MEASURING ACADEMIC LIBRARY EFFICIENCY AND ALIGNMENT WITH INSTITUTIONAL RESOURCE UTILIZATION PRIORITIES USING DATA ENVELOPMENT ANALYSIS: AN ANALYSIS OF INSTITUTIONS OF HIGHER EDUCATION IN TEXAS AND THEIR LIBRARIES

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SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

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BY

CHRISTINE M. SHUPALA, M.L.S., M.B.A.

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To the Dean of the Graduate School,

I am submitting herewith a dissertation written by Christine M. Shupala erititled "Measuring Academic Library Efficiency and Alignment with Institutional Resource Utilisation Priofities using Data Envelopment Analysis: An Analysis of Institutions of Higher Education in Texas and their Libraries." I have exainined this dissertaüon for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree Doctor of Philosophy with a major in Library and Information Studies.

Keith Swigger, Ph.D., Major Professor

We have read this dissertation and recommend its acceptance:

Director

Accepted:

Interim-Dean of the raduate School

DEDICATION

To my husband Andy Shupala, who believes that I can do anything even when I doubt, and to my daughter Lindsay Shupala, who never thought it strange that she grew up in a library. I could not have accomplished this without your support.

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ABSTRACT

CHRISTINE M. SHUPALA

MEASURING ACADEMIC LIBRARY EFFICIENCY AND ALIGNMENT WITH INSTITUTIONAL RESOURCE UTILIZATION PRIORITIES USING DATA ENVELOPMENT ANALYSIS: AN ANALYSIS OF INSTITUTIONS OF HIGHER EDUCATION IN TEXAS AND THEIR LIBRARIES

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Academic and library administrators are increasingly required to demonstrate efficiency in programs, services, and operations as well as effectiveness. An important component of efficiency measurement is identification of a relevant peer group against which to compare the administrative unit to determine relative efficiency. The two-fold purpose of this study is to identify efficiencies related to teaching and research in academic libraries and institutions of higher education (IHEs) and to determine the usefulness of data envelopment analysis (DEA) as an efficiency measurement tool for the academic administrator.

Using a population of academic libraries and IHEs in Texas as a case study, variables were identified that represented the teaching- and research- related inputs and outputs for IHEs and academic libraries. Three separate models types were developed for each administrative level in each year of the two-year study. The first focused on teaching efficiency; the second focused on research efficiency; the third combined teaching and research to examine overall efficiency. Separate variables were selected for each

administrative level to represent the teaching- and research-related inputs and outputs for the administrative level. Data were gathered for 2007 and 2008 for both academic libraries and IHEs to permit model stability testing. Each model was completed once in each study year. A total of twelve individual models were completed across the two years of study.

In the first phase of the study, variables were selected based on an extensive review of the literature and the researcher’s professional judgment, following the process the academic administrator might employ to select variables. All variables for each model were calculated, transformed as needed, and tested for isotonicity using a correlation matrix. Variables were entered into the DEA analysis tool and relative efficiency scores were calculated using input-oriented CCR-CRS and BCC-VRS models. The initial calculations indicated that scale was a factor in efficiency and BCC-VRS was employed to determine final efficiency scores. Discrimination in each model was increased using a backward removal of variables procedure. Each model identified the relative efficiency of the academic libraries and IHEs in the study population.

In the second phase of the study efficiency scores for the population of IHEs and academic libraries were subjected to statistical analysis. Related-samples Wilcoxon signed rank tests and Spearman’s rho correlations were performed to test the stability of the model and identify both significant differences in and correlations of scores at each administrative level across years. The Mann-Whitney U test was used to identify relationships in efficiency scores across administrative levels in each year of the study.

An institutional control filter was applied to all analyses to determine the extent to which institutional control influenced its efficiency score. Additional analyses were conducted using Spearman's rho and Holms sequential Bonferroni to determine the influence of institution size and Carnegie degree classification on efficiency scores.

Results of the DEA process and analysis identified the method's strengths and pitfalls. The process highlighted the influence of population size and homogeneity, of data availability and imbalances, and of the method used to increase model discrimination. Difficulties arising from these influences were addressed and final efficiency scores were presented. Statistical analyses identified general trends in efficiency at both the academic library and the IHE levels of administration and suggest that size, classification, and control may influence efficiency.

While results of the study indicate that the complexity of DEA may limit its usefulness to academic administrators, the study provides a foundation from which additional efficiency analysis tools may be developed in the context of an overall assessment plan. Academic and library administrators wishing to pursue DEA analysis will find this study useful as they identify variables, processes, populations, data, and relevant DEA models. The study also provides a foundation for future research in IHE and library efficiency analysis and highlights research opportunities in data collection and preparation, variable selection, population identification, and discrimination methods.

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CHAPTER I

INTRODUCTION

1.1 Introduction: Background

It is not news to state that institutions of higher education and the libraries that serve them are under increased pressure to demonstrate accountability to state and federal authorities as well as to regional and discipline-specific accrediting bodies. Indeed, the move toward greater accountability and enhanced performance measurement has been a topic of discussion in the literature of higher education for the past several decades. As early as the 1970s both institutions of higher education (IHEs) and states were developing means of assessing both student and institutional performance. The two-fold purpose of assessment was for continuous improvement and for accountability, with continuous improvement assessment conducted at the local, institutional level for a largely internal audience and accountability conducted primarily to demonstrate compliance for external audiences (Ewell 2008). Still, throughout the 1970s and 1980s most performance measurement was performed at a local level. The 1980s saw external stakeholders in higher education become increasingly frustrated with a lack of consistent, comparative data available with which to make comparisons across institutions as most available data were primarily institution-centered and locally focused. This frustration led to a strengthened national accountability movement, centralized statewide reporting systems, and the development and use of mandated performance indicators (Gaither 1997). In

1985 the first national conference on the topic of accountability in higher education was held (Ewell 2008).

The early part of the twenty-first century saw a continued increase in pressure on IHEs from multiple constituencies to produce accountability data. The Business Higher Education Forum (BHEF), a national coalition of college and university presidents, Fortune 500 CEOs and other prominent leaders, called for a "greater capacity to measure and publicly account for general knowledge and skill levels" at the collegiate level (Business Higher Education Forum 2004, 9). Focusing on advancing college and workplace readiness initiatives as well as science, technology, engineering, and mathematics (STEM) initiatives, the BHEF conducts research and identifies strategies and policy reforms to address deficiencies in higher education. It saw the lack of accountability measures in economic terms, noting that by the year 2020 the US economy would need more than twelve million more skilled workers than were being produced at the time of their report, and that "closing the degree attainment gap could add $230 billion in national wealth, and as much as $80 billion in new tax revenues per year (Business Higher Education Forum 2004, 9)." Its findings indicated that employers increasingly sought specific skills and knowledge in new graduates, including the ability to work in teams, to problem solve, to think critically, to write well, to communicate, to multitask, to work in multicultural and global environments, and to continue to learn after graduation (Business Higher Education Forum 2004, 10). Its report, *Public Accountability for Student Learning in Higher Education*, emphasized the disconnect between assessment of student learning and reporting of measures for accountability, recognizing that while IHEs might be effectively assessing and improving outcomes locally they were ineffective at communicating those efforts to external stakeholders through understandable accountability measures. The report emphasized the importance of modifying both the means of assessment for improvement and accountability and the methods of communicating results as demographics and sources of revenue changed.

Shortly after the Business Higher Education Forum's report in 2004, the State Higher Education Executive Officers created the National Commission on Accountability in Higher Education. Its 2005 report weighed in on the topic, largely condemning the state of performance measurement and accountability reporting for higher education at the time. "[A]ccountability for better results is imperative, but more accountability of the kinds generally practiced will not help improve performance. Our current system of accountability can best be described as cumbersome, over-designed, confusing, and inefficient. It fails to answer key questions, it overburdens policymakers with excessive, misleading data, and it overburdens institutions by requiring them to report it" (National Commission on Accountability in Higher Education 2005, 6). The commission called for an improved accountability system that provided valid and dependable information, encouraged aspirations rather than minimum standards, focused seriously on performance improvement, moved beyond superficial comparisons, and that provided clear and relevant information to all stakeholders.

While both of these reports preceded what has widely become known as the Spellings Commission report, it is this report that is undoubtedly the most widely recognized report on accountability in higher education. It highlighted many issues in higher education but focused particularly on the need for improvements in access, affordability, financial aid, learning outcomes assessment, transparency and accountability, and innovation. It cited rising time to degree rates and falling literacy rates and suggested that while IHEs were doing much to attract students they were doing little to ensure that students were retained and graduated or that they were achieving necessary learning outcomes at the baccalaureate level. The report recommended cost-cutting and productivity increasing measures as well as increased institutional capacity and the development of more transparent accountability systems with more performance based measures (Commission on the Future of Higher Education 2006).

A 2011 review of progress made since the Spellings Commission report's release suggested that some progress has been made in the areas of access, affordability and accountability, though not necessarily because of the report. Field (2011) suggested that many of the reforms recommended by the report were already underway at the time of the report's release but that they received increased attention because of the report and subsequent controversy. Field provided a scorecard, highlighting areas in which progress had been made in the years since the Spellings Commission report. In the time since the release of the report, the politics in Washington at changed dramatically, with the House of Representatives changing majority parties twice and occupation of the White House shifting from Republican to Democrat. At the same time community college enrollments increased nationally, state funding for higher education decreased, and the country entered a recessionary period.

The scorecard suggested that the greatest area of improvement was in access. High school graduation standards were more closely aligned with college and employer expectations. Other improvements had occurred in performing early assessments of student college readiness. Expanding early college and dual enrollment programs, advanced placement and international baccalaureate courses also saw significant improvements. Finally, the National Assessment of Educational Progress, which measures readiness for college or the workplace in high school seniors, was improved through redesign. Improving access overall, reducing time to degree completion, and revising transfer credit standards in IHEs saw only minor improvements.

In the area of affordability, significant progress was made only in simplifying the federal student financial aid application and information process. There were minor improvements in state level financial aid provision. The overhaul of the entire financial aid system and the accreditation system, as well as the move to decrease the regulatory burden on IHEs saw no improvement. In the area of accountability, the only area that saw significant improvement was incentives for states, higher education associations, and IHEs to develop better accountability systems. Other areas that saw minor improvement were the development of consumer friendly databases that demonstrate IHE performance and student learning, the development of protected systems that collected and analyzed student level data, the use of assessment to measure student learning outcomes, and public release of data that demonstrated IHE performance on completion rates and student learning through accreditation agencies. While students entering college were marginally better prepared in math and reading than they were five years ago and were more likely to graduate from college, they were graduating from college with higher debt levels. Field did not directly address the lack of publicly available data regarding student achievement of learning outcomes.

Academic libraries, too, have increasingly focused attention on performance evaluation as they have struggled to demonstrate both their contribution to the goals and objectives of the IHE they serve and their ability to use resources both efficiently and effectively. As a part of this effort, libraries began to look at performance assessment both in terms of local measures and comparative measures, examining how efficiently and effectively their resources were used and how well they compared to other libraries in a peer group (Shim 1999). The development of performance and accountability measures in academic libraries paralleled the development of similar measures in IHEs. In 1977, White surveyed various quantitative measures proposed for evaluating library efficiency and effectiveness, recognizing that they were not meant to stand alone but rather to be used in conjunction with other measures to obtain a clear picture of the library's ability to meet goals and objectives and fulfill user needs. "…[P]ressure from funding agencies and taxpayers to obtain the most cost effective services possible has forced librarians to turn to quantitative measures of performance. These statistics, while not able to measure quality or the impact of information on library users, are relatively easy to gather, document and understand (1977, 128)."

White (1977) cited three reasons for the increased emphasis on quantitative measures: accountability, goals and objectives, and costs. On the accountability front, quantitative measures could be used to relate output to cost. Quantitative measures also assisted in identifying strengths and weaknesses and in measuring progress related to goals and objectives. Finally, quantitative measures allowed libraries to track rising costs of materials and equipment and assisted in identifying the most efficient methods for using available funds. As with measures used in IHEs of the day, the majority of measures used in academic libraries were locally focused and did little to allow for comparisons across libraries.

In the late 1980s Van House surveyed the state of assessment in academic libraries and noted several trends. Increased interest in performance assessment in academic libraries was linked to the increased size and complexity of libraries. Researchers outside the library had discovered libraries as research sites, including economists and operations researchers. There was a growing demand for accountability in the public sector. The availability of grant funding which required an evaluation component, and the increased emphasis on formal planning in higher education, which also required an evaluation/assessment component, contributed to increased interest in academic library performance assessment. The development of a body of literature on assessment that was specifically aimed at assisting librarians with the process encouraged the increased interest (Van House 1989). Powell (1992) also recognized what he called the “growing pressure” for libraries to be accountable for how they use their limited resources, and to deliver information in both an economical and efficient manner. Wallace (2001) emphasized the increased importance placed upon the ability of academic libraries to demonstrate that they were both effective and efficient in meeting both internal goals and objectives and the goals and objectives of parent institutions. She traced the evolution of academic library assessment through its focus on inputs in the 1970s, to its increased emphasis on efficiency in the 1980s, the addition of evaluation of output quality in the 1990s and an incorporation of outcomes in the 2000s. She noted, however, that literature focusing on outcomes did not incorporate measures that examined the library as a whole but rather primarily looked at individual services within the library. Lindauer (1998) also recognized that measures of the whole library or of the library as a part of the institution it served appeared in the literature only when the literature was focused on accreditation or institutional planning.

The success of any organization, including institutions of higher education (IHEs) and the libraries that serve them, depends upon its ability to operate both efficiently and effectively (Shim 1999). While it is possible for an organization to operate efficiently but not effectively, or effectively but not efficiently, it is most likely that the efficient organization is also effective and vice versa (B. Cronin 1982b; Neuman and Easun 1994). A comprehensive assessment program includes performance measures that address both efficiency and effectiveness.

