina-Columbia	0	-10.16	0	-27.83	0	28.81
University of South Florida	-39.95	0	-15.56	0	0	5.3
University of Utah	-9.3	-35.03	0	0	-7.97	19.26
University of Virginia-Main Campus	0	-50.39	0	-47.75	-36.11	13.99
University of Washington-Seattle Campus	0	-43.71	0	-54.74	-19.22	8.13
University of Wisconsin-Madison	0	-32.62	0	-42.57	-29.31	29.38
Virginia Polytechnic Institute and State University	-6.43	-11.58	0	0	-48.47	18.17
Washington State University	-13.3	-8.64	0	0	-25.9	10.54
Wayne State University	-12.73	-9.04	0	-1.48	0	105.54

Notes: x1 =state09_div100000, x2 =eandg01_div100000, x3 =total_undergraduates, x4 =total_executive_admin_managerial_w_other_professionals, x5 =total_faculty_all, y1 =BACHELORDEGREES; y2 =GRAD_RATE_150_n4YR

Appendix C: Overall GTE, LPTE, and SE scores for public Carnegie 15 research universities: Graduation rate efficiency

DMU	Name	GTE	GTIE (%)	LPTE	LPTIE (%)	SE	SIE (%)
DMU 1	Arizona State University at the Tempe Campus	0.72	28.24	0.72	28.22	1.00	0.03
DMU 7	Colorado State University	0.85	14.73	0.86	14.16	0.99	0.67
DMU 13	Florida State University	1.00	0.00	1.00	0.00	1.00	0.00
DMU 15	Georgia Institute of Technology-Main Campus	0.76	24.17	1.00	0.47	0.76	23.81
DMU 17	Indiana University-Bloomington	1.00	0.00	1.00	0.00	1.00	0.00
DMU 18	Iowa State University	0.81	19.02	0.81	18.80	1.00	0.27
DMU 20	Kansas State University	0.70	29.66	0.71	28.68	0.99	1.38
DMU 21	Louisiana State University and Agricultural & Mechanical College	0.79	20.63	0.80	20.00	0.99	0.78
DMU 23	Michigan State University	0.86	13.88	0.92	8.21	0.94	6.18
DMU 24	Montana State University	0.63	37.34	1.00	0.00	0.63	37.34
DMU 26	North Carolina State University at Raleigh	0.64	35.62	0.65	35.10	0.99	0.80
DMU 28	Ohio State University-Main Campus	0.61	38.54	0.74	25.70	0.83	17.28
DMU 29	Oregon State University	0.73	27.46	0.79	20.78	0.92	8.43
DMU 30	Pennsylvania State University-Main Campus	0.86	14.31	1.00	0.00	0.86	14.31
DMU 32	Purdue University-Main Campus	0.81	18.96	0.87	12.66	0.93	7.21
DMU 36	Stony Brook University	0.58	42.11	0.61	39.03	0.95	5.05
DMU 37	SUNY at Albany	0.75	24.59	1.00	0.00	0.75	24.59
DMU 38	SUNY at Buffalo	0.62	37.91	0.62	37.68	1.00	0.38
DMU 39	Texas A & M University	1.00	0.00	1.00	0.00	1.00	0.00
DMU 40	The University of Tennessee	0.53	47.13	0.59	41.50	0.90	9.63
DMU 41	The University of Texas at Austin	0.41	59.30	1.00	0.00	0.41	59.30
DMU 44	University of Alabama at Birmingham	0.28	71.71	0.53	46.96	0.53	46.67
DMU 45	University of Arizona	0.64	35.72	0.66	34.08	0.98	2.49
DMU 46	University of California-Berkeley	0.72	27.74	0.77	23.07	0.94	6.07
DMU 47	University of California-Davis	0.88	12.48	0.93	7.01	0.94	5.89
DMU 48	University of California-Irvine	0.84	15.83	0.85	14.68	0.99	1.35
DMU 49	University of California-Los Angeles	0.79	20.59	0.84	15.97	0.95	5.49
DMU 50	University of California-Riverside	0.95	4.58	1.00	0.00	0.95	4.58
DMU 51	University of California-San Diego	0.90	9.80	0.94	6.04	0.96	4.01
DMU 52	University of California-Santa Barbara	1.00	0.00	1.00	0.00	1.00	0.00
DMU 53	University of California-Santa Cruz	1.00	0.48	1.00	0.00	1.00	0.48

DMU 54	University of Cincinnati-Main Campus	0.31	68.60	0.32	68.42	0.99	0.55
DMU 55	University of Colorado at Boulder	1.00	0.00	1.00	0.00	1.00	0.00
DMU 56	University of Colorado Denver	0.11	88.70	0.18	82.37	0.64	35.92
DMU 57	University of Connecticut	0.79	20.81	0.79	20.62	1.00	0.23
DMU 58	University of Delaware	1.00	0.00	1.00	0.00	1.00	0.00
DMU 59	University of Florida	0.87	13.40	0.95	5.06	0.91	8.78
DMU 60	University of Georgia	0.77	22.91	0.78	21.60	0.98	1.68
DMU 61	University of Hawaii at Manoa	0.37	62.99	0.42	57.56	0.87	12.78
DMU 62	University of Illinois at Chicago	0.75	25.24	0.97	3.07	0.77	22.87
DMU 63	University of Iowa	0.74	26.16	0.74	25.68	0.99	0.64
DMU 64	University of Kansas	0.67	32.96	0.67	32.63	1.00	0.48
DMU 65	University of Kentucky	0.64	36.12	0.64	35.84	1.00	0.44
DMU 66	University of Maryland-College Park	0.72	27.53	0.73	26.72	0.99	1.11
DMU 68	University of Michigan-Ann Arbor	0.95	5.14	1.00	0.00	0.95	5.14
DMU 69	University of Minnesota-Twin Cities	0.57	43.04	0.65	35.20	0.88	12.11
DMU 70	University of Missouri-Columbia	0.52	48.07	0.64	36.09	0.81	18.75
DMU 71	University of Nebraska-Lincoln	0.71	28.59	0.72	28.39	1.00	0.28
DMU 72	University of New Mexico-Main Campus	0.30	69.70	0.35	64.56	0.85	14.51
DMU 73	University of North Carolina at Chapel Hill	0.91	8.89	0.93	6.86	0.98	2.19
DMU 76	University of Pittsburgh-Pittsburgh Campus	0.81	18.69	0.82	18.19	0.99	0.61
DMU 78	University of South Carolina-Columbia	0.74	25.78	0.74	25.60	1.00	0.24
DMU 79	University of South Florida	0.54	46.18	0.54	46.11	1.00	0.13
DMU 81	University of Utah	0.27	72.70	0.27	72.52	0.99	0.66
DMU 82	University of Virginia-Main Campus	1.00	0.00	1.00	0.00	1.00	0.00
DMU 83	University of Washington-Seattle Campus	0.63	37.25	0.70	29.87	0.89	10.53
DMU 84	University of Wisconsin-Madison	0.81	18.92	0.89	11.13	0.91	8.77
DMU 86	Virginia Polytechnic Institute and State University	0.99	1.31	1.00	0.49	0.99	0.83
DMU 87	Washington State University	0.56	44.17	0.56	44.04	1.00	0.24
DMU 89	Wayne State University	0.18	81.73	0.18	81.64	1.00	0.48

Notes: GTE =global technical efficiency, GTIE(%) =global technical inefficiency=(1-GTE)*100, LPTE =local pure technical efficiency, LPTIE(%) =local pure technical inefficiency=(1-LPTE)*100, SE =scale efficiency, SIE(%)= scale inefficiency=(1-SE)*100