Offered here, in the context of a study of IHEs and academic libraries in Texas, is an examination of one means by which IHEs and the libraries that serve them might assess library efficiency in order to determine its usefulness in an overall assessment program both for the library and the institution. It recognizes that IHEs are placing increased emphasis on the efficient use of resources in the furtherance of their missions and that teaching and research are core aspects of those missions. Institutional efficiency studies to date have examined both efficiencies with respect to teaching and research in combination and efficiencies with respect to teaching and research in isolation. While it is recognized that IHE missions also address social needs in the form of service, adequate measures of service efficiency have not yet been developed so this aspect of mission is typically not included in efficiency studies (Cohn and Cooper 2004; Jill Johnes and Yu 2008). This study also recognizes that units within the IHE such as the academic library exist to support the institutional mission. The library, as a part of the IHE it serves, is accountable for maximizing the efficient use of its resources in furtherance of the IHE mission.

The goal of this study is to determine whether academic libraries in the state of Texas are maximizing efficiency and maintaining efficiency ratings in alignment with those of the IHE they serve. This study uses Data Envelopment Analysis (DEA) to first determine institutional efficiency using inputs and outputs related to teaching and research for a group of IHEs in the state of Texas during the two year period 2007-2008, noting the relative efficiency of institutions among the group. Next it seeks to determine the relative efficiency of the academic library within each institution for the same two year period with regard to teaching and research inputs and outputs and whether its efficiency rating correlates with that of the institution it serves. Within the context of this study, and in keeping with the use of DEA, efficiency is operationalized as maximizing the use of inputs and/or increasing outputs relative to the use of inputs. An entity is seen as efficient within the comparison group if it is able to produce more with a given level of inputs or to produce at the same level with a reduced level of inputs. Efficiency is a measure of the entity's ability to transform inputs or resources into outputs or services, or to produce a level of outputs with a minimum amount of inputs (Shim 2003; Cooper, Seiford, and Tone 2007a). A second goal of this study is to determine the usefulness of DEA as an assessment tool in the higher education environment.

1.2 Research Questions

This study uses DEA to examine four related questions with the goal of determining the extent to which academic libraries and the institutions they serve are maximizing efficiency related to teaching and research, the extent to which the efficiency scores for libraries are related to the scores for the institutions they serve, and the extent to which some institutional factors might affect library efficiency scores.

1. Among IHEs belonging to the study sample, what is the relative efficiency of each with respect to teaching and research?

To address this question DEA models are developed and efficiency analyses are run on the population of IHEs using both the Charnes, Cooper and Rhodes constant returns to scale (CCR-CRS) model and the Banker, Charnes and Cooper variable returns to scale (BCC-VRS) model for each of the three performance models, teaching, research and overall performance. The results of the analysis include the relative efficiency ratings for each IHE with respect to the measures selected for both teaching and research.

2. Among the IHEs belonging to the study sample, what is the relative efficiency of the libraries that serve the institutions with respect to activities related to teaching and research?

To address this question DEA models are developed and efficiency analyses are run on the population of academic libraries using both the CCR-CRS model and the BCC-VRS model for each of the three performance models, teaching, research and overall performance. The results of the analysis include the relative efficiency ratings for each academic library with respect to the measures selected for both teaching and research.

3. To what extent do the library efficiency ratings for teaching and research correlate with the IHE efficiency ratings for teaching and research, for the libraries and IHEs in the study sample?

This question is accompanied by two sets of hypotheses which are designed to address the correlation of efficiency ratings across the two year study period. They also examine significant differences in efficiency ratings across administrative levels within years. The first set considers the stability of efficiency ratings for both the libraries and the IHEs in the study sample across the two years of the study and in each of the three models, teaching, research and overall performance. The results at each administrative level are considered both for the entire population and filtered by level of institutional control (whether the IHE is public or private).

According to the population of decision making units, or DMUs:

1a. For either level of control, there is no significant difference nor correlation for the teaching efficiency measurements of the library administrative level between years 2007 and 2008.

1b. For either level of control, there is no significant difference nor correlation for the teaching efficiency measurements of the institutional administrative level between years 2007 and 2008.

2a. For either level of control, there is no significant difference nor correlation for the research efficiency measurements of the library administrative level between years 2007 and 2008.

2b. For either level of control, there is no significant difference nor correlation for the research efficiency measurements of the institutional administrative level between years 2007 and 2008.

3a. For either level of control, there is no significant difference nor correlation for the overall efficiency measurements of the library administrative level between years 2007 and 2008.

3b. For either level of control, there is no significant difference nor correlation for the overall efficiency measurements of the institutional administrative level between years 2007 and 2008.

A second set of hypotheses considers whether there is a significant difference in efficiency ratings for the population of libraries and the population of IHEs. Efficiency ratings are tested for significant difference for the entire population and sub-populations according to type of institutional control in each year of the study and in each of the three performance models, teaching, research, and overall.

According the population of DMUs:

1a. For either level of control, there is no significant difference between the teaching efficiency measurements of library and institutional administrative levels in year 2007.

1b. For either level of control, there is no significant difference between the teaching efficiency measurements of library and institutional administrative levels in year 2008.

2a. For either level of control, there is no significant difference between the research efficiency measurements of library and institutional administrative levels in year 2007.

2b. For either level of control, there is no significant difference between the research efficiency measurements of library and institutional administrative levels in year 2008.

3a. For either level of control, there is no significant difference between the overall efficiency measurements of library and institutional administrative levels in year 2007.

3b. For either level of control, there is no significant difference between the overall efficiency measurements of library and institutional administrative levels in year 2008.

The fourth research question is designed to discover whether efficiency ratings increased or decreased based on administrative levels, institutional size, or the degree level of the IHE.

4. What impact, if any, do institution specific factors such as size, classification, and control (public or private) have on IHE and library efficiency ratings and the extent to which they are correlated?

Separate sets of hypotheses are presented to address this question. The first set of hypotheses focuses on the correlation of efficiency scores and administrative level in each of the three models, teaching, research and overall performance. It considers the correlation between the administrative level (academic library or IHE) and efficiency ratings. In each case, the overall population is considered then filters are applied to address the type of institutional control.

According to the population of DMUs:

1a. For either level of control, there is no significant correlation between the teaching efficiency measurements and administrative level in year 2007.

1b. For either level of control, there is no significant correlation between the teaching efficiency measurement and administrative level in year 2008.

2a. For either level of control, there is no significant correlation between the research efficiency measurement and administrative level in year 2007.

2b. For either level of control, there is no significant correlation between the research efficiency measurement and administrative level in year 2008.

3a. For either level of control, there is no significant correlation between the overall efficiency measurement and administrative level in year 2007.

3b. For either level of control, there is no significant correlation between the overall efficiency measurement and administrative level in year 2008.

A second set of hypotheses focuses on the impact of IHE size and IHE degree classification on efficiency scores for the population of academic libraries and IHEs combined. Its focus is on determining the extent to which IHE size and IHE degree classification have an impact on the efficiency scores of both levels of administration.

1a. For either level of control, there is no significant pairwise correlation between the teaching efficiency measurement and institutional size and DMU degree level in year 2007.

1b. For either level of control, there is no significant pairwise correlation between the teaching efficiency measurement and institutional size and DMU degree level in year 2008.

2a. For either level of control, there is no significant pairwise correlation between the research efficiency measurement and institutional size and DMU degree level in year 2007.

2b. For either level of control, there is no significant pairwise correlation between the research efficiency measurement and institutional size and DMU degree level in year 2008.

3a. For either level of control, there is no significant pairwise correlation between the overall efficiency measurement and institutional size and DMU degree level in year 2007.

3b. For either level of control, there is no significant pairwise correlation between the overall efficiency measurement and institutional size and DMU degree level in year 2008.

A final set of hypotheses is designed to examine the relationship between efficiency and IHE size and IHE degree classification at each level of administration, academic library and IHE. It differs from the set of hypotheses above in that it isolates efficiency scores for each level in its comparison. The focus of this set is on determining whether IHE size and IHE classification affected efficiency at either level of administration even when they might not affect efficiency for both levels of administration.

1a. For either level of control, there is no significant pairwise correlation between the academic library/IHE teaching efficiency measurement and institutional size and DMU degree level in year 2007.

1b. For either level of control, there is no significant pairwise correlation between the academic library/IHE teaching efficiency measurement and institutional size and DMU degree level in year 2008.

2a. For either level of control, there is no significant pairwise correlation between the academic library/IHE research efficiency measurement and institutional size and DMU degree level in year 2007.

2b. For either level of control, there is no significant pairwise correlation between the academic library/IHE research efficiency measurement and institutional size and DMU degree level in year 2008.

3a. For either level of control, there is no significant pairwise correlation between the academic library/IHE overall efficiency measurement and institutional size and DMU degree level in year 2007.

3b. For either level of control, there is no significant pairwise correlation between the academic library/IHE overall efficiency measurement and institutional size and DMU degree level in year 2008.

1.3 Purpose of the Study

Performance and accountability measures have become increasingly important for IHEs and the academic libraries that serve them. To date there have been no satisfactory objective measures developed that allow an academic library to assess its efficiency locally as well as to compare itself to peer institutions. This study will determine whether DEA may serve as one such measure for academic libraries and may be incorporated into a comprehensive assessment plan.

1.4 Definitions

This section includes the most essential definitions for terms and abbreviations used throughout this study.

- Data Envelopment Analysis (DEA)—a non-parametric linear programming technique that permits the incorporation of multiple inputs and outputs into an analysis that evaluates the relative efficiency of the population of homogeneous entities included in the comparison group.
- Decision Making Unit (DMU)—the entity, organization, or unit under study in the Data Envelopment Analysis. In order to be designated as a DMU the entity must have decision-making control over resources (inputs) and outputs. The group of DMUs considered for comparison in the DEA must be relatively homogeneous.
- CCR—a type of Data Envelopment Analysis that assumes constant returns to scale and convexity of the frontier, allowing the measurement of technical efficiency. This DEA was developed by Charnes, Cooper, and Rhodes in 1978 and does not incorporate consideration of DMU size in the evaluation.
- BCC—a type of Data Envelopment Analysis that assumes variable returns to scale and convexity of the frontier, allowing the measurement of both technical efficiency and scale efficiency. This extension of DEA was developed by Banker, Charnes and Cooper in 1984.

- CRS—constant returns to scale, an assumption in the CCR DEA model which provides that the size (scale) of the DMU has no impact on the efficiency of the DMU.
- VRS—variable returns to scale, an assumption in the BCC DEA model which provides that the size (scale) of the DMU may impact the efficiency of the DMU.
- Efficient Frontier—the piecewise linear convex curve formed by the efficient DMUs in the population of DMUs under analysis and which envelops all other DMUs under analysis, thus giving the method its name “Data Envelopment Analysis” (Avkiran 2001).
- Efficiency—the measure of the ability of an entity, or DMU, to transform resources/inputs into the production of outputs/services (Shim 2003, 312). There are two primary types of efficiency measures in Data Envelopment Analysis: technical efficiency and scale efficiency.
- Technical Efficiency—occurs when a DMU cannot produce more output from its existing inputs. Some argue that technical efficiency is the only valid performance measure, aside from the delivery of quality education, for tertiary IHEs (Abbott and Doucouliagos 2003).
- Scale Efficiency—“the extent to which a DMU can take advantage of returns to scale by altering its size toward the optimal size (defined as the region in which there are constant returns to scale in the relationship between inputs and outputs) (Abbott and Doucouliagos 2003, 91)”.

- IHE—institution of higher education, used throughout this study to refer to a public or private institution of higher learning in the state of Texas that offers at least a four-year (baccalaureate) degree and may also offer master's, professional, and doctoral degrees. Specialist institutions, institutions offering only two-year degrees or institutions offering only graduate degrees are excluded from the definition and the study population. This entity reports annually to the Integrated Postsecondary Education Data System.
- Academic library—within the context of this study, used to refer to the component of the IHE as defined above that acquires resources including but not limited to books, serials, media, non-print materials, microforms, cartographic materials, archival materials, and full-text database access. It provides services including but not limited to book, media, and other print and non-print material circulation, interlibrary loan, information literacy instruction, and reference services and other user services. This entity has reported annually to the Integrated Postsecondary Education Data System and the Texas Academic Library Statistics Program.
- IPEDS—Integrated Postsecondary Education Data System. This data center allows the user to create data sets for institutions of higher education based on specific variables or institutional characteristics or to download all data on all institutions for a specific year, for use in any data analysis tool. Data sets on

academic libraries are collected biennially in even numbered years and may be downloaded for analysis using any number of data analysis tools.

- TALS—Texas Academic Library Statistics. This data center allows the user to download the complete file resulting from the Texas Academic Library Survey which is collected in odd numbered years. Once downloaded the data sets can be analyzed using any number of data analysis tools.

1.5 Limitations and Assumptions

This study is limited by its use of available statistics collected through several sources. The Integrated Postsecondary Education Data System (IPEDS) is used to collect data specific to the academic libraries and IHEs in the study. The Texas Academic Library Survey (TALS) provides additional library-related data for the study. The Texas Higher Education Coordinating Board's (THECB) Accountability System provides some institution level data. The Web of Knowledge© and Scopus© are used to gather faculty/research publication data. Because the first three datasets were collected by federal and state agencies for other purposes, they require some modifications for the purposes of the study; however because the data submission was mandated the datasets are relatively complete. It is assumed that institutions answered each question accurately and completely, and that each institution followed reporting procedures correctly. The use of only two relatively comprehensive citation resources for the location of faculty research products introduces the possibility that some faculty research products may be overlooked in the gathering of data. The assumption is made, however, that between these two multidisciplinary sources, a majority of peer reviewed products will be located. The use of Scopus also permits the inclusion of patents. The intention of the review is to apply a methodology which allows the researcher to arrive at a number of intellectual products for each IHE that is consistent across the research sample.

This study focuses upon IHEs in the state of Texas that reported data to IPEDS and whose libraries completed the IPEDS Academic Library Survey and the TALS Academic Library Survey during the years under study. Institutions are included only if they offer a bachelor’s degree or higher and if they are not specialized institutions. Only institutions with complete data sets for the two years under study, 2007-2008, are included in the analysis. No results can be generalized to institutions outside the state of Texas, to institutions offering less than a bachelor’s degree or to specialized institutions, without further study.

1.6 Significance of the Research to Library and Information Studies

While researchers have used DEA to study institutional efficiency with respect to teaching and research and have used DEA to study the efficiency of academic libraries, no study to date has compared library efficiency to institutional efficiency to determine whether academic libraries were maintaining alignment with the IHEs they serve in the areas of teaching and research. This study will contribute to the literature by providing additional information for library managers both on the efficiency of academic libraries relative to their institutions in the state of Texas and on the usefulness of DEA as a tool for library performance assessment. It will assist in determining whether DEA as a research tool for librarians and library managers is able to provide specific useful data in the analysis of individual administrative unit or level efficiency differences. It will also assist in determining whether the complexity of the method limits its usefulness as a research and decision-making tool in libraries.

If the DEA analysis proves useful in this project, this study will provide a basis for future studies that may compare institutions and their libraries across regions, types of institutions, or historical periods. Librarians and library managers may also find that they can adapt this methodology for use in their own institutional assessments. If the method does not prove useful results then this also provides important information for librarians as they continue to search for appropriate ways to assess the library’s contribution to the accomplishment of institutional mission.

CHAPTER II

REVIEW OF LITERATURE

2.1 Introduction: Background

Traditional institutions of higher education (IHEs) are primarily non-profit or not-for-profit organizations that produce largely intangible products—educated students and research. While it is important to any IHE to have objectives such as remaining financially sound and operating with fiscal responsibility, neither of these demonstrates progress toward the primary goals of the IHE, producing educated students and research. The library is a unique administrative service unit within the IHE in that it, too, produces largely intangible products that contribute to the achievement of IHE goals (Kantor and Saracevic 1999). The difficulty thus lies in defining and then measuring the contribution of the library to the overall goals and objectives of the IHE, given the intangibility of the primary products of both entities. Because ideally the academic library service environment is integrated with the educational service environment, alignment of assessment processes is a necessary component of evaluation (L. N. White and Blankenship 2007).

There can be no doubt that IHEs operate in an environment that is constrained by limited resources and increased demands for accountability. The report "A Test of Leadership" released in 2006 by the U.S. Commission on the Future of Higher Education was critical of higher education and called for significant improvements in the areas of access, affordability, financial aid, learning outcomes, transparency and accountability, and innovation. It cited rising time to degree rates and falling adult literacy rates and argued that while a great deal of effort was expended getting students into IHEs, not enough effort was focused on graduating students or on ensuring that those that were graduated had achieved learning outcomes at the baccalaureate level. It also stated that little was being done by IHEs to ensure that they were capitalizing on institutional capacity, improving productivity, enhancing effectiveness, or using research on teaching and learning to benefit students (Commission on the Future of Higher Education 2006, 9–13). The report recommended that policy makers and institutional leaders cut costs and increase productivity, increase the supply of education, and develop a transparent accountability system with performance based measures (2006, 33–44). This report was not the first to recommend changes to the higher education assessment and accountability system. Indeed two other reports released in the previous eighteen months had made similar recommendations. The Business Higher Education Forum's 2004 report called for an improved accountability system that ensured IHEs developed effective measures and clearly communicated the results of their assessment processes in an understandable format to external stakeholders (Business Higher Education Forum 2004). The National Commission on Accountability in Higher Education called for a system that provided valid and dependable information, discouraged IHEs from achieving minimum standards, focused seriously on performance improvement, avoided superficial comparisons, and provided clear and relevant information to all stakeholders. It contrasted this with the current system which it described as “cumbersome, over-designed, confusing, and inefficient.” It faulted the current system because it “fails to answer key questions, it overburdens policymakers with excessive, misleading data, and it overburdens institutions by requiring them to report it (National Commission on Accountability in Higher Education 2005, 6).” The Spellings Commission’s report followed a number of other reports and summarized criticisms of and concerns about higher education accountability. These concerns were held by a wide variety of higher education stakeholders including Democrats and Republicans, business leaders, policy makers, students and parents, and those in the field of higher education itself. The Spellings report required a proactive and intelligent response in several areas including assessment instruments, benchmarking, and transparency (Ewell 2008).

State governments have also been involved in monitoring the performance of public IHEs using accountability and assessment mechanisms for decades. Statewide accountability systems have used various approaches and performance indicators designed to help IHEs improve performance but many of these have suffered from lack of collaboration between higher education officials and state policy makers, lack of agreement on the purpose of measures, lack of clarity about the design of and audience for the measures, and sheer volume of data collected (Layzell 1999; Wellman 2001; Martinez and Nilson 2006).

Even as the demands on institutions for increased accountability and increased educational and research outputs have increased, funding available to support the production of those outputs decreased. State support for higher education declined throughout the 1980s and, though appropriations leveled off and some gains were made in the 1990s, overall there was a $7.7 billion dollar decrease in state support for higher education. By the first decade of the twenty-first century costs began to increase significantly for IHEs and technology leveled the playing field by enabling institutions to offer their educational product anytime and anywhere. The education market place became more competitive. During this the same period the economy worsened and as state budgets declined appropriations for higher education, a largely discretionary item, shrank (Gaither 1999; Business Higher Education Forum 2004; Adams III and Shannon 2006; Cheslock and Gianneschi 2008). By 2011 with a recession in place and state appropriations for higher education continuing their decline, public IHEs, which rely primarily on state appropriations and tuition revenues to fund the educational mission, faced difficult decisions related to raising tuition, further reducing spending, risking declines in quality, and the possible loss of faculty who would leave for institutions with better compensation packages. In many states what ensued was a clash between IHE administrators and legislators over who was to blame for the increased burden on students and their families (Kiley 2011).

Data available through the Delta Cost Project assists in illustrating the changes in revenue sources for IHEs both public and private nationally. The Delta Cost Project's mission is “to improve public accountability for spending in higher education through the presentation of measures that put financial information into context, showing how money is spent and how that spending relates to institutional performance (Desrochers and Wellman 2011, 5).” Its report “Trends in College Spending, 1999-2009” examines the impact of the most recent recession on higher education funding and spending patterns during this period as well as implications for the future. The report’s analysis of data for the period 1999-2009 found that for 2009 across public institutions the average student subsidy fell by 3-5 percent and in private institutions the subsidy fell by over 8 percent, reaching a ten-year low. At the same time tuition costs continued to increase, rising to levels at which they now cover more than half of the education and related (E&R) costs at public research institutions, almost half at public comprehensive institutions, and a third of costs at community colleges. The ten-year analysis shows an increase of 12-14 percent in tuition costs overall at public four-year institutions (9 percent at community colleges) during the ten year period. Tuition increases in 2009 averaged 1.5 to 2 percentage points for just one year, equaling or surpassing cumulative increases for the past five years nationally.

In private IHEs costs also increased during the same period, with student share of educational costs rising from 69.7 percent to 73.9 percent of total educational costs at private research institutions between 1999 and 2009, from 81.9 percent to 89.9 percent of total educational costs at private master’s institutions, and from 62.2 percent to 70.0

percent of total educational costs at private baccalaureate institutions on average nationally (Desrochers and Wellman 2011, 33).

Public sector tuition increases in 2009 were “almost entirely the result of cost-shifting to replace institutional subsidies, rather than to finance new spending (Desrochers and Wellman 2011, 35).” Indeed, in public four-year institutions tuition dollars replaced virtually all other lost revenues and in community colleges the increases in tuition were not enough to offset decreases in other revenues and overall spending by institutions decreased as a result. Thus while students spent more on education, the institutions actually had less to spend on the education they provided for students. For example, in 2009 overall tuition increases at a public master’s institution increased by $225. At the same time state and local appropriations decreased an average of $590, leaving a deficit of $365. In spite of this the average increase in spending on education per student was $26. Institutions reduced spending in other areas, including deferred maintenance and administrative overhead in order to maintain spending in education-related expenses. Additionally, findings indicated that public institutions, which enroll more students than private institutions, had fewer resources and spent less per student.

Using data from the Integrated Postsecondary Education Data System (IPEDS) data collection the Delta Cost Project developed an eleven year matched set of statistical information on IHEs for use in analysis. Institutional data in the dataset were drawn from the IPEDs surveys on finance, enrollments, completions, staffing and student aid and were adjusted for inflation and standardized by FTE enrollments. The project used a matched set of institutions, meaning that it only used data from an IHE if it reported a complete set of data for all project years. Overall the matched set accounted for approximately ninety percent of two- and four-year institutions in the public and private non-profit sectors, organized by Carnegie classification sectors as they were identified in 2005 (Desrochers and Wellman 2011, 6). The project then made these data publicly available to others. Based on summary data provided by the project, an analysis of the changes in sources for IHEs from 1999-2009 was conducted.

Figure 2.1 illustrates the portion of education costs funded by tuition and by subsidies for public institutions at the research, masters, and community college levels from 1999-2009. It shows the clear decline in state funding for higher education nationally and the relative increase in reliance on tuition as a source of funding for all three types of public institutions. The decline in subsidies is most noticeable in the research and master's level institutions.

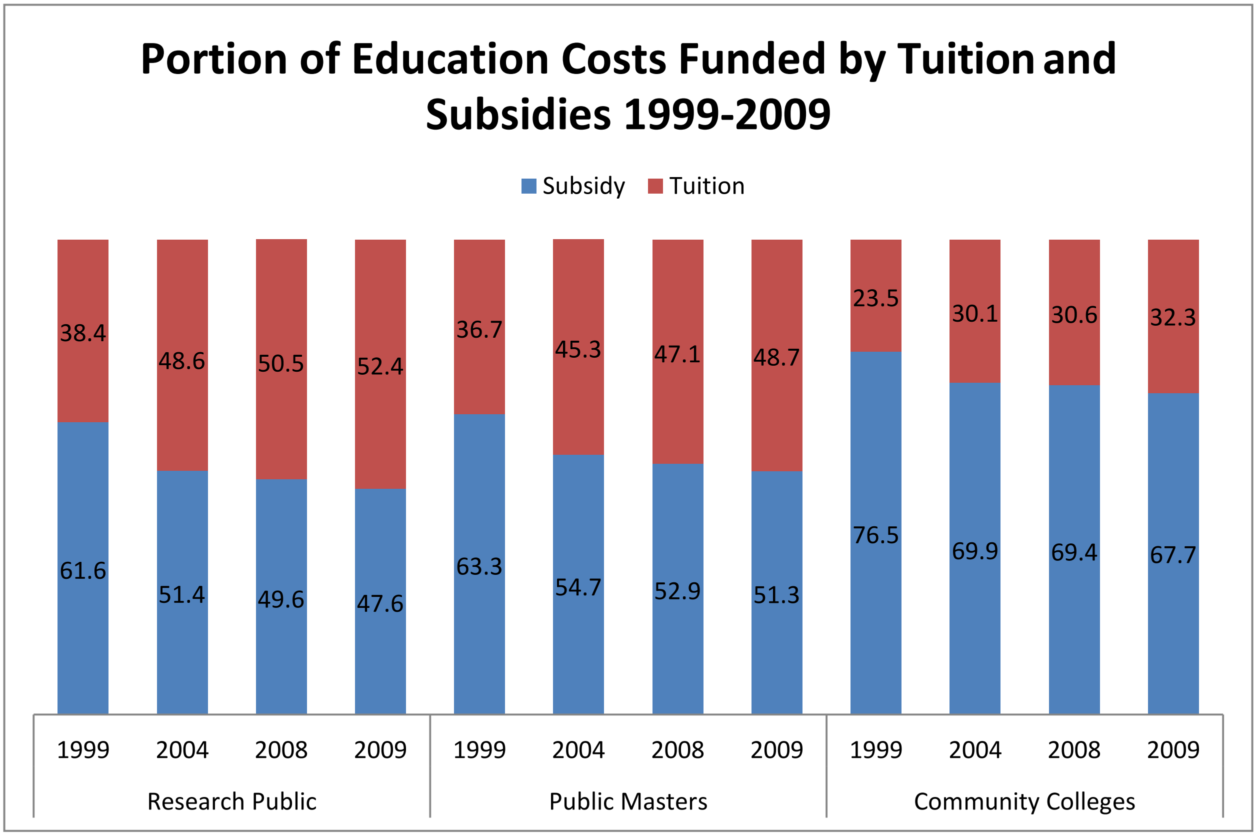

Figure 2.1: Portion of education costs funded by tuition and subsidies 1999-2009

In addition to net tuition and state and local appropriations, other sources of revenue for IHEs include federal appropriations and federal, state and local grants and contracts; auxiliary enterprises, hospitals, independent operations and other sources; and private and affiliated gifts, grants, contracts, investment returns, and endowment income. For public IHEs, the decade from 1999-2009 saw research institutions increase reliance on tuition revenues, raising these revenues an average of 5.78 percent as state and local appropriations declined an average of 7.72 percent. Overall tuition increased 34.16 percent over the decade while state appropriations declined 23.52 percent. At the same time revenues from federal appropriations and federal, state and local contracts increased by an average of 7.28 percent and as a result of the economic downturn investment and endowment returns and gifts declined an average of 8.07 percent (See figure 2.2). For public master's institutions tuition increased an average of 7.89 percent over the decade while state and local appropriations declined 9.78 percent over the same period. This represented an overall tuition revenue increase of 31.67 percent and a decline in state appropriations of 21.57 percent. Federal appropriations and federal, state and local contracts only increased an average of 1.77 percent, while investment and endowment returns declined an average of 0.98 percent (See figure 2.3).