Appendix D: Overall input/output slacks for public Carnegie 15 research universities: Graduation rate efficiency

	Input Reduction					Output Addition
	Slack %					Slack %
Name	x1	x2	x3	x4	x5	y2
Arizona State University at the Tempe Campus	-7.9	0	-22.4	-19.1	0	39.32
Colorado State University	0	0	-17.7	-70	0	16.49
Florida State University	0	0	0	0	0	0
Georgia Institute of Technology-Main Campus	-68.4	-36.2	0	-47.2	-42.2	0.48
Indiana University-Bloomington	0	0	0	0	0	0
Iowa State University	-30.5	0	0	0	-28	23.15
Kansas State University	-4.31	0	-5.02	-5.37	0	40.21
Louisiana State University and A & M College	-39.3	-14	0	-11.1	0	25
Michigan State University	-25	-17.5	0	-23.9	0	8.94
Montana State University	0	0	0	0	0	0
North Carolina State University at Raleigh	-59.7	-19.6	0	0	-5.73	54.09
Ohio State University-Main Campus	-57	-23.1	0	-27.6	-8.79	34.59
Oregon State University	0	0	-3.86	0	0	26.23
Pennsylvania State University-Main Campus	0	0	0	0	0	0
Purdue University-Main Campus	0	-0.78	0	0	-29.9	14.5
Stony Brook University	-67	-29.5	0	0	-17.5	64.02
SUNY at Albany	0	0	0	0	0	0
SUNY at Buffalo	-69.6	-13.4	0	0	-12.9	60.46
Texas A & M University	0	0	0	0	0	0
The University of Tennessee	-49.5	-6.8	0	0	-14.6	70.93
The University of Texas at Austin	0	0	0	0	0	0
University of Alabama at Birmingham	-79.4	-73.9	0	-66.9	-40.5	88.54
University of Arizona	-45.8	-9.09	0	-37.8	0	51.69
University of California-Berkeley	-51.6	-0.89	0	0	-9.67	29.99
University of California-Davis	-53.9	-8.1	0	0	-11.3	7.53
University of California-Irvine	-29.2	-4.66	0	0	-9.72	17.21
University of California-Los Angeles	-51	-15.8	0	0	-1.17	19.01
University of California-Riverside	0	0	0	0	0	0
University of California-San Diego	-44.2	-21.2	0	-24.2	0	6.42
University of California-Santa Barbara	0	0	0	0	0	0
University of California-Santa Cruz	0	0	0	0	0	0
University of Cincinnati-Main Campus	0	0	0	-6.12	-27.4	216.67
University of Colorado at Boulder	0	0	0	0	0	0
University of Colorado Denver	0	-48.9	0	0	-63	467.25
University of Connecticut	-27.2	-5.43	0	0	0	25.98
University of Delaware	0	0	0	0	0	0
University of Florida	-74.3	-33.9	0	-12.7	-31.8	5.33
University of Georgia	-53.8	0	0	-11.3	-7.68	27.55
University of Hawaii at Manoa	-60.2	-37.9	0	0	-32.6	135.64
University of Illinois at Chicago	-60	-41.2	0	-55.7	-43.5	3.17
University of Iowa	-39.7	0	0	-31.9	-10.4	34.56
University of Kansas	-23.5	0	0	-7.24	-15.7	48.44

University of Kentucky	-51.8	-13.8	0	-18.6	0	55.86
University of Maryland-College Park	-54.6	-26.8	0	0	-38.6	36.46
University of Michigan-Ann Arbor	0	0	0	0	0	0
University of Minnesota-Twin Cities	-72.5	-55.8	0	-47.6	-49.8	54.32
University of Missouri-Columbia	-42.2	0	-9.17	-26.4	-31.6	56.46
University of Nebraska-Lincoln	-23	0	-6.36	0	0	39.65
University of New Mexico-Main Campus	-54.5	0	-25.2	-14.5	-7.94	182.19
University of North Carolina at Chapel Hill	-66.7	-27.5	0	0	-19.9	7.36
University of Pittsburgh-Pittsburgh Campus	0	-40.8	0	-46.7	-32.1	22.23
University of South Carolina-Columbia	0	-3.86	0	-23	0	34.4
University of South Florida	-43.5	0	-29.9	-0.32	0	85.56
University of Utah	-34.9	-33.5	0	0	-8.41	263.84
University of Virginia-Main Campus	0	0	0	0	0	0
University of Washington-Seattle Campus	-51.8	-55.5	0	-63.9	-32.3	42.58
University of Wisconsin-Madison	-49.7	-44.7	0	-52.1	-39.5	12.53
Virginia Polytechnic Institute and State University	-43.6	-4.82	0	0	-23.6	0.49
Washington State University	-37.7	0	0	0	-8.04	78.7
Wayne State University	-24.7	-9.58	0	-1.34	0	444.61

Notes: x1 =state09_div100000, x2 =eandg01_div100000, x3 =total_undergraduates, x4 =total_executive_admin_managerial_w_other_professionals, x5 =total_faculty_all,; y2 =GRAD_RATE_150_n4YR

Appendix E: Overall GTE, LPTE, and SE scores for public Carnegie 16 research universities: Baccalaureate degree production

DMU	Name	GTE	GTIE (%)	LPTE	LPTIE (%)	SE	SIE (%)
DMU 1	Auburn University Main Campus	0.38	61.69	0.40	59.88	0.95	4.52
DMU 4	Bowling Green State University-Main Campus	0.67	33.17	0.74	25.96	0.90	9.74
DMU 10	Clemson University	0.43	56.54	0.45	55.48	0.98	2.37
DMU 11	College of William and Mary	0.52	48.21	0.75	24.77	0.69	31.16
DMU 12	Colorado School of Mines	0.41	58.91	1.00	0.00	0.41	58.91
DMU 14	Florida Atlantic University	0.58	41.83	0.59	40.92	0.98	1.54
DMU 16	Florida International University	0.57	43.44	0.59	41.39	0.97	3.49
DMU 18	George Mason University	0.41	58.55	0.42	58.48	1.00	0.15
DMU 20	Georgia State University	0.42	57.99	0.42	57.58	0.99	0.96
DMU 23	Indiana University-Purdue University-Indianapolis	0.28	72.36	0.31	69.02	0.89	10.78
DMU 24	Jackson State University	0.51	48.60	0.99	0.95	0.52	48.10
DMU 25	Kent State University-Kent Campus	0.52	48.47	0.53	46.71	0.97	3.31
DMU 29	Miami University-Oxford	0.83	17.48	0.97	2.86	0.85	15.05
DMU 30	Michigan Technological University	0.40	60.37	0.56	43.92	0.71	29.33
DMU 31	Mississippi State University	0.39	61.00	0.40	59.73	0.97	3.15
DMU 32	New Jersey Institute of Technology	0.33	67.30	0.40	60.07	0.82	18.11
DMU 33	North Carolina A & T State University	0.50	49.68	0.66	34.09	0.76	23.66
DMU 34	North Dakota State University-Main Campus	0.41	58.94	0.45	54.63	0.91	9.50
DMU 36	Northern Arizona University	0.39	60.51	0.41	59.18	0.97	3.26
DMU 37	Northern Illinois University	1.00	0.00	1.00	0.00	1.00	0.00
DMU 38	Ohio University-Main Campus	0.48	51.75	0.49	50.93	0.98	1.66
DMU 39	Oklahoma State University-Main Campus	0.42	58.49	0.42	58.43	1.00	0.14
DMU 40	Old Dominion University	0.59	40.80	0.64	36.18	0.93	7.24
DMU 43	San Diego State University	1.00	0.00	1.00	0.00	1.00	0.00
DMU 44	South Dakota State University	0.45	54.63	0.59	40.54	0.76	23.69
DMU 45	Southern Illinois University Carbondale	0.53	46.91	0.54	46.25	0.99	1.23
DMU 47	SUNY at Binghamton	0.49	50.59	0.52	48.16	0.95	4.68
DMU 48	SUNY College of Environmental Science and Forestry	0.30	70.02	1.00	0.00	0.30	70.02
DMU 50	Temple University	0.39	60.63	0.53	46.91	0.74	25.83
DMU 51	Texas Tech University	0.49	51.46	0.52	48.41	0.94	5.92
DMU 52	The University of Alabama	0.34	65.88	0.36	63.77	0.94	5.83
DMU 53	The University of Montana	0.53	46.68	0.72	28.36	0.74	25.57