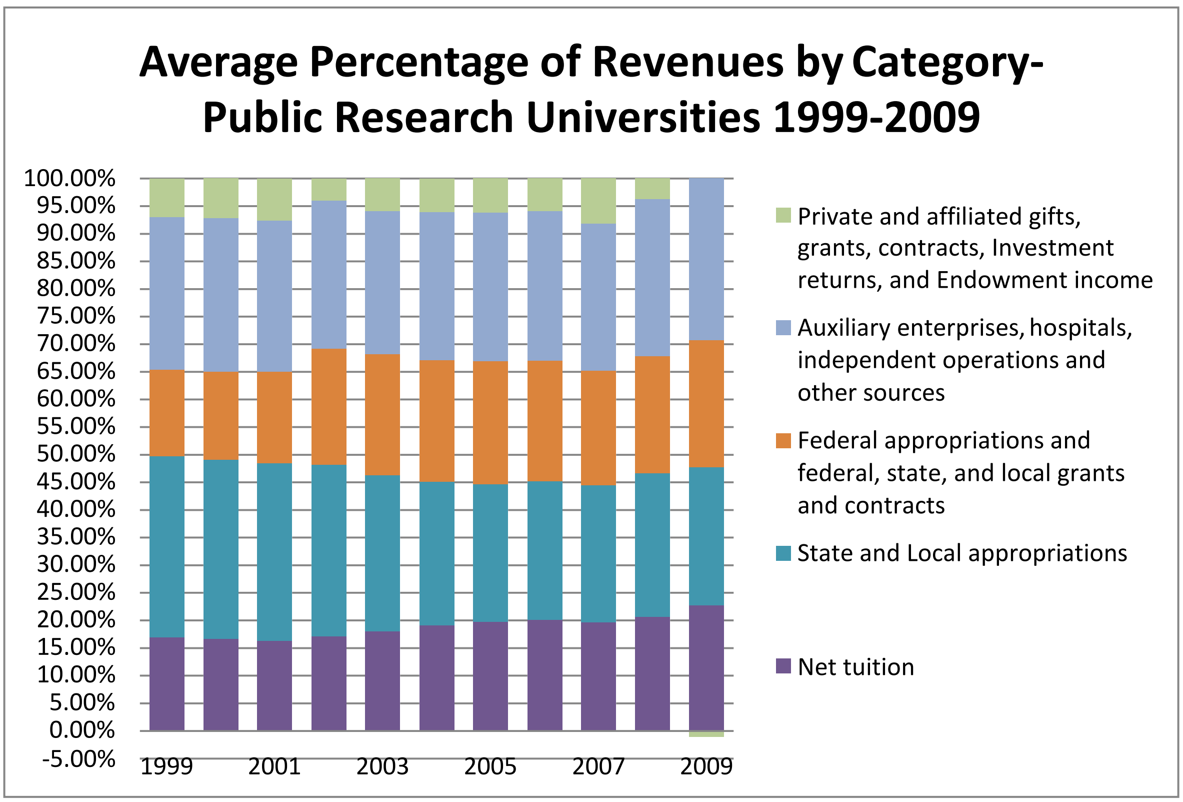

Figure 2.2: Average percentage of revenues by category-public research universities 1999-2009

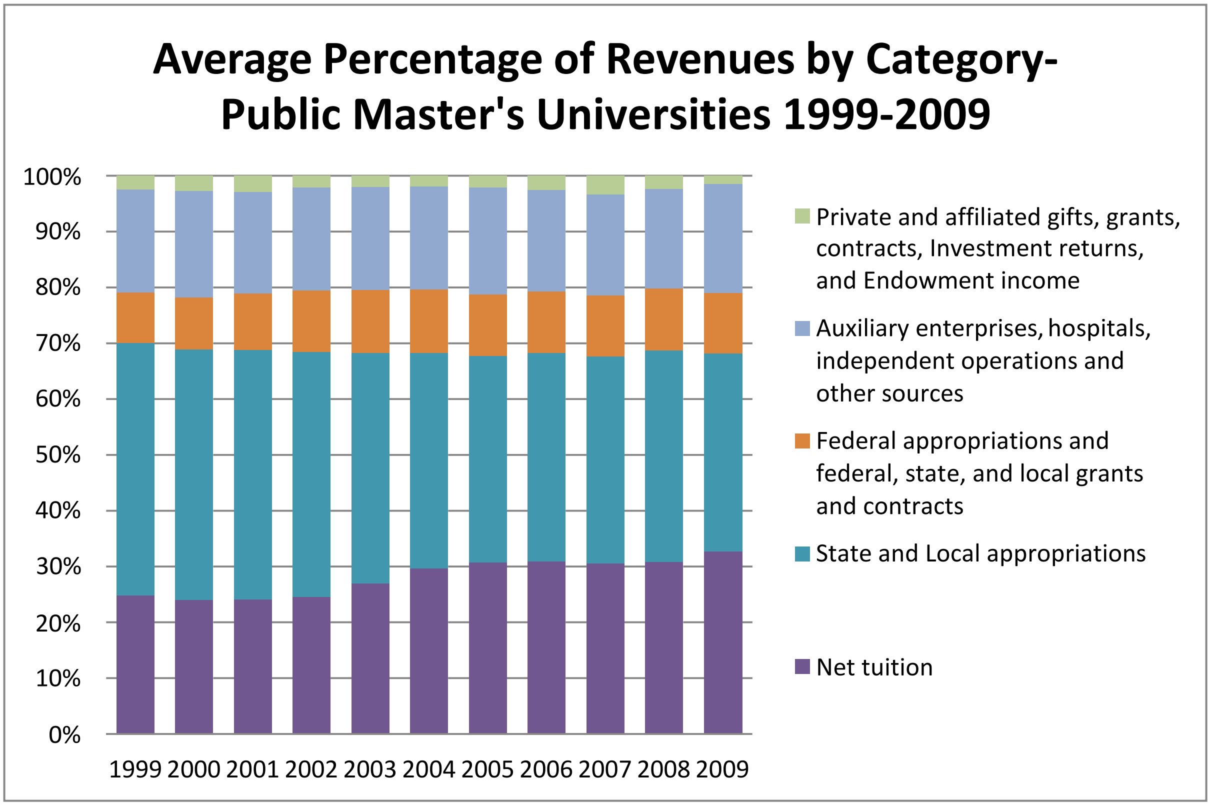

Figure 2.3: Average percentage of revenues by category-public master's universities 1999-2009

On the private IHE side, there is far less reliance on state and local appropriations as a source of revenue and far greater reliance on income from investment and endowment income. At the private research institution level, investment and endowment income losses of more than 100 percent in 2009 increased reliance on tuition, federal appropriations, and auxiliary enterprises to three times their 2008 levels. Until 2008, however, reliance on tuition had only increased by 4.78 percent over the decade and reliance on state appropriations which comprised less than 2 percent of the overall budget, rose by only 0.47 percent. Overall there was an increase of 19.99 percent in tuition rates and an increase in state support of 66.29 percent for this class of IHEs. Figure 2.4 illustrates these changes.

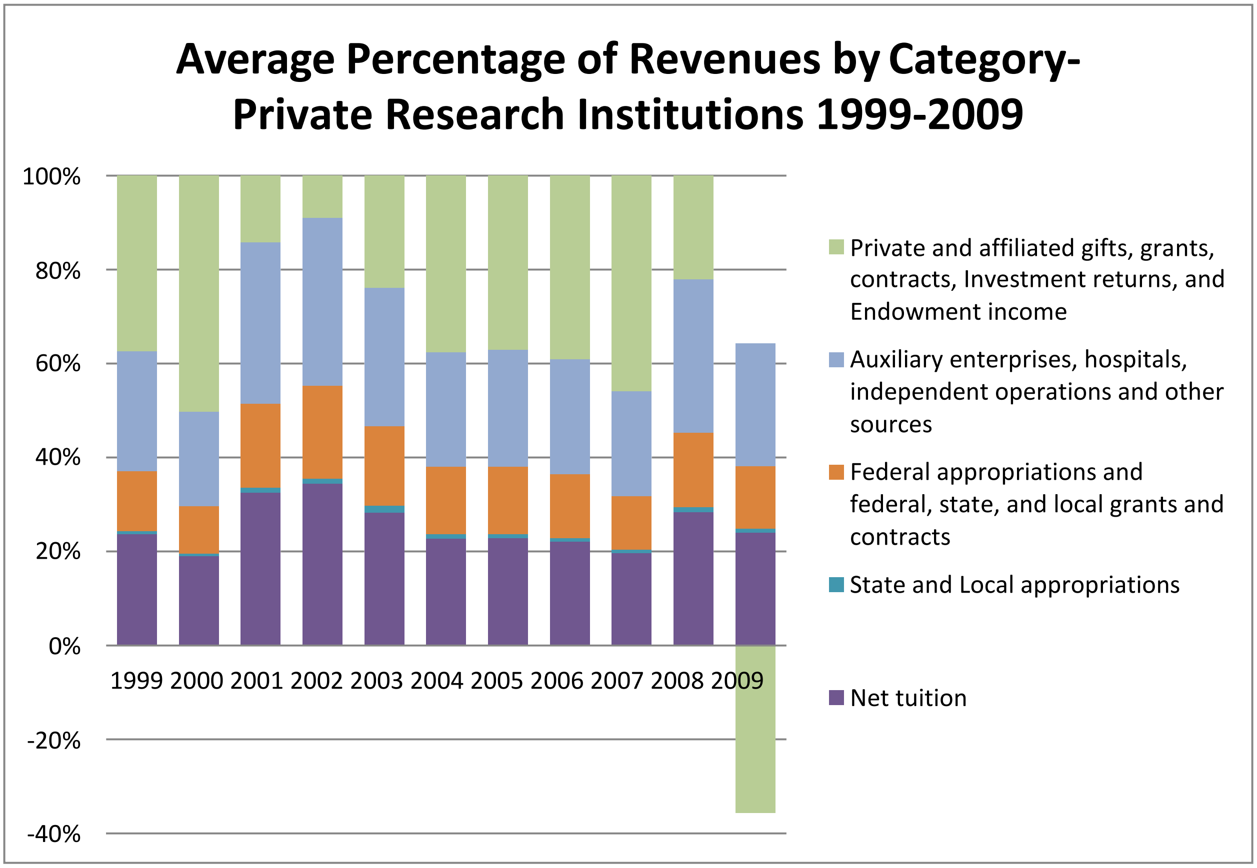

Figure 2.4: Average percentage of revenues by category-private research institutions 1999-2009

Private Master's Institutions rely much more heavily on tuition as a source of revenue. The decade 1999-2009 saw tuition increase as a portion of revenues an average of 25.10 percent, and state appropriations, which have consistently accounted for less than 2 percent of revenues, declined by 0.1 percent. Over the decade the tuition rates increased by 45.44 percent while state appropriations declined by 4.68 percent. Revenue from auxiliary enterprises increased by 4.94 percent over the decade and made up some of the revenue lost in investments and endowments which declined 11.83 percent between 1999 and 2008, accounting for a decline in revenues of 49.99 percent and another sharp drop of 157.45 percent between 2008 and 2009. Figure 2.5 illustrates these trends.

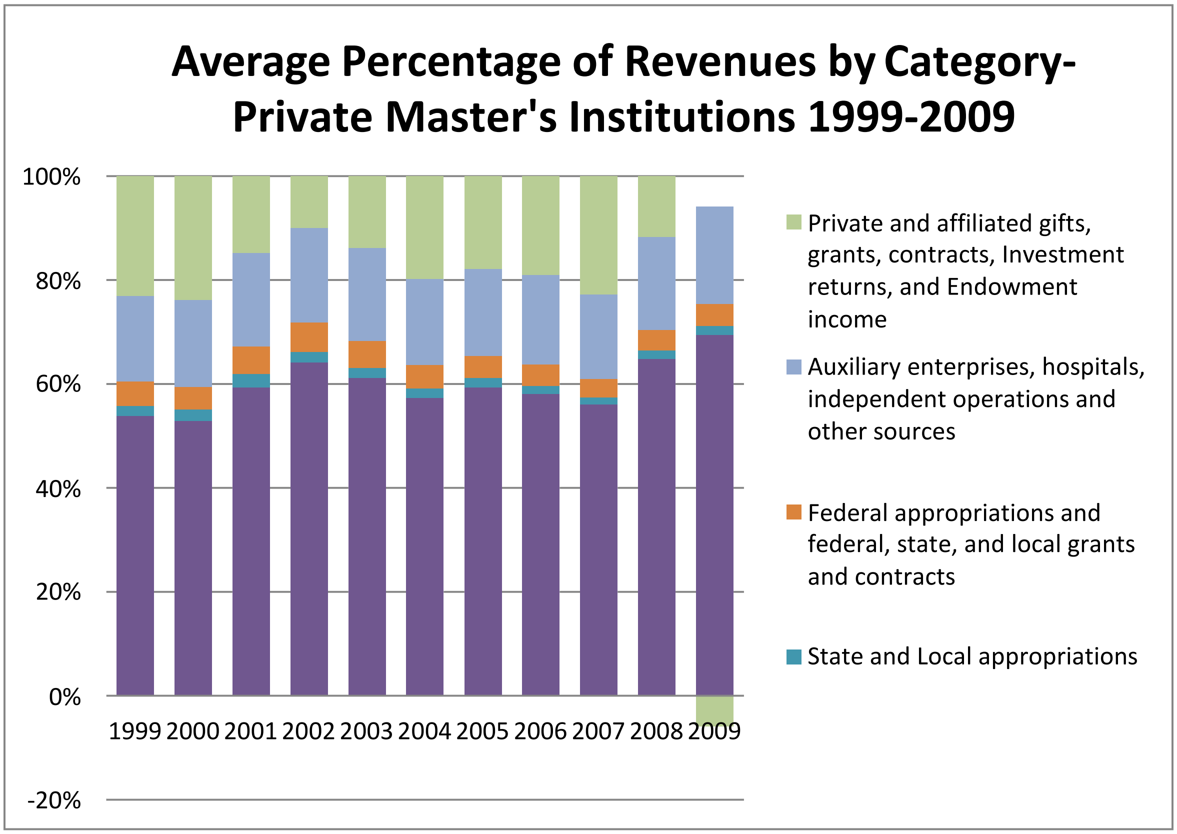

Figure 2.5: Average percentage of revenues by category-private master's institutions 1999-2009

Private bachelors institutions, like other private IHEs, receive little state support and rely primarily on tuition, auxiliary enterprises, and investments and endowments as sources of revenue. During the period 1999-2008 these IHEs increased revenue from tuition 16.41 percent and revenue from state and local appropriations increased by 0.68

percent. Average tuition rose 47.44 percent during the period and state and local appropriations rose 44.72 percent, while remaining less than 2.5 percent of total revenues. In 2009, dramatic losses in endowments and investments of more than 63 percent meant that tuition revenues took on a greater significance, accounting for more than 100 percent of total revenues. Likewise, auxiliary enterprises, which accounted for only 23.28 percent of total revenues in 2008 averaged 46.88 percent of revenues in 2009. Figure 2.6 illustrates these trends.

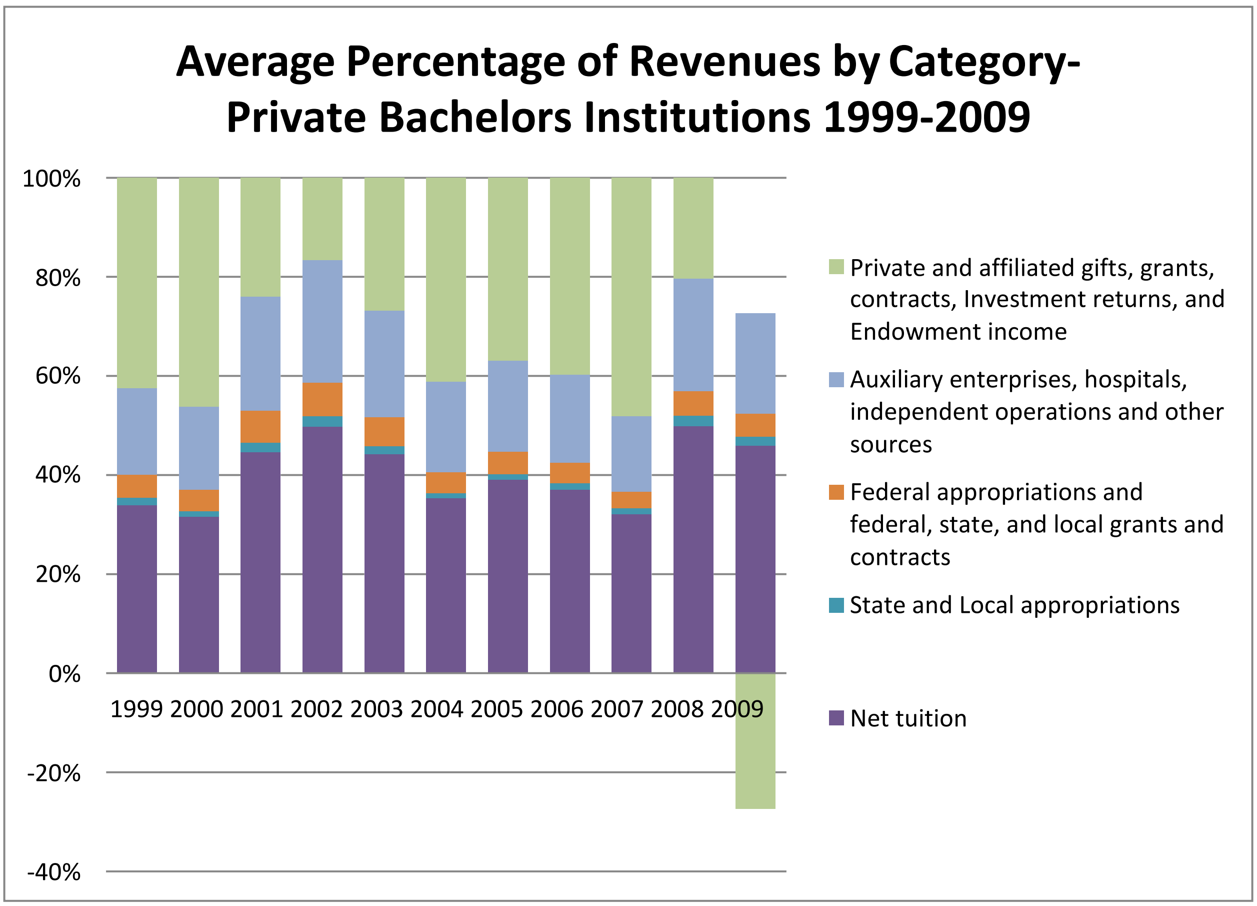

Figure 2.6: Average percentage of revenues by category-private bachelors institutions 1999-2009

As the level of resources available decreased, IHEs have increasingly been called upon to demonstrate to multiple constituencies that they not only are effective but that they are using resources efficiently in the production of graduates and research. Breu and Raab emphasized that both budget and quality of higher education issues came together to create an environment in which higher education administrators were “more willing to accept the notion of efficiency and its measurement in making informed managerial decisions.” They also noted that a problem associated with looking at higher education in a “production paradigm is the notion that several of the outputs of higher education are quite intangible (1994, 34). Still in the production context graduation levels/rates have become one of the major output performance indicators of higher education efficiency, with retention rates being a second important and often quoted measure.

The Business Higher Education Forum’s 2004 report focused on increasing educational productivity as a means not only of cutting costs but also of protecting and improving the quality of the educational product. In particular it recommended that IHEs proactively participate in developing new assessment instruments that were able to clearly communicate the extent to which they met established standards or goals. It also emphasized the need for alternative instruments or measures to account for variations in IHE types and missions (Business Higher Education Forum 2004).

The National Commission on Accountability in Higher Education’s Report suggested that the national agenda for higher education should be “improving student attainment, sustaining and enhancing the quality of research and service, and increasing productivity (2005, 10).” The Commission’s report highlighted the public priorities of “improving access, graduation rates and learning; increased efficiency, closing achievement gaps; generating beneficial research; improving the quality of life in communities; and producing graduates able to meet critical workforce needs (2005, 12).” These it compared to IHE priorities, which were often placed in the context of competition with other IHEs, to obtain resources and prestige, recruit students and faculty, and upgrade their mission. It demonstrated how these IHE priorities were not opposed to the public priorities and were in fact “intrinsically grounded” in them but showed how the public priorities might be minimized when competition was intense and suggested that an improved accountability system was one means of ensuring that public priorities remained at the top of the IHE agenda. The report further recommended that the number of measures be focused on and limited to those measures that related to public priorities and that the measures have the ability to address questions that were related to those priorities. It recognized that more data did not necessarily equate to more accountability and that state increases in reporting requirements had often resulted in IHEs meeting reporting requirements rather than in actual improvements or increases in efficiency. Finally, the report asserted that a call for increased attention to public priorities was not a call for increased regulation of IHEs but a call for increased cooperation among stakeholders to ensure that public priorities remained a primary focus (2005, 12–19). The report recognized that quality of education and efficiency or widespread participation in education appeared to be contradictory goals but asserted that both were achievable by financing "improvements in both scale and quality by pursuing necessary productivity gains *and* making strategic public investments (National Commission on Accountability in Higher Education 2005, 29)."

The academic library, as a support unit within the IHE, has also felt increased pressure to demonstrate both its efficiency and its effectiveness. As early as 1973, researchers were highlighting the importance of evaluation in academic libraries. De Prospo and Altman pointed to the unwillingness of budget officials to accept the idea of the "goodness" of library services without quantifiable evidence as funding became increasingly scarce. Orr argued for the use of mathematical models which could demonstrate that libraries were using resources efficiently. Both warned that libraries should develop measures and criteria by which they might determine whether resources were used to maximum advantage or others would impose criteria and measures on them (De Prospo and Altman 1973; Orr 1973).

At the same time, researchers focused on library assessment advocated linking library assessment to the overall mission, goals and objectives of the parent institution (Hamburg et al. 1970; Hamburg, Ramist, and Bommer 1972; Rzasa and Baker 1972; Orr 1973; DuMont and DuMont 1979; Kantor 1984; Pritchard 1996; Lindauer 1998; Wallace 2001; L. N. White and Blankenship 2007). Hamburg (1970) cited the importance of allocating limited resources to achieve maximum benefit given the economic pressures libraries faced. In terms of academic libraries, he and fellow researchers asserted that "…the objectives [of the library] must be defined in terms of the needs and requirements of the personnel involved in the teaching and research efforts of that particular university (Hamburg et al. 1970, 11)." Others also stressed the need for academic library evaluation that was conducted in the context of the larger organization because of the influence that both library users and the funders have on it (Rzasa and Baker 1972; DuMont and DuMont 1979). Kantor (1984) linked objective measurement to the demonstration of library efficiency and program effectiveness with respect to the activities, goals and objectives of the larger institution. Library and academic administrators might employ objective measures to identify areas of strength and weakness, as well as to define the costs associated with the support of both teaching and research. Pritchard (1996) recognized that few libraries were accountable only to themselves and focused on the larger context for assessment. She (1996)asserted that "[t]he major objective for academic libraries, especially in an environment of increasing economic pressure, structural change, and technological innovation, must be to align themselves with the structures of higher education and the criteria by which those institutions are judged (1996, 573)." Lindauer (1998) highlighted the internal focus of library assessment processes, which failed to address how libraries contribute to institutional goals. Common errors libraries make in the assessment process included the failure to organize data in ways that are meaningful to academic and other administrators outside the library, failure to use common language that is easily understood by these administrators, and presentation of data without providing sufficient explanation about how library resources/services make a difference to student learning or to faculty research/scholarship or other campus-wide goals (Lindauer 1998, 546–547). Wallace (2001) recommended a consistent methodology that included performance indicators/measures and benchmarks. Such measures would take into account the goals and objectives of the parent institution, accrediting institutions and the libraries, and could be presented in a meaningful way for all the involved groups (that is, without unnecessary jargon). It would also allow for comparison among libraries and could be easily tailored to different types of institutions. White and Blankenship (2007) argued that a lack of alignment between library and institutional assessment processes could cause negative and long-term consequences for the library. They pointed out that the transitions occurring in academic libraries in recent years raised numerous questions related to service quality, organizational performance and impact, resource efficiency and utilization, and support of the larger institution's goals and objectives. They asserted that it was the library's responsibility to ensure that alignment occurred and that assessment was able to measure the extent of alignment as well as the extent to which the library's programs and services were efficient and effective (2007, 108–109).

In October 2011 the Association of College & Research Libraries (ACRL) Board of Directors approved a completely revised "Standards for Libraries in Higher Education (Anon. 2011c)." Intended as a framework and guide for comparative, contextualized assessment, the new standards were developed to assist all types of academic libraries in designing and implementing comprehensive assessment programs aligned with the mission, goals, and objectives of the IHEs they serve. The introduction to the document emphasized the importance of demonstrating the value of academic libraries and documenting contributions to IHE institutional effectiveness. The document acknowledged that the library operated within the larger context not only of the IHE it served, but also the overarching political, social, and economic climates in which higher education operates. Echoing the voices of library researchers such as Pritchard, Wallace, Lindauer, White and Blankenship, and others, it highlighted the increased integration of library standards in regional accreditation criteria and focused on incorporating the language of accreditors into the standards.

Prior to drafting the standards, the ACRL Standards in Higher Education Task Force surveyed library directors from all types of academic libraries to determine the level of knowledge of, interest in, and use of existing ACRL standards. The task force also requested input regarding essential elements of revised standards. Of the 1,260 library directors who received the survey, 988 responded and 833 completed the survey, a response rate of more than 66 percent. Less than half of respondents used the existing standards and sixteen percent were unaware of their existence. Respondents indicated the importance of relating revised standards to regional accreditation standards and an interest in training/professional development in the use of the standards. Results indicated a general desire for guidance on creating benchmarks and conducting self-studies. There was also an increased focus on outcomes assessment and a need for assistance in designing and implementing outcomes based assessment plans. The task force used feedback from the survey to develop a draft of the standards, then sought input from the library community on the draft before presenting a final version to the ACRL Board for approval (Iannuzzi and Brown 2010).

The standards distinguish between outcomes-based assessments, which are user centered, and performance-based assessments, which are library centered. The document discusses the importance of addressing both aspects in any comprehensive library assessment plan. The text incorporates the common language of higher education assessment, providing a vehicle through which library assessment personnel may effectively communicate desired outcomes and measures, assessment plans, and results of assessment. Common assessment language was employed to augment the library's ability to demonstrate its value and contribution to the IHE mission in a way that university administrators and other stakeholders might readily understand.

Nine broad principles define core assessment concerns for academic libraries, including library collections, services, personnel, environments, and assessment. They communicate library-identified roles and concerns within the context of the larger IHE served by the library. Performance indicators for each principle highlight aspects of the principle that can be addressed by measurable outcomes or objectives. The document is ambitious in its attempt to establish principles that can be applied across IHE and library types. It links several directed performance indicators to each standard. It also provides sample outcomes for some performance indicators, illustrating how libraries might evaluate themselves within the context of their individual institutional missions and goals.

While the standards provide a starting point for establishing integrated and comprehensive assessment plans, the length and complexity of the principles, performance indicators and outcomes may discourage consistent use of the standards. For those who are relatively new to academic library assessment the standards are intimidating and overwhelming. With a focus on outcomes and effectiveness evaluation, it relegates efficiency measures primarily to an appendix. As a result efficiency measures appear less important in the overall context of assessment. Thus the level of importance that university administrators place on efficiency measures is not adequately addressed. While numerous articles and documents outside the library world were consulted in the drafting of the standards, the linkages between the library assessment plan and the larger IHE assessment environment are not necessarily direct and clear. While library directors and others in the library community were encouraged to provide input in the standards' development, it does not appear that other stakeholders were surveyed or consulted. Like previous standards, these continue to focus on the role the academic library wishes to play in the IHE rather than consistently emphasizing the need for library programs, operations, services and assessment to address the roles the IHE expects it to perform. The document is an improvement over previous standards in terms of alignment with accreditation requirements and recognition of the assessment environment. However, it remains library-centric in its development, reflecting limited consultation with and input from IHE stakeholders outside the library world. It assumes that the roles academic libraries have identified as important mirror the roles that IHE administrators, library users, and other stakeholders would acknowledge as essential to the mission of the IHE. In spite of early acknowledgements of the importance of alignment with the mission, goals, and concerns of the IHE organization served by the library, it does not, as a whole, appear to base its development on IHE mission and needs.