DMU 54	University of Akron Main Campus	0.43	56.64	0.47	53.15	0.93	7.45
DMU 55	University of Alabama in Huntsville	0.31	68.82	0.52	48.31	0.60	39.68
DMU 56	University of Alaska Fairbanks	0.15	85.47	0.15	84.99	0.97	3.22
DMU 57	University of Arkansas Main Campus	0.32	68.39	0.32	67.76	0.98	1.93
DMU 58	University of Central Florida	0.67	33.20	0.96	3.97	0.70	30.44
DMU 61	University of Houston	0.42	58.38	0.51	49.26	0.82	17.97
DMU 62	University of Idaho	0.41	59.45	0.44	55.62	0.91	8.62
DMU 63	University of Louisiana at Lafayette	0.62	37.52	0.72	28.00	0.87	13.22
DMU 64	University of Louisville	0.31	69.02	0.32	68.41	0.98	1.93
DMU 65	University of Maine	0.35	64.90	0.44	55.52	0.79	21.10
DMU 66	University of Maryland-Baltimore County	0.39	60.70	0.42	57.62	0.93	7.28
DMU 67	University of Memphis	0.39	61.00	0.40	59.70	0.97	3.22
DMU 68	University of Mississippi Main Campus	0.42	57.98	0.47	53.29	0.90	10.03
DMU 69	University of Nevada-Las Vegas	0.38	61.79	0.39	60.59	0.97	3.03
DMU 70	University of Nevada-Reno	0.38	61.75	0.40	59.80	0.95	4.85
DMU 71	University of New Hampshire-Main Campus	0.66	33.79	0.70	30.42	0.95	4.84
DMU 72	University of New Orleans	0.32	68.09	0.38	62.24	0.85	15.50
DMU 73	University of North Carolina at Greensboro	0.45	55.15	0.47	52.84	0.95	4.90
DMU 74	University of North Dakota	0.34	65.67	0.38	61.83	0.90	10.04
DMU 75	University of North Texas	0.70	30.46	0.72	27.99	0.97	3.44
DMU 76	University of Oklahoma Norman Campus	0.39	60.54	0.41	59.30	0.97	3.05
DMU 77	University of Oregon	0.77	22.54	0.89	10.68	0.87	13.28
DMU 78	University of Rhode Island	0.49	50.74	0.59	40.57	0.83	17.12
DMU 79	University of Southern Mississippi	0.41	58.68	0.48	52.39	0.87	13.21
DMU 80	University of Toledo-Main Campus	0.45	54.64	0.47	52.62	0.96	4.25
DMU 82	University of Vermont	0.55	44.68	0.70	29.83	0.79	21.17
DMU 83	University of Wisconsin-Milwaukee	0.50	49.92	0.52	47.83	0.96	4.00
DMU 84	University of Wyoming	0.38	62.05	0.41	59.09	0.93	7.24
DMU 85	Utah State University	0.43	56.93	0.45	54.79	0.95	4.74
DMU 86	Virginia Commonwealth University	0.48	52.11	0.48	51.68	0.99	0.89
DMU 88	West Virginia University	0.36	63.85	0.40	59.59	0.89	10.54
DMU 89	Western Michigan University	0.81	19.16	0.87	13.29	0.93	6.78
DMU 90	Wichita State University	0.42	57.97	0.49	51.02	0.86	14.19
DMU 91	Wright State University-Main Campus	0.44	56.40	0.48	52.16	0.91	8.88

Notes: GTE =global technical efficiency, GTIE(%) =global technical inefficiency=(1-GTE)*100, LPTE =local pure technical efficiency, LPTIE(%) =local pure technical inefficiency=(1-LPTE)*100, SE =scale efficiency, SIE(%)= scale inefficiency=(1-SE)*100

Appendix F: Overall input/output slacks for public Carnegie 16 research universities: baccalaureate degree production

	Input Reduction					Output Addition
	Slack %					Slack %
Name	x1	x2	x3	x4	x5	y1
Auburn University Main Campus	-42.82	-42.21	-4.52	-40.9	-18.24	149.24
Bowling Green State University-Main Campus	0	-25.46	-42.95	0	-30.24	35.06
Clemson University	-32.82	-49.02	0	-45.9	-40.56	124.62
College of William and Mary	0	-28.02	-2.06	-49.82	-31.33	32.93
Colorado School of Mines	0	0	0	0	0	0
Florida Atlantic University	-23.6	0	-20.69	0	-5.63	69.26
Florida International University	-27.9	-18.5	-39.61	-15.97	-3.49	70.62
George Mason University	-11.1	-18.47	0	-25.18	-24.53	140.87
Georgia State University	-31.7	-26.27	-12.66	-14.27	0	135.72
Indiana University-Purdue University-Indianapolis	-40.26	-56.69	-10.78	-66.74	-26.2	222.75
Jackson State University	-0.74	-44.09	-55.72	-68.68	0	0.96
Kent State University-Kent Campus	0	-26.6	-51.06	-17.28	-37.26	87.65
Miami University-Oxford	0	-46.97	-53.56	-43.49	-39.8	2.94
Michigan Technological University	0	-17.44	-3.1	-16.71	0	78.31
Mississippi State University	-33.85	-47.5	0	-48.19	-22.93	148.33
New Jersey Institute of Technology	-11.71	-37.53	0	-23.88	-23.82	150.44
North Carolina A & T State University	-23.88	-33.37	-39.7	0	0	51.72
North Dakota State University-Main Campus	0	-19.63	-24.62	-17.32	-7.74	120.4
Northern Arizona University	-18.25	-10.51	-6.75	-12.07	0	144.96
Northern Illinois University	0	0	0	0	0	0
Ohio University-Main Campus	0	-25.47	-33.24	-18.55	-34.11	103.81
Oklahoma State University-Main Campus	-33.01	-28.78	0	-29.56	-21.9	140.57
Old Dominion University	0	-1.85	-18.9	0	-8.21	56.68
San Diego State University	0	0	0	0	0	0
South Dakota State University	0	-11.12	-29.91	-22.58	0	68.18
Southern Illinois University Carbondale	-20.54	-42.8	0	-35.79	-37.51	86.06
SUNY at Binghamton	-28.94	-11.37	0	-0.43	-1.73	92.9
SUNY College of Environmental Science and Forestry	0	0	0	0	0	0
Temple University	-33.02	-54.24	-25.83	-56.77	-39.59	88.37
Texas Tech University	-6.09	-16.19	-17.83	-5.91	-12.49	93.82
The University of Alabama	-16.42	-28.8	-10.27	-10.54	-5.83	176.02
The University of Montana	0	-29.3	-42.73	-52.86	-10.96	39.59
University of Akron Main Campus	0	-34.25	-49.8	0	-53.27	113.43
University of Alabama in Huntsville	0	-21.64	-17.55	-46.51	0	93.47
University of Alaska Fairbanks	-52.5	-40.73	-26.8	-1.85	-15.69	566.12
University of Arkansas Main Campus	-37.63	-48.33	0	-46.76	-13.97	210.19
University of Central Florida	-43.46	-30.44	-54.36	-33.7	-32.77	4.13
University of Houston	-19.76	-35.54	-31.39	-37.04	-17.97	97.08
University of Idaho	-25.59	-33.24	0	0	-16.55	125.34
University of Louisiana at Lafayette	0	-1.88	-25	0	-10.83	38.88
University of Louisville	-27.83	-56.49	0	-52.75	-47.16	216.59
University of Maine	-29.6	-37.67	-39.7	-38.32	-21.1	124.81
University of Maryland-Baltimore County	-1.11	-26.61	0	-10.74	-20.89	135.94
University of Memphis	-3.56	-17.92	0	0	-29.6	148.15