2.2 Efficiency v. Effectiveness

Efficiency and effectiveness are complementary components of the assessment process. In the late 1970s library researchers were already linking the two. They attempted to relate library standards and statistics in terms of both efficiency and effectiveness and to develop meaningful measures that could be used in an overall assessment program (DuMont and DuMont 1979). Cronin (1985) highlighted the increased emphasis on measurable objectives in the library literature on evaluation, observing two distinct themes. First, data collection and quantitative analysis focused on efficiency of operations followed by data manipulation to determine effectiveness of operations. Second, statistical analysis was used to assist managers in decision making. In an often cited work, Knightly (1979) listed four primary types of evaluation that were possible in the library/organizational context: effort evaluation, examining primarily inputs; process evaluation, examining the appropriateness and efficiency of programs and activities; effectiveness evaluation, examining the extent to which outputs accomplish organizational objectives; and impact evaluation, examining the extent to which accomplished objectives meet the needs of the parent organization or the larger community. To these he added a fifth type of evaluation, cost-benefit or cost-effectiveness evaluation. He noted that each of these had a place in a comprehensive assessment program but that most managers focused on one type of evaluation and ignored others almost entirely. In a study of more than seventy library annual reports he found that more than 50 percent focused on process (efficiency) evaluation, while only slightly more than 31 percent included output (effectiveness) evaluation, 17 percent included input (effort) evaluation, and virtually no reports included impact evaluation. He also found that most managers used a very small number of criteria in their evaluation process. He recommended that managers begin incorporating multiple types of evaluation and multiple types of measures into comprehensive assessment programs.

Effectiveness has been defined as “to what extent we are meeting our goals and objectives (Ralli 1987, 2),” while efficiency has been defined as “the ratio between effort and performance (Ralli 1987, 2).” Put more simply, effectiveness indicates that “the right job as been done” while efficiency focuses on the extent to which “the job has been done right” (T. Chen 1997b, 72). With regard to resource utilization, efficiency measures determine whether the entity (department, unit, institution) being assessed is achieving objectives with a minimum use of resources. Improvements in efficiency may have a positive impact on effectiveness if the entity being assessed has selected the optimal means of achieving its objectives.

Blaise Cronin discussed the relationship between efficiency and effectiveness in a 1982 presentation published in ASLIB Proceedings:

> "Efficiency is a feature of a service which can be achieved without taking into account the organization's overall aims or intentions….Efficiency can be measured without reference to effectiveness, though that does not mean that consideration of efficiency should not be taken into account when assessing performance effectiveness. Whenever possible efficiency should be striven for within the framework of an organization's or institution's programme of objectives (B. Cronin 1982b, 274)."

What is most notable is the notion that effectiveness can exist without efficiency and/or efficiency without effectiveness but, as Cronin later describes, one would expect a more efficient organization to provide more effective service. He suggests that greater efficiency leads to greater effectiveness. He does not suggest that greater effectiveness necessarily leads to greater efficiency (B. Cronin 1982b). Neuman and Easun (1994) agree that an organization can be effective but not efficient or efficient but not effective; however, they argue that it is more likely for an efficient library to be effective and an effective library to be efficient. Lindsay (1982) brings efficiency and effectiveness together conceptually, noting that efficiency links inputs with outputs and effectiveness links outputs with goals or other criteria. In the context of higher education, assessing an institution's (or an institutional component's) overall performance requires "asking what it is accomplishing and how well it is carrying out its tasks….how effective is the institution in attaining its goals, and how efficiently does it use its resources in the process? (1982, 177)"

Thus, efficiency and effectiveness have been shown in the literature to be important and complementary components of the evaluative process. They have been alternatively viewed as separate processes that nevertheless informed one another (Knightly 1979) and as links in the evaluation chain (Lindsay 1982; M. J. Cronin 1985). Studies of effectiveness are inherently qualitative while studies of efficiency are inherently quantitative. In the literature of IHEs and of academic libraries there has been a dichotomy, with a much greater focus on studying effectiveness, or quality, and a reluctance to produce pure studies of efficiency. While it can be said that there were many efforts to develop quantitative measures for academic libraries, it cannot be said that these efforts resulted in comprehensive studies of academic library efficiency. Similarly at the IHE level there have been many more studies conducted on the topic of IHE or IHE program quality than of IHE efficiency. While there has been much discussion of the need to examine IHE efficiency, there has been comparatively little analysis of data to determine actual levels of efficiency in IHEs. Given that there are relatively few efficiency studies conducted at either the IHE or the academic library unit level it is impossible to determine at this time whether efficiency and effectiveness are indeed correlated as has been suggested (B. Cronin 1982b; Neuman and Easun 1994). The lack of efficiency studies at both the IHE and the academic library level and the current political and social environments in which IHEs and the academic libraries that serve them find themselves suggest the need for this study's focus on efficiency measures at both levels.

This study focuses on measures of efficiency for both IHEs and the academic libraries that serve them, recognizing that efficiency is one component of an overall assessment program and that a complete program requires both efficiency and effectiveness measures. There is a large body of literature on effectiveness measures for both libraries and IHEs; however, comparatively little has been done to explore efficiency measures in the academic context. The purpose here is to explore efficiency concepts and tools as they have been applied in the higher education setting. Efficiency is not something that academic institutions and their components are typically comfortable measuring. "It is true to say that by and large academic institutions do not systematically attempt to determine efficiency because of the difficulty in measuring educational output (Ralli 1987, 2)." Educators have asserted that educational goals are "too elusive, value-based, and imponderable for goal achievement and hence for effectiveness to be measurable…[and]…many still regard the notion of efficiency to be wholly inappropriate in the context of the educational process (Lindsay 1982, 177)." Lindsay (1982) noted even in the 1980s that the issue was no longer whether the assessments were appropriate or could be prevented but how they might be improved.

The definition of efficiency incorporates four concepts: relativity, conditionality, performance, and constraint. Efficiency is relative and invites comparison. Indeed, efficiency cannot be measured absolutely. No entity can be absolutely efficient or absolutely inefficient; it can only be efficient or inefficient in comparison to some other or others and the evaluator must determine what the measures of efficiency are and who (or what) comprises the comparison group. An entity can be 100 percent efficient in comparison to this group and using the selected measures but that does not mean that it can be considered absolutely efficient. If other measures were introduced or other comparators, the efficiency rating might change. Efficiency is also conditional. As noted previously, efficiency is judged according to criteria that are chosen by someone or some group as relevant in a given context. These conditions, if changed, can affect the overall efficiency ratings of the entities being compared. Third, efficiency is a quantitative measure of performance. It does not address the quality of the entity being measured but rather determines whether it is making the best use of its resources in producing outputs for the criteria being assessed. Finally, efficiency is constrained. Because resources are constrained, or limited, and there are other factors that limit what an entity can do, it is impossible to be absolutely efficient. An entity can only be efficient relative to other entities given available resources and externally imposed limits (Neuman and Easun 1994). Thus efficiency is a relative measure of an entity's performance with respect to some other (or others) based on specific criteria given available resources and constraints. Measures of efficiency are particularly useful, especially in the social and political context in which IHEs and libraries find themselves because relative efficiency can be improved. Decision-makers have the ability to make decisions based on the information provided by these assessments that can improve an organization's relative efficiency given its resources, constraints and context.

The method of measuring efficiency applied in this study, Data Envelopment Analysis (DEA), provides a means for measuring aspects of efficiency based on selected inputs and outputs. It also demonstrates the use of resources to managers and administrators and assists in determining areas for possible improvement. One goal of this study is to determine whether it is possible to use DEA to design entity specific measures of efficiency that also allow comparison with peers and whether measures can be easily modified and adapted for incorporation into the entity's comprehensive assessment plan. To assist in addressing this and other research objectives, the remainder of this literature review will describe DEA, providing background information, a brief discussion of the alternatives to DEA, a description of the advantages and disadvantages of DEA, its basic assumptions and operations, the DEA models, and rules for selection of inputs and outputs. This is followed by a review of relevant studies conducted using DEA to study IHE, IHE department, and academic library efficiency. Finally a brief summary will place this study in the context of existing literature.

2.3 Data Envelopment Analysis

Data Envelopment Analysis (DEA) is a non-parametric linear programming technique that enables the researcher to incorporate large numbers of variables and constraints into an analysis that can be used in decision-making, benchmarking, and what-if scenarios (Cooper, Seiford, and Tone 2007a, 1–3). An extension of ratio analysis developed by Farrell (1957) and further refined and extended by Charnes, Cooper and Rhodes (1978), then Banker, Charnes and Cooper (1984) and others, DEA can be used to evaluate the relative efficiency of a group of entities or decision making units (DMUs) based on the observed data for multiple inputs and outputs generated by the DMU's activities. It is used when there is a relatively homogeneous set of DMUs to be analyzed (Boussofiane, Dyson, and Thanassoulis 1991). DEA measures the relative efficiency of each entity in the group under study in comparison to every other entity in the group (Avkiran 2001).

Recall that efficiency itself is necessarily defined as a relative measure, comprised of a ratio of outputs over inputs, set in the context of the group of entities being compared and limited by available resources and other environmental factors (Neuman and Easun 1994). Because efficiency is not absolute it can be affected, or altered, through changes in management behavior. DEA allows this measurement to occur and identifies the areas in which relative inefficiencies are present so that improvements may be made and relative efficiency may be increased as a result.

2.3.1 DEA versus Other Methods of Analysis

Data envelopment analysis is not the only method that may be used to assess the efficiency of an entity. Other methods include ratio analysis and statistical techniques such as regression analysis and stochastic frontier analysis.

Ratio analysis, or performance indicators, may be used to assess efficiency in instances in which there is a single input and a single output to be compared. In these cases the measure of efficiency is the output divided by the input. However, in most organizational situations there are more than one input and output to be considered in an evaluation of overall efficiency. Ratio analysis permits only the one-to-one evaluation of a single input and a single output at a time, making a determination of overall efficiency difficult. Ratio analysis also makes it difficult to determine how individual variables interact with one another (Geva-May 2001; Shim 2003; Taylor 2010). Colbert, Levary and Shaner (2000) note that ratio analysis may be used in a market situation but the process requires multiple steps. First individual ratios must be calculated, then weights must be assigned to each based on its relative market value. Finally, individual weighted ratios must be aggregated into a single measure. In an educational context in which a "market value" cannot necessarily be assigned to each input and output, ratio analysis becomes a less effective means of determining overall organizational efficiency. A significant weakness of ratio analysis is the difficulty in reaching agreement on the importance to be placed on various inputs and outputs. As a consequence, when multiple ratios are used to compare entities an individual entity will appear stronger in one ratio but weaker in another and unless the relative importance of the ratios has been predetermined the value of the analysis is unclear (T. Chen 1997b).

Multiple regression, or regression analysis, is another method that has been used as a means of measuring overall efficiency. DEA differs from regression analysis in that while regression analysis seeks to explain away as much of the variation as possible, DEA does not wish to explain away all differences. The goal of DEA is not to make all firms perfectly efficient but to identify genuine differences in efficiency (Farrell 1957, 270). In regression analysis output level is calculated as a function of input levels. The analysis generates a regression line that indicates average efficiency for the entities in the study population (Shim 2003). Those organizations that lie above the line are considered efficient, while those that lie below the line are considered inefficient. The line itself represents the best summary of the distribution of the data points and is frequently created using an ordinary least squares, or OLS, method. In this method, the squares of the distances between the points and the possible regression lines are summed and the regression line that is selected is the one that has the lowest total aggregate sum. Regression analysis assists in determining correlation but not causation, and the closer that data points are to the line the stronger the relationship. The distance between points and the regression line are considered standard error and are used to determine the strength of the relationship; the greater the distance between the data point and the line, the weaker the relationship. The resulting graph looks something like that which appears below as Figure 2.7 (Dizikes 2010).

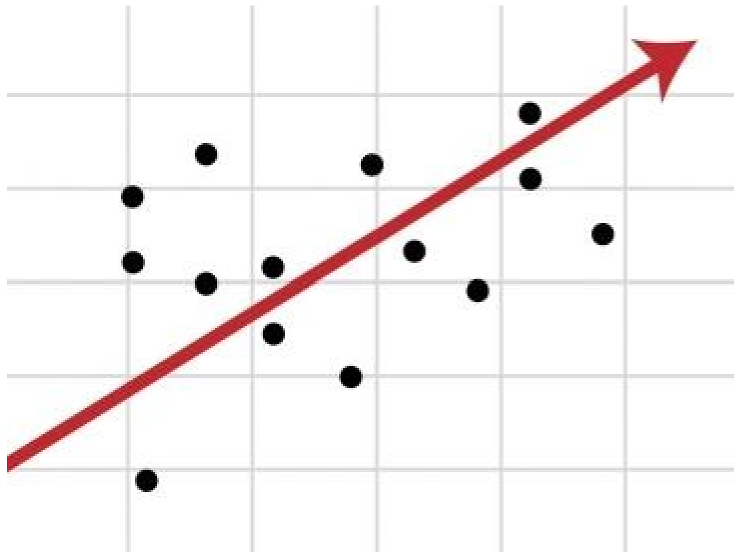

Figure 2.7: Regression line

Regression permits the inclusion of multiple inputs as independent variables; however, it only allows the inclusion of one output as the dependent variable unless a multiple equation regression model is run. The single equation regression model requires that all outputs be combined into a single output measure or indicator to allow the model to determine overall average efficiency. The multiple equation regression model does not produce an overall efficiency rating. Instead it produces multiple residuals which provide different measures of an organization's operating efficiency (Colbert, Levary, and Shaner 2000). Unlike DEA, which provides a measure of best performance, regression provides a measure of average performance.