University of Mississippi Main Campus	0	-20.1	-9.41	-16.19	0	114.09
University of Nevada-Las Vegas	-12.03	-14.85	-13.92	-2.9	-4.42	153.76
University of Nevada-Reno	-43.33	-47.42	0	0	-18.43	148.76
University of New Hampshire-Main Campus	0	-45.18	-41.26	-71.71	-32.26	43.73
University of New Orleans	-7.64	-17.09	-12.66	-34.79	0	164.81
University of North Carolina at Greensboro	-13.37	-6.14	0	0	-18.58	112.04
University of North Dakota	0	-21.84	-0.27	-26.93	-5.49	162.02
University of North Texas	0	-19.08	-45.95	-2.04	-14.38	38.86
University of Oklahoma Norman Campus	-13.88	-35.89	-3.05	-31.93	-23.92	145.72
University of Oregon	0	-48.99	-43.17	-35.94	-47.2	11.95
University of Rhode Island	0	-41.02	-30.11	-16.58	0	68.26
University of Southern Mississippi	0	-16.69	-11.53	-28.24	0	110.04
University of Toledo-Main Campus	-0.03	-30.83	0	0	-14.92	111.08
University of Vermont	0	-62.73	-30.39	-54.25	-31.05	42.51
University of Wisconsin-Milwaukee	0	-25.81	-40.36	-21.22	-24.06	91.69
University of Wyoming	-46.35	-36.76	0	-35.19	-27.97	144.43
Utah State University	-27.29	-37.58	-39.64	-17.34	0	121.19
Virginia Commonwealth University	-17.31	-42.64	0	0	-41.02	106.96
West Virginia University	-32.29	-43.92	-10.54	-28.08	-35.7	147.47
Western Michigan University	0	-29.05	-30.23	0	-29.23	15.32
Wichita State University	0	-9.15	-26.62	0	-13.89	104.17
Wright State University-Main Campus	-23.91	-35.81	-20.96	-24.81	0	109.01

Notes: x1 =state09_div100000, x2 =eandg01_div100000, x3 =total_undergraduates, x4 =total_executive_admin_managerial_w_other_professionals, x5 =total_faculty_all, y1 =BACHELORDEGREES; y2 =GRAD_RATE_150_n4YR

Appendix G: Overall GTE, LPTE, and SE scores for public Carnegie 16 research universities: Graduation rate efficiency

DMU	Name	GTE	GTIE (%)	LPTE	LPTIE (%)	SE	SIE (%)
DMU 1	Auburn University Main Campus	0.78	22.36	0.85	15.37	0.92	8.25
DMU 4	Bowling Green State University-Main Campus	0.93	6.56	0.97	2.91	0.96	3.76
DMU 10	Clemson University	0.71	29.14	0.80	19.53	0.88	11.94
DMU 11	College of William and Mary	1.00	0.00	1.00	0.00	1.00	0.00
DMU 12	Colorado School of Mines	0.68	31.90	1.00	0.00	0.68	31.90
DMU 14	Florida Atlantic University	0.29	70.57	0.30	69.63	0.97	3.07
DMU 16	Florida International University	0.40	60.32	0.43	56.96	0.92	7.82
DMU 18	George Mason University	0.41	59.17	0.43	56.83	0.95	5.42
DMU 20	Georgia State University	0.36	64.42	0.36	64.35	1.00	0.20
DMU 23	Indiana University-Purdue University-Indianapolis	0.17	82.87	0.20	79.92	0.85	14.69
DMU 24	Jackson State University	0.68	31.65	1.00	0.00	0.68	31.65
DMU 25	Kent State University-Kent Campus	0.53	46.72	0.57	42.99	0.93	6.55
DMU 29	Miami University-Oxford	1.00	0.00	1.00	0.00	1.00	0.00
DMU 30	Michigan Technological University	0.73	27.30	0.81	19.46	0.90	9.73
DMU 31	Mississippi State University	0.44	55.94	0.46	54.31	0.96	3.58
DMU 32	New Jersey Institute of Technology	0.37	63.25	0.41	59.45	0.91	9.39
DMU 33	North Carolina A & T State University	0.80	19.89	1.00	0.00	0.80	19.89
DMU 34	North Dakota State University-Main Campus	0.27	72.96	0.28	72.04	0.97	3.29
DMU 36	Northern Arizona University	0.44	55.75	0.45	55.06	0.98	1.54
DMU 37	Northern Illinois University	0.51	48.61	0.52	48.20	0.99	0.79
DMU 38	Ohio University-Main Campus	0.78	22.03	0.89	10.83	0.87	12.56
DMU 39	Oklahoma State University-Main Campus	0.58	41.78	0.63	37.27	0.93	7.18
DMU 40	Old Dominion University	0.42	58.29	0.45	54.75	0.92	7.83
DMU 43	San Diego State University	0.72	27.85	0.80	20.11	0.90	9.68
DMU 44	South Dakota State University	0.56	44.03	0.67	32.77	0.83	16.74
DMU 45	Southern Illinois University Carbondale	0.34	65.82	0.39	61.22	0.88	11.86
DMU 47	SUNY at Binghamton	0.84	15.96	0.87	13.36	0.97	3.00
DMU 48	SUNY College of Environmental Science and Forestry	0.45	54.99	1.00	0.00	0.45	54.99
DMU 50	Temple University	0.47	52.71	0.66	33.90	0.72	28.47
DMU 51	Texas Tech University	0.69	31.28	0.78	22.45	0.89	11.39
DMU 52	The University of Alabama	0.48	52.03	0.53	47.22	0.91	9.12
DMU 53	The University of Montana	0.45	54.51	0.53	47.46	0.87	13.42
DMU 54	University of Akron Main Campus	0.39	61.48	0.39	60.89	0.99	1.50
DMU 55	University of Alabama in Huntsville	0.30	69.83	0.36	64.14	0.84	15.89
DMU 56	University of Alaska Fairbanks	0.09	91.03	0.11	88.97	0.81	18.66
DMU 57	University of Arkansas Main Campus	0.48	52.49	0.49	51.37	0.98	2.30
DMU 58	University of Central Florida	0.78	22.44	1.00	0.00	0.78	22.44
DMU 61	University of Houston	0.32	67.58	0.41	59.19	0.79	20.57

DMU 62	University of Idaho	0.59	40.58	0.62	37.82	0.96	4.44
DMU 63	University of Louisiana at Lafayette	0.63	36.97	0.72	28.31	0.88	12.08
DMU 64	University of Louisville	0.34	66.49	0.40	60.10	0.84	16.00
DMU 65	University of Maine	0.41	58.80	0.53	46.67	0.77	22.74
DMU 66	University of Maryland-Baltimore County	0.48	51.84	0.49	50.90	0.98	1.92
DMU 67	University of Memphis	0.26	74.29	0.26	73.88	0.98	1.57
DMU 68	University of Mississippi Main Campus	0.59	41.23	0.60	39.67	0.97	2.58
DMU 69	University of Nevada-Las Vegas	0.28	72.18	0.31	69.44	0.91	8.95
DMU 70	University of Nevada-Reno	0.46	54.13	0.47	53.04	0.98	2.33
DMU 71	University of New Hampshire-Main Campus	0.78	21.97	0.94	5.73	0.83	17.22
DMU 72	University of New Orleans	0.27	73.40	0.30	69.72	0.88	12.16
DMU 73	University of North Carolina at Greensboro	0.49	51.46	0.51	49.11	0.95	4.61
DMU 74	University of North Dakota	0.57	43.12	0.58	42.32	0.99	1.38
DMU 75	University of North Texas	0.43	56.92	0.43	56.75	1.00	0.38
DMU 76	University of Oklahoma Norman Campus	0.67	32.99	0.74	26.31	0.91	9.07
DMU 77	University of Oregon	0.78	22.46	0.78	22.44	1.00	0.03
DMU 78	University of Rhode Island	0.71	28.53	0.76	23.65	0.94	6.39
DMU 79	University of Southern Mississippi	0.34	66.09	0.35	64.87	0.97	3.46
DMU 80	University of Toledo-Main Campus	0.69	30.86	0.70	29.86	0.99	1.43
DMU 82	University of Vermont	0.69	30.78	0.69	30.57	1.00	0.30
DMU 83	University of Wisconsin-Milwaukee	0.41	59.26	0.42	57.94	0.97	3.12
DMU 84	University of Wyoming	0.44	56.44	0.44	56.32	1.00	0.27
DMU 85	Utah State University	0.39	60.67	0.40	59.57	0.97	2.72
DMU 86	Virginia Commonwealth University	0.46	53.90	0.49	51.45	0.95	5.05
DMU 88	West Virginia University	0.57	43.50	0.69	31.29	0.82	17.76
DMU 89	Western Michigan University	1.00	0.00	1.00	0.00	1.00	0.00
DMU 90	Wichita State University	0.26	74.40	0.30	70.44	0.87	13.38
DMU 91	Wright State University-Main Campus	0.50	50.27	0.53	47.39	0.95	5.48

Notes: GTE =global technical efficiency, GTIE(%) =global technical inefficiency=(1-GTE)*100, LPTE =local pure technical efficiency, LPTIE(%) =local pure technical inefficiency=(1-LPTE)*100, SE =scale efficiency, SIE(%)= scale inefficiency=(1-SE)*100

Appendix H: Overall input/output slacks for public Carnegie 16 research universities: Graduation rate efficiency

	Input Reduction					Output Addition
	Slack %					Slack %
Name	x1	x2	x3	x4	x5	y2
Auburn University Main Campus	-70.9	-38.92	0	-50.65	-21.43	18.17
Bowling Green State University-Main Campus	-5.73	0	-14.53	0	-16.26	3
Clemson University	-65.9	-43.1	0	-48.02	-35.45	24.27
College of William and Mary	0	0	0	0	0	0
Colorado School of Mines	0	0	0	0	0	0
Florida Atlantic University	-63.58	0	-26.68	-16.37	-13.47	229.32
Florida International University	-50.34	-9.43	-26.89	-21.76	0	132.32
George Mason University	-58.28	-15	0	-38.68	-28.39	131.66
Georgia State University	-66.01	-18.37	-5.72	-24.9	0	180.47
Indiana University-Purdue University-Indianapolis	-64.76	-53.16	0	-70.79	-26.58	398.03
Jackson State University	0	0	0	0	0	0
Kent State University-Kent Campus	-6.34	-0.4	-22.63	0	-20.51	75.39
Miami University-Oxford	0	0	0	0	0	0
Michigan Technological University	-7.91	-9.3	0	-1.44	0	24.16
Mississippi State University	-65.61	-40.11	0	-47.66	-12.67	118.86
New Jersey Institute of Technology	-36.52	-25.26	0	-5.64	0	146.59
North Carolina A & T State University	0	0	0	0	0	0
North Dakota State University-Main Campus	-28.95	0	-2.32	-11.71	0	257.7
Northern Arizona University	-56.89	-1.8	0	-23.57	0	122.53
Northern Illinois University	-54.12	0	-3.73	-22.42	-9.89	93.06
Ohio University-Main Campus	-7.49	-5.35	0	-7.97	-20.92	12.15
Oklahoma State University-Main Campus	-68.57	-25.77	0	-42.32	-25.94	59.42
Old Dominion University	-46.06	0	-28.26	-0.59	-11.14	121.01
San Diego State University	-53.75	-17.75	-36.32	0	-17.61	25.18
South Dakota State University	-11.33	0	-15.12	-19.88	-6.27	48.75
Southern Illinois University Carbondale	-61.19	-38.3	0	-42.98	-36.53	157.9
SUNY at Binghamton	-60.62	-4.91	0	-10.7	0	15.42
SUNY College of Environmental Science and Forestry	0	0	0	0	0	0
Temple University	-43.71	-47.04	0	-56.25	-33.58	51.28
Texas Tech University	-34.66	-6.68	0	-12.04	-9.07	28.94
The University of Alabama	-51.29	-23.15	0	-21.77	-6.59	89.46
The University of Montana	0	-6.88	-14.32	-39.5	0	90.32
University of Akron Main Campus	-0.76	0	-14.05	0	-31.12	155.72
University of Alabama in Huntsville	-11.12	-11.22	0	-42.52	0	178.84
University of Alaska Fairbanks	-59.49	-31.2	-0.48	0	-6.86	806.52
University of Arkansas Main Campus	-68.8	-43.06	0	-50.32	-8.88	105.64
University of Central Florida	0	0	0	0	0	0
University of Houston	-22.91	-23.07	0	-32.23	-5.69	145.04
University of Idaho	-54.87	-25.69	0	0	-8.03	60.83
University of Louisiana at Lafayette	-30.35	0	-33.67	0	-9.87	39.49
University of Louisville	-63.9	-52.06	0	-55.94	-44.06	150.63
University of Maine	-16.79	-21.44	0	-26.31	-1.98	87.5
University of Maryland-Baltimore County	-42.06	-13.18	0	0	-2.64	103.66
University of Memphis	-48.04	-9.39	0	0	-26.61	282.89
University of Mississippi Main Campus	-36.56	-10.56	0	-19.74	0	65.77
University of Nevada-Las Vegas	-44.15	-6.76	0	-12.38	-3.11	227.28

University of Nevada-Reno	-69.01	-42.02	0	0	-14.62	112.93
University of New Hampshire-Main Campus	-0.33	-20.6	0	-62.97	-8.87	6.08
University of New Orleans	-37.56	-5.15	0	-32.24	0	230.25
University of North Carolina at Greensboro	-50.48	0	-5.58	0	-16.92	96.51
University of North Dakota	-35.66	-12.36	0	-21.37	0	73.38
University of North Texas	-41.6	0	-32.88	-1.56	-5.15	131.21
University of Oklahoma Norman Campus	-57.67	-32.57	0	-43.79	-27.44	35.71
University of Oregon	-12.47	-15.91	0	0	-21.41	28.93
University of Rhode Island	-6.89	-22.31	0	0	0	30.98
University of Southern Mississippi	-33.78	-6.09	0	-30.98	0	184.65
University of Toledo-Main Campus	-33.91	-23.1	0	0	-7.5	42.56
University of Vermont	-6.72	-43.7	0	-21.36	0	44.03
University of Wisconsin-Milwaukee	-21.21	0	-11.96	-8.66	-6.36	137.78
University of Wyoming	-69	-20.22	0	-17.75	-0.88	128.94
Utah State University	-59.08	-26.49	-29.98	-14.26	0	147.34
Virginia Commonwealth University	-59.97	-41.33	-12.48	0	-42.36	105.96
West Virginia University	-60.29	-39.4	0	-36.96	-36.12	45.55
Western Michigan University	0	0	0	0	0	0
Wichita State University	-23.64	0	-16.18	-3.85	-18.45	238.34
Wright State University-Main Campus	-52.29	-19.7	-1.12	-8.39	0	90.08