Stochastic frontier analysis is parametric frontier technique that permits the use of multiple inputs and outputs and is the primary alternative to DEA. Stochastic frontier analysis is a regression technique and as such it requires that both the functional relationship between inputs and outputs and the distribution of the inefficiency term be defined prior to analysis (Taylor 2010). Because of this many researchers choose to define the relationship in a flexible manner which can introduce bias into the results. Stochastic methods are statistical methods, based on sampling theory and as such they are able to separate the effect of noise from the effect of inefficiency to arrive at interpretable results that may be generalizable to a larger population. Parametric methods, such as stochastic frontier analysis, have some advantages over DEA in that they are better able to predict future performance for a group of entities, to estimate confidence levels or perform other statistical tests that DEA as a non-parametric method does not allow. They also allow the testing of assumptions. In contrast to stochastic frontier analysis, DEA is a nonparametric method that is not based on sampling but is based on the observations of a specific population. It does not separate the effects of noise from those of inefficiency but examines the observations for the population only in comparison to others in the observed population and gives efficiency/inefficiency results in relation to the population. As a result DEA is less prone to error than the stochastic method (Abbott and Doucouliagos 2003; Haynes and Dinc 2005; Taylor 2010). Abbott and Doucouliagos (2003) assert that DEA's advantage over stochastic frontier analysis is its ability to calculate both technical and scale efficiency using only input and output quantity without pre-defining the functional relationship between inputs and outputs, the form of the frontier, or the inefficiency distribution. Another advantage is its ability to handle multiple units of measure in a single calculation.

2.3.2 DEA: Advantages and Disadvantages

Every research method has advantages and disadvantages and DEA is no exception. The primary advantage of DEA is that there is no need to specify the functional relationship between the inputs and outputs prior to running the analysis. The researcher must only specify the inputs and the outputs that are to be considered for the DMUs which are responsible for converting inputs into outputs and identify the set of DMUs that will be used in the comparison and for determining relative efficiency scores. The method is also specific to the DMU rather than associated with a statistical average (Ahn, Charnes, and Cooper 1988a). Other advantages include that it is relatively free of specification errors and that it can yield more accurate estimates of efficiency than regression techniques (Taylor 2010). It also has the advantage of not requiring cost data as do other available techniques, which makes it useful in evaluating non-profit and not-for-profit organizations. This is particularly useful in evaluating higher education institutions where the economic value of inputs and outputs are frequently not readily available or easily determined. The method does not require assumptions of linearity as regression techniques do, nor does it require predetermination of weights for inputs and outputs (Ahn, Charnes, and Cooper 1988b; Colbert, Levary, and Shaner 2000). DEA is useful as a decision-making tool because it allows managers and decision-makers to select the inputs and outputs that they consider most representative of the organization's activities for use in the analysis (Neuman and Easun 1994; Avkiran 2001). In order to select appropriate variables for inclusion, decision makers must understand and explicitly state organizational objectives. Ideally, the objectives become the output variables and the resources needed to achieve the objectives become the input variables (Avkiran 2001).

As with any technique there are also disadvantages. First, just as efficiency can only be defined in relative terms, DEA is relative measure. It provides a measure of efficiency that relates the DMUs under study only to each other. If DMUs are added to or removed from the population the relative efficiency scores are likely to change and the efficient frontier will shift. It cannot provide an absolute measure of efficiency because, as has already been noted, the determination of efficiency is comparative rather than absolute and thus an absolute measure cannot exist (Colbert, Levary, and Shaner 2000; Avkiran 2001). It can provide a ratio measure that demonstrates, in a given context, how well a DMU is performing in comparison to other selected DMUs. DEA is a modeling technique. Any model is a simplified version of the real world and as such may not capture all of the complexity inherent in the organization or its environment (Neuman and Easun 1994). DEA can yield biased estimates of efficiency if relevant variables are left out of the analysis. Identifying the relevant variables to be used as inputs and outputs can be problematic especially within the context of higher education organizations (Ahn, Charnes, and Cooper 1988b; Colbert, Levary, and Shaner 2000). Because it is an extremal technique it is more sensitive to extreme observations, or outliers, than other methods may be and is likely to identify entities with a unique mix of inputs and outputs as being on the efficient frontier simply because of their unique mix. The technique is also sensitive to the number of inputs and outputs entered into the analysis. The greater the number of inputs and outputs relative to the number of DMUs under study the less discriminating the technique will be in identifying efficient DMUs (Wagner and Shimshak 2007; Taylor 2010). Two common methods are used to alleviate the problem of discrimination efficiency due to unique mix. In some studies, weighting constraints are added to the model, allowing each input and output to vary only within constraining parameters. Shim (1999; 2003) used constraining weights in his study of academic research libraries to limit input usage and output results. In other studies, isotonicity tests are conducted using potential inputs and outputs to determine their relationship. Isotonicity tests are essentially correlation matrices completed on all input-output combinations to test the strength and significance of relationships. DEA requires non-negative relationships between inputs and outputs indicating that an increase in input use does not decrease output. Optimal inputs and outputs are those with a majority of positive, strongly correlated and significant relationships. Inputs which correlate negatively to outputs indicate that the isotonicity principle has been violated and such inputs should be considered for removal prior to conducting analysis. After the initial DEA analysis is conducted, a lack of discriminatory power resulting from the inclusion of too many inputs and outputs can be resolved through the backward removal of variables. The backward removal of variables is based in large part on the results of initial isotonicity testing and is used to remove variables that contribute limited or redundant information to the analysis. Backward removal is generally conducted on both inputs and outputs, alternating variable removal between inputs and outputs based on information provided by the isotonicity test and the initial DEA analysis. As a result of variable removal, the model becomes increasingly able to discriminate among the entities included in the analysis, providing more accurate efficiency ratings. Chen (1997b) employed the backward elimination of variables process in a study of Taiwanese academic library efficiency. Finally, while decision makers may select the inputs and outputs they consider most representative of the organization's activities, this can present an opportunity to control or bias the results of the analysis if the purpose of analysis and the limitations of the method are not understood (Neuman and Easun 1994).

2.3.3 DEA: Background and Brief Explanation of Method

As has already been stated, efficiency is measured as a ratio. Measuring efficiency in the simplest case where a DMU has only one input and one output requires a simple ratio of the output over the input to determine efficiency. However, in most cases DMUs have multiple inputs and outputs with dissimilar units of measure. This complexity can be incorporated into an efficiency measure by defining it as the sum of weighted outputs over the sum of weighted inputs and allowing weights to be defined by each DMU so that its efficiency score is maximized in the process (Boussofiane, Dyson, and Thanassoulis 1991). The DEA efficiency score is a ratio of the weighted sum of outputs over the weighted sum of inputs. DEA compares a set of similar DMUs to determine which are operating most efficiently relative to the others. Efficiency scores for DMUs are calculated individually through a weighting of individual inputs and outputs that will maximize the efficiency score for the unit. In the calculation phase, which occurs within the DEA model, each DMU is given the opportunity to be the focus, during which its efficiency score is optimized and all DMUs are compared to it using the weights that favor it. If during this comparison it looks as good as other DMUs it receives a score of 1. However, if another DMU looks at least as good as the DMU of focus during comparison, then the DMU of focus receives a score between 0 and 1. After the comparisons are completed with each DMU as the DMU of focus, the most efficient DMUs are said to be 100 percent efficient and are located on the efficient frontier. Those that are less efficient are behind the frontier and a secondary analysis may be conducted to determine the source of their inefficiency (Shim 2003; Reichmann 2004; Cooper, Seiford, and Tone 2007a).

Writing in 1957, Farrell provided a measure of productive efficiency that both accounted for inputs and outputs and avoided the problems that were associated with previously developed index numbers, which either focused only on one input and ignored all others or added a firm's inputs into a single quantity. His method, which was applied initially to agricultural production, was widely cited by later researchers as the "Farrell efficiency measure"[1] and led to the development of what is known today as Data Envelopment Analysis, or DEA. In his original work, "The Measurement of Productive Efficiency," Farrell described in detail the estimation of an efficient production function based on the observations of the inputs and outputs of a number of firms, creating a

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[1] See for example Charnes, Cooper and Rhodes. 1978, which discusses the Farrell efficiency measure extensively as a resource in and the basis for the development of the CCR model of data envelopment analysis.

benchmark of best practice against which the firms in the comparison group could measure themselves. Using actual inputs and outputs of firms in the group he demonstrated how a virtual benchmark firm could be created based on the weighted averages of the firms in the population and against which all firms in the group could be compared. Farrell's work distinguished between technical efficiency and other types of efficiency such as price and overall efficiency, with overall efficiency being composed of both technical and price efficiency. Farrell made several qualifications regarding the technical efficiency of a firm. He noted that it was relative to the set of firms from which the function was estimated and that if more firms were added to the analysis it would reduce the technical efficiency of any given firm. He also noted the heterogeneous nature of the measures of the inputs. He asserted that the heterogeneity of factors did not matter as long as it was spread evenly over firms and that only when there were differences in the average quality of factors between firms would a firm's efficiency reflect the quality of inputs and efficiency of management. He also argued that technical efficiency would always reflect, to some extent, the quality of inputs and that it was impossible to entirely separate the efficiency of management from the quality of input factor (Farrell 1957).

Charnes, Cooper, and Rhodes (1978) extended Farrell's model to not-for-profit entities and created what has become known as the CCR model (after the three authors) of data envelopment analysis (DEA). CCR employs two primary assumptions. First, it assumes that there is a constant returns to scale, or that the size of the decision making unit in the analysis is not a factor. Second, it assumes that the piecewise linear curve that forms the efficient frontier is convex. In 1984 Banker, Charnes, and Cooper further extended the CCR model to allow the consideration of scale in the model, thus permitting the separate measurement and evaluation of scale efficiency and technical efficiency. This new model became known as the BCC model, after its authors, and has been widely employed and cited as such in the DEA research literature.

Although it began with the Farrell efficiency measure as a technique for measuring efficiency of profit making enterprises, the primary uses of DEA have historically been in the evaluation of management and program efficiencies of entities known as decision making units, or DMUs, of not-for-profit entities (or subunits within these entities) or entities for which prices of some resources or outputs were difficult to determine. Examples of such entities are hospitals (Valdmanis, Bernet, and Moises 2010), nursing homes (Shimshak, Lenard, and Klimberg 2009), schools (Grosskopf and Moutray 2001), and institutions of higher education (Ahn et al. 1989). It has been used to study such diverse entities as governmental, quasi-governmental, commercial and profit making ventures including state and/or national governments (Hauner and Kyobe 2010), state police forces (Gorman and Ruggiero 2008), the military (Charnes et al. 1985), banks and financial institutions (Bergendahl and Lindblom 2008; Rajiv D. Banker, Chang, and Lee 2010), the hospitality industry (Reynolds and Thompson 2007), and the transportation industry (Pathomsiri et al. 2008), among others. While DEA automatically uses its linear programming model to determine optimal weights for each DMU's inputs and outputs, more recent DEA models have incorporated the ability to apply constraints to the weighting within the model as a means of increasing the discriminatory power of the analysis. The application of constraints can reduce the possibility of individual DMUs appearing efficient because of unique weighting schemes. As noted earlier, Shim (1999) established and applied weights within his DEA model assessing the efficiency of ARL libraries. However, others argue that establishing weights must be done only with great care as they can introduce error or bias into the model if not applied judiciously. Weighting multiple variables disrupts optimization within the model (Avkiran 2001). As noted above, a second method of increasing the discrimination of the analysis is the backward removal of variables that are determined to provide limited or redundant information. In this method the results of both isotonicity testing and the initial DEA analysis inform the removal of variables, one at a time, until an acceptable level of discrimination has been reached (T. Chen 1997b).

2.3.4 DEA Models

DEA Models can generally be classified in three broad areas, at least one of which has been discussed briefly above. These categories or areas include the shape of the envelopment surface, the treatment of scale, and the overall model orientation.

Models can be classified according to whether the envelopment surface, or frontier, is assumed to be piecewise and linear or non-linear. The vast majority of models run in DEA are assumed to be piecewise linear, though a few studies have been conducted using an alternative model with a non-linear frontier (Shim 1999). A review of the literature of DEA studies conducted using IHEs or academic libraries as DMUs found no studies that employed a model other than that which incorporated a piecewise linear frontier and that is the model that will be incorporated in this study.

Models can also be classified according to how they treat scale—whether they assume constant returns to scale or variable returns to scale. Scale refers to the size of operations of the organization or DMU. The CCR model assumes constant returns to scale while the BCC model incorporates variable returns to scale. Constant returns to scale (CRS) assumes that there is no significant relationship between the scale of operations and efficiency while variable returns to scale (VRS) assumes that there is a relationship (Avkiran 2001). Within the CCR-CRS model fewer DMUs are found to be efficient because both technical and scale inefficiencies are identified in a single measure. The BCC-VRS model incorporates variable returns to scale, dissecting the measure of technical efficiency to provide a measure of technical efficiency that is not affected by the size of the organization. This measure of "pure technical efficiency" is attributable largely to management practices (Shim 1999). Efficiencies or inefficiencies related to the scale of operations are calculated separately. These are provided as increasing returns to scale, if an organization can achieve economies by increasing size, or decreasing returns to scale if the organization is experiencing inefficiency because it is too large. Avkiran (2001) recommends running both models (CCR-CRS and BCC-VRS) to determine if DMU size is a factor in the analysis. If the efficiency scores are different between the two models for a large number of the DMUs then scale is a significant factor in efficiency. The CRS score will then represent technical efficiency and incorporate inefficiency due to the input/output configuration and size of operations. The VRS score will represent pure technical efficiency without consideration of scale. Scale efficiency can then be calculated by dividing pure technical efficiency (the VRS score) into technical efficiency (the CRS score). While both IHEs and academic libraries have little control over their ability to increase scale compared to for-profit organizations, it is important in the context of this study to be able to distinguish between inefficiencies that can be attributed to scale inefficiencies and technical inefficiencies, or inefficiencies that may be attributed to management. Therefore this study will employ both the CCR and the BCC models in its analysis.

Finally, DEA models may be input-oriented or output-oriented. An input-oriented model focuses on reducing inputs while producing the same level of outputs. These are known as input minimization models. An output-oriented model focuses on increasing output while maintaining the same level of input. These are known as output maximization models. A third alternative is to have a non-oriented model that focuses on neither inputs nor outputs. Haynes and Dinc (2005) assert that determining which orientation to use depends upon the purpose of the analysis—whether it is policy-related or administrative. If the purpose is administrative then the orientation should be input minimization. If the purpose is focused on policy then the orientation should be output maximization because this aspect of evaluation frequently requires institutions to examine how much output is produced with a given input.