Notes: x1 =state09_div100000, x2 =eandg01_div100000, x3 =total_undergraduates, x4 =total_executive_admin_managerial_w_other_professionals, x5 =total_faculty_all,; y2 =GRAD_RATE_150_n4YR

Appendix I: Overall GTE, LPTE, and SE scores for private non-profit Carnegie 15 research universities: Baccalaureate degree production

DMU	Name	GTE	GTIE (%)	LPTE	LPTIE (%)	SE	SIE (%)
DMU 2	Boston University	1.00	0.00	1.00	0.00	1.00	0.00
DMU 3	Brandeis University	1.00	0.00	1.00	0.00	1.00	0.00
DMU 4	Brown University	1.00	0.00	1.00	0.00	1.00	0.00
DMU 5	Carnegie Mellon University	0.84	16.15	0.84	15.93	1.00	0.26
DMU 6	Case Western Reserve University	0.67	32.71	0.68	31.72	0.99	1.45
DMU 8	Columbia University in the City of New York	0.88	11.80	0.89	11.37	1.00	0.49
DMU 9	Cornell University	0.93	7.27	0.93	7.19	1.00	0.09
DMU 10	Dartmouth College	0.96	3.55	0.97	3.26	1.00	0.30
DMU 11	Duke University	0.84	16.34	0.84	16.07	1.00	0.32
DMU 12	Emory University	0.80	19.83	0.80	19.54	1.00	0.36
DMU 14	Georgetown University	0.94	5.65	0.96	4.30	0.99	1.41
DMU 16	Harvard University	0.68	31.52	0.74	26.23	0.93	7.17
DMU 19	Johns Hopkins University	0.96	3.93	0.96	3.68	1.00	0.26
DMU 22	Massachusetts Institute of Technology	1.00	0.00	1.00	0.00	1.00	0.00
DMU 25	New York University	0.92	7.99	1.00	0.00	0.92	7.99
DMU 27	Northwestern University	0.82	18.23	0.82	18.20	1.00	0.04
DMU 31	Princeton University	0.90	10.11	0.90	9.68	1.00	0.47
DMU 33	Rensselaer Polytechnic Institute	1.00	0.00	1.00	0.00	1.00	0.00
DMU 34	Rice University	1.00	0.00	1.00	0.00	1.00	0.00
DMU 35	Stanford University	0.91	9.14	0.91	8.86	1.00	0.30
DMU 42	Tufts University	1.00	0.00	1.00	0.00	1.00	0.00
DMU 43	Tulane University of Louisiana	1.00	0.00	1.00	0.00	1.00	0.00
DMU 67	University of Miami	0.86	14.39	0.86	14.30	1.00	0.11
DMU 74	University of Notre Dame	1.00	0.00	1.00	0.00	1.00	0.00
DMU 75	University of Pennsylvania	0.83	16.76	0.84	16.13	0.99	0.76
DMU 77	University of Rochester	0.86	14.41	0.86	14.36	1.00	0.05
DMU 80	University of Southern California	1.00	0.00	1.00	0.00	1.00	0.00
DMU 85	Vanderbilt University	0.87	12.61	0.88	12.25	1.00	0.41
DMU 88	Washington University in St Louis	0.94	6.08	0.96	4.14	0.98	2.03
DMU 90	Yale University	0.87	12.62	0.88	12.47	1.00	0.17
DMU 91	Yeshiva University	0.77	22.86	0.82	18.43	0.95	5.43

Notes: GTE =global technical efficiency, GTIE(%) =global technical inefficiency=(1-GTE)*100, LPTE =local pure technical efficiency, LPTIE(%) =local pure technical inefficiency=(1-LPTE)*100, SE =scale efficiency, SIE(%)= scale inefficiency=(1-SE)*100

Appendix J: Overall input/output slacks for private non-profit Carnegie 15 research universities: baccalaureate degree production

	Input Reduction					Output Addition
	Slack %					Slack %
Name	x1	x2	x3	x4	x5	y1
Boston University	0	0	0	0	0	0
Brandeis University	0	0	0	0	0	0
Brown University	0	0	0	0	0	0
Carnegie Mellon University	0	-30.33	0	-34.25	-31.63	18.95
Case Western Reserve University	-62.69	-9.46	0	-42.98	0	46.46
Columbia University in the City of New York	-32.95	-32.67	0	-63.08	0	12.82
Cornell University	-91.68	-13.84	0	0	-1.43	7.75
Dartmouth College	-52.63	-25.56	0	-25.1	0	3.37
Duke University	-51.51	-39.11	0	-69.5	0	19.15
Emory University	-39.59	-10.06	0	-47.27	0	24.28
Georgetown University	0	-27.59	0	-8.55	-28.85	4.49
Harvard University	0	-78.17	-0.4	-67.36	-65.73	35.56
Johns Hopkins University	-71.46	-33.41	0	-44.31	0	3.82
Massachusetts Institute of Technology	0	0	0	0	0	0
New York University	0	0	0	0	0	0
Northwestern University	-1.36	-38.01	0	-12.31	0	22.25
Princeton University	0	-52.76	0	-38.75	-36.11	10.72
Rensselaer Polytechnic Institute	0	0	0	0	0	0
Rice University	0	0	0	0	0	0
Stanford University	0	-74.84	0	-59.81	-62.02	9.73
Tufts University	0	0	0	0	0	0
Tulane University of Louisiana	0	0	0	0	0	0
University of Miami	-90.98	0	0	-4.09	-8.6	16.68
University of Notre Dame	0	0	0	0	0	0
University of Pennsylvania	-71.46	-36.97	0	-40.56	0	19.23
University of Rochester	-55.29	0	0	-50.22	-9.75	16.77
University of Southern California	0	0	0	0	0	0
Vanderbilt University	0	-55.69	0	-77.97	-23.22	13.96
Washington University in St Louis	0	-67.29	0	-59.39	-64.22	4.32
Yale University	-37.41	-35.19	0	-44.3	0	14.25
Yeshiva University	-97.38	-34.06	0	-39.35	-34.83	22.6

Notes: x1 =state09_div100000, x2 =eandg01_div100000, x3 =total_undergraduates, x4 =total_executive_admin_managerial_w_other_professionals, x5 =total_faculty_all, y1 =BACHELORDEGREES; y2 =GRAD_RATE_150_n4YR

Appendix K: Overall GTE, LPTE, and SE scores for private non-profit Carnegie 15 research universities: Graduation rate efficiency

DMU	Name	GTE	GTIE (%)	LPTE	LPTIE (%)	SE	SIE (%)
DMU 2	Boston University	1.00	0.00	1.00	0.00	1.00	0.00
DMU 3	Brandeis University	1.00	0.00	1.00	0.00	1.00	0.00
DMU 4	Brown University	0.99	0.56	1.00	0.00	0.99	0.56
DMU 5	Carnegie Mellon University	0.89	11.26	0.90	9.79	0.98	1.63
DMU 6	Case Western Reserve University	0.66	33.82	0.66	33.82	1.00	0.00
DMU 8	Columbia University in the City of New York	0.72	27.52	0.75	24.77	0.96	3.65
DMU 9	Cornell University	0.88	11.69	1.00	0.00	0.88	11.69
DMU 10	Dartmouth College	1.00	0.00	1.00	0.00	1.00	0.00
DMU 11	Duke University	1.00	0.00	1.00	0.00	1.00	0.00
DMU 12	Emory University	0.69	30.93	0.72	28.22	0.96	3.77
DMU 14	Georgetown University	0.84	15.89	0.86	13.51	0.97	2.75
DMU 16	Harvard University	0.69	30.99	0.75	25.22	0.92	7.72
DMU 19	Johns Hopkins University	0.78	21.90	0.79	21.10	0.99	1.01
DMU 22	Massachusetts Institute of Technology	0.90	9.80	0.90	9.77	1.00	0.03
DMU 25	New York University	0.58	42.11	0.76	23.56	0.76	24.27
DMU 27	Northwestern University	0.85	14.56	0.93	7.49	0.92	7.64
DMU 31	Princeton University	0.99	0.80	1.00	0.00	0.99	0.80
DMU 33	Rensselaer Polytechnic Institute	0.97	2.52	1.00	0.00	0.97	2.52
DMU 34	Rice University	0.93	7.21	1.00	0.00	0.93	7.21
DMU 35	Stanford University	0.99	1.12	1.00	0.00	0.99	1.12
DMU 42	Tufts University	0.99	1.37	1.00	0.09	0.99	1.29
DMU 43	Tulane University of Louisiana	1.00	0.00	1.00	0.00	1.00	0.00
DMU 67	University of Miami	0.65	35.44	0.71	29.37	0.91	8.59
DMU 74	University of Notre Dame	1.00	0.00	1.00	0.00	1.00	0.00
DMU 75	University of Pennsylvania	0.78	21.68	0.91	9.30	0.86	13.64
DMU 77	University of Rochester	0.71	28.60	0.73	27.30	0.98	1.79
DMU 80	University of Southern California	0.63	36.89	0.74	25.55	0.85	15.23
DMU 85	Vanderbilt University	0.91	8.59	0.93	6.53	0.98	2.20
DMU 88	Washington University in St Louis	0.74	25.92	0.76	23.69	0.97	2.92
DMU 90	Yale University	0.98	1.95	0.99	1.40	0.99	0.56
DMU 91	Yeshiva University	0.79	20.69	0.89	10.89	0.89	11.00

Notes: GTE =global technical efficiency, GTIE(%) =global technical inefficiency=(1-GTE)*100, LPTE =local pure technical efficiency, LPTIE(%) =local pure technical inefficiency=(1-LPTE)*100, SE =scale efficiency, SIE(%)= scale inefficiency=(1-SE)*100

Appendix L: Overall input/output slacks for private non-profit Carnegie 15 research universities: graduation rate efficiency

	Input Reduction					Output Addition
	Slack %					Slack %
Name	x1	x2	x3	x4	x5	y2
Boston University	0	0	0	0	0	0
Brandeis University	0	0	0	0	0	0
Brown University	0	0	0	0	0	0
Carnegie Mellon University	0	0	0	0	-37.57	10.85
Case Western Reserve University	-43.12	-3.7	0	-32.13	-34.98	51.11
Columbia University in the City of New York	0	-37.24	0	-12.24	-36.67	32.93
Cornell University	0	0	0	0	0	0
Dartmouth College	0	0	0	0	0	0
Duke University	0	0	0	0	0	0
Emory University	-33.4	-2.55	0	0	-34.75	39.31
Georgetown University	0	-9.87	0	0	-21.63	15.62
Harvard University	0	-78.17	-0.4	-67.36	-65.73	33.72
Johns Hopkins University	-67.46	-51.55	0	0	-53.63	26.75
Massachusetts Institute of Technology	-38.77	-69.82	0	-39.09	-81.3	10.83
New York University	-74.24	-37.61	-12.16	-30.46	-23.89	30.82
Northwestern University	0	-43.39	0	0	-25.44	8.1
Princeton University	0	0	0	0	0	0
Rensselaer Polytechnic Institute	0	0	0	0	0	0
Rice University	0	0	0	0	0	0
Stanford University	0	0	0	0	0	0
Tufts University	-41.29	0	0	-5.4	-39.08	0.09
Tulane University of Louisiana	0	0	0	0	0	0
University of Miami	-39.19	0	0	-5.25	-30.25	41.58
University of Notre Dame	0	0	0	0	0	0
University of Pennsylvania	0	-36.1	0	-12.12	-15.28	10.25
University of Rochester	-53.3	0	0	-40.32	-49.81	37.55
University of Southern California	0	-20.89	0	-9.51	-13.89	34.31
Vanderbilt University	0	-12.85	0	-58.92	0	6.99
Washington University in St Louis	0	-63	0	-57.11	-60.43	31.05
Yale University	-22.59	-47.59	0	0	-49.56	1.41
Yeshiva University	-97.38	-34.06	0	-39.35	-34.83	12.22

Notes: x1 =state09_div100000, x2 =eandg01_div100000, x3 =total_undergraduates, x4 =total_executive_admin_managerial_w_other_professionals, x5 =total_faculty_all, y1 =BACHELORDEGREES; y2 =GRAD_RATE_150_n4YR

Appendix M: Overall GTE, LPTE, and SE scores for private non-profit Carnegie 16 research universities: Baccalaureate degree production

DMU	Name	GTE	GTIE (%)	LPTE	LPTIE (%)	SE	SIE (%)
DMU 2	Baylor University	0.90	10.35	0.91	8.91	0.98	1.59
DMU 3	Boston College	1.00	0.00	1.00	0.00	1.00	0.00
DMU 5	Brigham Young University	1.00	0.00	1.00	0.00	1.00	0.00
DMU 6	Catholic University of America	0.80	19.79	0.84	15.63	0.95	4.92
DMU 7	Clark Atlanta University	0.83	16.58	1.00	0.00	0.83	16.58
DMU 8	Clark University	0.94	6.08	1.00	0.00	0.94	6.08
DMU 9	Clarkson University	1.00	0.00	1.00	0.00	1.00	0.00
DMU 13	Drexel University	0.79	20.89	0.82	18.03	0.97	3.49
DMU 15	Florida Institute of Technology	0.73	27.36	0.77	23.06	0.94	5.60
DMU 17	Fordham University	1.00	0.00	1.00	0.00	1.00	0.00
DMU 19	George Washington University	0.99	1.27	0.99	0.59	0.99	0.69
DMU 21	Howard University	0.90	9.68	1.00	0.00	0.90	9.68
DMU 22	Illinois Institute of Technology	0.75	24.71	0.75	24.69	1.00	0.03
DMU 26	Lehigh University	0.96	4.20	0.97	3.21	0.99	1.02
DMU 27	Loyola University Chicago	0.91	9.08	0.92	8.12	0.99	1.04
DMU 28	Marquette University	0.97	3.29	0.97	2.73	0.99	0.58
DMU 35	Northeastern University	0.83	17.00	0.83	16.79	1.00	0.24
DMU 41	Polytechnic University	0.72	27.74	1.00	0.00	0.72	27.74
DMU 42	Saint Louis University-Main Campus	0.62	38.16	0.62	37.89	1.00	0.44
DMU 46	Stevens Institute of Technology	0.76	24.50	0.85	15.22	0.89	10.94
DMU 49	Syracuse University	0.93	7.50	0.95	4.98	0.97	2.65
DMU 59	University of Dayton	0.91	8.60	0.92	8.39	1.00	0.22
DMU 60	University of Denver	0.89	11.23	0.91	9.33	0.98	2.10
DMU 81	University of Tulsa	0.82	17.75	0.86	13.88	0.96	4.50
DMU 87	Wake Forest University	0.97	2.82	0.98	1.92	0.99	0.92

Notes: GTE =global technical efficiency, GTIE(%) =global technical inefficiency=(1-GTE)*100, LPTE =local pure technical efficiency, LPTIE(%) =local pure technical inefficiency=(1-LPTE)*100, SE =scale efficiency, SIE(%)= scale inefficiency=(1-SE)*100

Appendix N: Overall input/output slacks for private non-profit Carnegie 16 research universities: baccalaureate degree production

	Input Reduction					Output Addition
	Slack %					Slack %
Name	x1	x2	x3	x4	x5	y1
Baylor University	-60.96	-14.61	0	0	-24.33	9.78
Boston College	0	0	0	0	0	0
Brigham Young University	0	0	0	0	0	0
Catholic University of America	0	-30.67	0	-48.9	-43.09	18.53
Clark Atlanta University	0	0	0	0	0	0
Clark University	0	0	0	0	0	0
Clarkson University	0	0	0	0	0	0
Drexel University	-84.27	-27.67	0	-20.56	-21.39	22
Florida Institute of Technology	0	0	0	-8.75	-17.29	29.96
Fordham University	0	0	0	0	0	0
George Washington University	-12.4	-43.25	0	-54.17	-21.6	0.59
Howard University	0	0	0	0	0	0
Illinois Institute of Technology	-29.94	-65.98	0	-59.05	-66.72	32.78
Lehigh University	-44.15	-28.87	0	0	-24.88	3.31
Loyola University Chicago	-44.86	-20.57	0	0	-43.24	8.84
Marquette University	0	-6.22	0	0	-18.71	2.8
Northeastern University	0	-22.19	0	-10.54	-17.49	20.18
Polytechnic University	0	0	0	0	0	0
Saint Louis University-Main Campus	-10.76	0	0	-32.1	-35.18	61
Stevens Institute of Technology	0	-35.88	0	-29.69	-45.59	17.96
Syracuse University	-68.87	-14.28	0	-33.11	-22.41	5.24
University of Dayton	-1.24	0	0	0	-3.41	9.16
University of Denver	0	-13.74	0	-29.73	-30.66	10.29
University of Tulsa	0	-19.66	0	-42.79	0	16.11
Wake Forest University	-59.28	-81.94	0	-74.11	-58.77	1.95

Notes: x1 =state09_div100000, x2 =eandg01_div100000, x3 =total_undergraduates, x4 =total_executive_admin_managerial_w_other_professionals, x5 =total_faculty_all, y1 =BACHELORDEGREES; y2 =GRAD_RATE_150_n4YR

Appendix O: Overall GTE, LPTE, and SE scores for private non-profit Carnegie 16 research universities: Graduation rate efficiency

DMU	Name	GTE	GTIE (%)	LPTE	LPTIE (%)	SE	SIE (%)
DMU 2	Baylor University	1.00	0.00	1.00	0.00	1.00	0.00
DMU 3	Boston College	1.00	0.00	1.00	0.00	1.00	0.00
DMU 5	Brigham Young University	0.78	22.41	1.00	0.00	0.78	22.41
DMU 6	Catholic University of America	0.92	7.75	0.94	6.39	0.99	1.46
DMU 7	Clark Atlanta University	1.00	0.00	1.00	0.00	1.00	0.00
DMU 8	Clark University	1.00	0.00	1.00	0.00	1.00	0.00
DMU 9	Clarkson University	1.00	0.00	1.00	0.00	1.00	0.00
DMU 13	Drexel University	0.45	55.36	0.54	45.77	0.82	17.68
DMU 15	Florida Institute of Technology	0.65	34.58	0.66	33.95	0.99	0.95
DMU 17	Fordham University	0.85	15.34	0.87	13.43	0.98	2.21
DMU 19	George Washington University	0.85	15.05	0.91	9.25	0.94	6.39
DMU 21	Howard University	1.00	0.00	1.00	0.00	1.00	0.00
DMU 22	Illinois Institute of Technology	0.44	56.31	0.45	54.96	0.97	3.01
DMU 26	Lehigh University	1.00	0.00	1.00	0.00	1.00	0.00
DMU 27	Loyola University Chicago	0.60	40.15	0.63	36.92	0.95	5.11
DMU 28	Marquette University	1.00	0.46	1.00	0.00	1.00	0.46
DMU 35	Northeastern University	0.87	12.94	1.00	0.00	0.87	12.94
DMU 41	Polytechnic University	0.72	28.30	1.00	0.00	0.72	28.30
DMU 42	Saint Louis University-Main Campus	0.55	45.46	0.60	40.22	0.91	8.78
DMU 46	Stevens Institute of Technology	0.66	33.93	0.76	24.07	0.87	12.99
DMU 49	Syracuse University	0.87	12.97	1.00	0.00	0.87	12.97
DMU 59	University of Dayton	0.92	7.60	0.95	4.95	0.97	2.78
DMU 60	University of Denver	0.69	31.00	0.71	29.47	0.98	2.17
DMU 81	University of Tulsa	0.63	36.63	0.63	36.52	1.00	0.17
DMU 87	Wake Forest University	0.97	2.52	0.98	2.25	1.00	0.28

Notes: GTE =global technical efficiency, GTIE(%) =global technical inefficiency=(1-GTE)*100, LPTE =local pure technical efficiency, LPTIE(%) =local pure technical inefficiency=(1-LPTE)*100, SE =scale efficiency, SIE(%)= scale inefficiency=(1-SE)*100

Appendix P: Overall input/output slacks for private non-profit Carnegie 16 research universities: graduation rate efficiency

	Input Reduction					Output Addition
	Slack %					Slack %
Name	x1	x2	x3	x4	x5	y2
Baylor University	0	0	0	0	0	0
Boston College	0	0	0	0	0	0
Brigham Young University	0	0	0	0	0	0
Catholic University of America	0	0	0	-29.55	-32.48	6.82
Clark Atlanta University	0	0	0	0	0	0
Clark University	0	0	0	0	0	0
Clarkson University	0	0	0	0	0	0
Drexel University	-51.53	-23.85	0	0	-8.06	84.39
Florida Institute of Technology	0	0	-0.5	-9.7	-15.78	51.41
Fordham University	-21.37	-7.75	0	-15.51	0	15.52
George Washington University	0	-42.55	0	-52.48	-19.93	10.19
Howard University	0	0	0	0	0	0
Illinois Institute of Technology	-29.06	-65.44	0	-59.08	-66.34	122.01
Lehigh University	0	0	0	0	0	0
Loyola University Chicago	0	-12.65	0	0	-32.18	58.53
Marquette University	0	0	0	0	0	0
Northeastern University	0	0	0	0	0	0
Polytechnic University	0	0	0	0	0	0
Saint Louis University-Main Campus	0	0	-7.2	-40.21	-25.4	67.27
Stevens Institute of Technology	0	-35.88	0	-29.69	-45.59	31.7
Syracuse University	0	0	0	0	0	0
University of Dayton	0	-5.19	0	-14.51	0	5.21
University of Denver	0	-13.74	0	-29.73	-30.66	41.78
University of Tulsa	0	-18.12	0	-41.38	0	57.53
Wake Forest University	-34.35	-75.16	0	-74.5	-45.71	2.3

Notes: x1 =state09_div100000, x2 =eandg01_div100000, x3 =total_undergraduates, x4 =total_executive_admin_managerial_w_other_professionals, x5 =total_faculty_all, y1 =BACHELORDEGREES; y2 =GRAD_RATE_150_n4YR