DEA studies of IHEs and academic libraries are divided in their orientation. Many IHE studies have chosen an output maximization orientation, arguing that their mandate has been to increase production of research or of graduates (Avkiran 2001; Jill Johnes 2006b; Jill Johnes and Yu 2008; Ray and Jeon 2008; Tyagi, Yadav, and Singh 2009; Kantabutra and Tang 2010; J.-K. Chen and Chen 2011). Others have chosen an input minimization orientation because fiscal constraints and policy decisions have required resource reductions while maintaining output levels (Abbott and Doucouliagos 2003; Giménez and Martínez 2006; McMillan and Chan 2006; Fandel 2007; Kao and Hung 2008; Ng and Li 2009; Katharaki and Katharakis 2010). Studies that have chosen not to select an orientation have tended to run their DEA analysis in two steps, running first the CCR model then the BCC model and comparing results.[2] While McMillan and Chan (2006) adopted an input-oriented approach in their study of Canadian universities, they asserted that orientation was not likely to significantly affect DEA results. They further observed that input orientation predominated studies of university efficiency, suggesting that this was because in the long term universities have more control over input choices than they do over outputs. Ray and Jeon (2008) on the other hand, argue that any rating of universities or programs within universities should be focused on objective criteria and outputs; they argue for an output orientation to the DEA analysis.

There are considerably fewer studies of academic libraries conducted using DEA. These studies, like those of universities, are divided in their selection of orientation, with

[2] See for example Ahn, Charnes and Cooper. 1988, in which both the CCR and BCC models are applied to a set of public and private doctoral granting institutions in the U.S. to determine differences in relative efficiencies and whether they result from managerial, program, or scale inefficiencies.

some selecting an input minimization orientation (Shim 1999; Simon, Simon, and Arias 2011) and others selecting an output maximization orientation (Kao and Lin 1999; Reichmann 2004; Reichmann and Sommersguter-Reichmann 2006), depending on the nature of the study. Still others have failed to identify what orientation they selected, or if the study was conducted with a neutral orientation (T. Chen 1997b; Mann 1997; Kao and Liu 2003; Shim 2003; Kao and Hung 2008). In this study, it is necessary to select the same orientation for both groups of DMUs, the IHEs and the academic libraries, to ensure that comparisons can be made across the groups. Thus, this study employs an input minimization orientation. This is in keeping with the focus on determining whether DEA is a useful tool for administrators in evaluating efficiency and locating sources of inefficiency in the organization. It also suits the current economic environment in which resources are increasingly constrained and DMUs are focused on minimizing the level of inputs needed to produce outputs at the same (or higher) levels. The alternative output maximization model might have been selected as well under the assumption that inputs (resources) would remain constant and the policy environment would require increased output with the same level of inputs. As noted earlier, McMillan and Chan's (2006) observed that orientation did not have a significant effect on results in university studies.

2.3.5 DEA: Selection of Inputs and Outputs

The identification of inputs and outputs is a key stage in the Data Envelopment Analysis. Inputs and outputs selected must reflect the resources used and the outputs produced as well as the environment in which the DMU operates. Environmental factors may be included as either inputs or outputs depending on whether they add to resources or require a resource to overcome (Boussofiane, Dyson, and Thanassoulis 1991; Avkiran 2001; Wagner and Shimshak 2007). While it is important to include inputs and outputs that accurately reflect the activities of the organization, it is equally important to ensure that the analysis is not compromised by the inclusion of too many variables. The selection of inputs and outputs affects the discriminating power of the DEA analysis. However, researchers have not agreed entirely on the minimum number of DMUs required to ensure a robust analysis. Various rules of thumb have been suggested for determining the optimal number of variables and DMUs. Cooper, Seiford and Tone (2007b, 284) note that degrees of freedom increase with the number of DMUs in the comparison group, and decrease with the number of inputs and outputs in the analysis. They provide the rule of thumb that:

$$n \geq \max \{m \times s, 3(m + s)\}$$

where n is the number of DMUs, m is the number of inputs, and s is the number of outputs. In this case, they are suggesting that the product of inputs and outputs should not exceed the number of DMUs or, alternatively, that the number of DMUs must be equal to or greater than three times the sum of inputs plus outputs, whichever is the greater number. Boussifiane, Dyson and Thanassoulis (1991) similarly suggest that the minimum number of DMUs in a set should equal or exceed the multiple of the inputs and outputs. Golany and Roll (1989) suggest that the number of DMUs should be at least double the number of inputs and outputs, while others suggest that there should be three times as many DMUs as inputs and outputs (Bowlin 1998; Wagner and Shimshak 2007). Dyson et al (2001) suggest that two times the product of the inputs and outputs are needed to provide the level of discrimination necessary for analysis. Thus an analysis would require differing numbers of DMUs depending on the rule of thumb followed in preparing for the analysis. Table 2.1provides an example using four inputs and five outputs of the varying minimum numbers of DMUs that would be the required for an analysis based on the alternative rules of thumb. It includes the authors of the articles from which the rules were taken, the rule itself and the calculations for determining the number of decision making units, or DMUs, needed with the given example.

Table 2.1: Rules for determining the number of decision making units (DMUs)

Author	Rule	Number of DMUs According to Rule
Cooper, Seiford and Tone	m x s	4 x 5 = 20
Cooper, Seiford and Tone	3(m + s)	3(4 + 5) = 27
Boussifiane, Dyson and Thanassoulis	m x s	4 x 5 = 20
Golany and Roll	2 (m + s)	2(4 + 5) = 18
Bowlin	3(m + s)	3(4 + 5) = 27
Dyson et al.	2(m x s)	2(4 x 5) = 40
Wagner and Shimshak	3(m + s)	3(4 + 5) = 27

The selection of inputs and outputs for this study is based on a review of the relevant literature—IHE and academic library efficiency studies seeking to understand overall efficiency as well as efficiency with respect to teaching and research. A review of those studies follows. The discussion of the selection of inputs and outputs is included in Chapter III.

Data Envelopment Analysis (DEA) has been used to analyze the efficiency of IHEs, providing overall measures of efficiency as well as measures of efficiency with respect to teaching and research. A few studies have also been conducted using academic libraries as the study population and DEA as the research method. These studies primarily focused on overall efficiency of academic libraries, though some attempted to separate the research function of libraries from other functions. Presented below is a review the DEA literature as it relates to universities, followed by a review of the literature as it relates to academic libraries. Finally the current study will be placed in the context of the existing research literature.

2.4 DEA and Universities

Efficiency studies of IHEs have generally been of two types, those that have looked at the institution as a whole and those that have focused on one area, (or selected areas, sections, or departments) of the institution or institutions included in the study. Of those studies examining the overall institution, some have looked at the combined teaching and research product of the institution while others have examined either research or teaching in isolation. Studies that examined overall university level teaching and research performance combined generally studied universities within a category or type (Ahn, Charnes, and Cooper 1988b), within one country (Avkiran 2001; Abbott and Doucouliagos 2003; Jill Johnes 2006a; McMillan and Chan 2006; Katharaki and

Katharakis 2010; J.-K. Chen and Chen 2011), across a large region or state (Ahn et al. 1989; Fandel 2007), or some combination of these (Ahn et al. 1989).

In one of the earliest uses of DEA in the study of universities Ahn, Charnes and Cooper (1988b) applied DEA to 161 doctoral granting institutions in the United States. They compared both the usefulness of DEA analysis to traditional econometric analyses and the relative efficiencies of public and private doctoral granting institutions. In their examination of technical and scale efficiencies, they distinguished between institutions that supported medical schools and those that did not. Using the CCR model and data from 1984-1985, they first identified both managerial and production efficiencies for both public and private universities, then removed managerial efficiencies in the second stage by projecting each inefficient university onto the efficient frontier of its comparison group (public or private) using a CCR projection formula. They identified the resulting new efficient frontiers with program efficient operations and used these to compare public institutions with private institutions. Finally, they used the BCC model to study scale effects on the institutions in the study. Inputs selected represented the categories of labor and capital, with labor covering both faculty and staff and capital covering land, buildings, and equipment. Salaries were selected as the measure of faculty and staff input. Investment in physical plant and overhead expenses represented capital inputs. Outputs covered both teaching and research. Undergraduate and graduate students represented teaching output. Federal grants and contracts represented research output. Overall the authors found that public universities without medical schools had mean efficiency ratings that were higher than private universities without medical schools. Once managerial inefficiency was removed from the data, private universities became more efficient than public, and though the mean efficiency ratings remained higher for private universities and the variance among the groups was still higher for private than for public. They also found that when medical schools were present public universities were more efficient than private. Using the BCC model the authors examined scale efficiencies and most productive scale size. They determined that on average universities without medical colleges were operating at 65 percent efficiency and could reduce input usage up to 35 percent to achieve efficiency. Universities with medical schools had inefficiencies of a technical/managerial nature on the input side but not on the output side and if the inefficiencies could be corrected then expansion would be warranted to achieve most productive scale size. They demonstrated that when examining most productive scale size DEA was more useful and precise than traditional econometric models and provided several reasons for this. Banker’s MPSS applied to the individual DMU output-input mixes rather than to an average global output-input mix in the way econometric measures did. The BCC model dealt with multiple inputs and outputs rather than reducing the mix to a single derived measure or index measure or forcing the researcher to select a single output characteristic. DEA was more precise than econometric scale measures because econometric measures usually took place in the presence of technical inefficiency, while Banker’s measure occurred only after technical inefficiency was removed.

Another seminal work in the field was a study conducted by Breu and Raab (1994) examining the overall efficiency and student satisfaction at the top twenty-five national universities and liberal arts colleges in the United States. This often cited study used graduation rates and retention rates as outputs and as measures of student satisfaction. Inputs included SAT averages, percentage of faculty with doctorates, faculty to student ratio, expenditures per student, and tuition charges per student. They found that while the universities that were rated as the “best” by U.S. News & World Report expended funds to enhance reputation and prestige (i.e. measures of perceived quality and effectiveness), the enhanced reputation did not necessarily translate to enhanced student satisfaction. They asserted that universities should focus on enhancing efficiency rather than perceived quality as a means of enhancing student satisfaction. Where institutions had higher efficiency measures, students were more satisfied and were more likely to be retained and to graduate. Results also showed that institutions with higher efficiency measures were not always those with higher perceived quality and reputation measures and selected as “best” by U.S. News & World Report. As a part of the study they compared the results obtained through DEA with the results obtained through regression analysis to demonstrate the difference in the amount of information provided by the two methods and the difference in the level of complexity that each method was able to address. They argued that DEA was more useful than regression in efficiency analysis because of its flexibility and its ability to more easily deal with multiple inputs and outputs and the complex relationships between inputs and outputs.

Several of the studies conducted at the university level have been completed outside the United States. Both Avkiran (2001) and Abbot and Doucouliagos (2003) studied the overall performance of universities in Australia. Avkiran (2001) used three separate DEA performance models to capture overall performance with one representing teaching performance, one representing research performance, and one representing the ability of universities to attract fee-paying students. The analyses were run on data from 1995 under output maximization and used the VRS model for the thirty-six Australian government universities. All inputs and outputs were selected based on a review of literature. Inputs remained the same in each model—academic staff and non-academic staff—while outputs varied depending on the focus of the model. The research focused model used the Research Quantum Allocation (funding allocated to each university by the Australian government for research based on a composite index of research output for each university) as the single output. The teaching focused model included the retention rate from undergraduate to graduate school, the student progress rate, and the proportion of graduates employed as three outputs. The third model identified two outputs—the overseas fee-paying enrollments and the domestic fee paying enrollments. Findings indicated that Australian universities were operating at respectable levels of scale and technical efficiency but that there was room for improvement in the area of fee-paying enrollments. There was also some slack in input usage. Abbott and Doucouliagos (2003) examined the technical and scale efficiency of thirty-six government universities in Australia using the same 1995 dataset as the Avkiran study. This study was an input-oriented VRS model designed to measure efficiency in both teaching and research output. Inputs included total number of academic staff FTE, total number of non-academic staff FTE, expenditure on all non-labor inputs, and value of non-current assets. The teaching output was represented by the total number of FTE students at undergraduate and graduate levels. The research output was represented by the Research Quantum Allocation. Several models were run using between two and four inputs and including both outputs in each model. The authors found that overall Australian universities operated at high levels of efficiency in both teaching and research relative to one another but that there was still room for improvement at several universities. The authors suggested that international comparisons were needed to assess the competitiveness of Australian universities in a global marketplace. Such a study would determine whether the high levels of efficiency identified domestically were also evident in the global context in which Australian universities competed for students and research.

Studies of overall university performance using DEA in other country contexts have also taken place in the UK, Canada, Greece, and China. In the UK, Johnes (2006a) examined data on 109 IHEs in England for the academic year 2000-2001, using six inputs and three outputs. Inputs included expenditure on central administration, expenditure on libraries and information services, total depreciation and interest payable, total number of FTE academic staff for teaching and research, total number in FTE of postgraduate students, and total number of FTE undergraduate students studying for a first degree multiplied by the average A-level points for first year full-time undergraduate students.

A-level points referred to the score that students received on exams and was used as a measure of student quality. Outputs included total number of first degrees awarded, total number of higher degrees awarded, and value of current grants for research awarded by the Higher Education Funding Council for England. She found relatively high levels of efficiency across institutions. She considered this remarkable given the lack of profit motivation within the sector and attributed the efficiency at least in part to the increasing level of competition for students. In a study of forty-five Canadian universities, McMillan and Chan (2006) compared the results of efficiency analysis using DEA and stochastic frontier analysis. They found some significant differences in the initial efficiency results obtained from the two methods. They also highlighted differences in the sensitivity of the results to environmental factors and to the means of incorporating environmental factors in the analysis. Further examination of the results, however, showed that overall relative efficiency rankings of the universities under study were remarkably consistent across the two methods. They urged caution when interpreting the results from any frontier approach, recommending that any efficiency study employ more than one method to better determine an entity's relative efficiency. They failed, in their conclusions, to point out the stark differences in the methods and the likelihood that these differences caused the initial contrasts in ratings to emerge. They also did little to highlight the remarkable similarity in the final ranking of universities in both methods. Katharaki and Katharakis (2010) applied DEA to a study of twenty Greek universities to determine the technical efficiency of resource utilization. Performance indicators, factor analysis and econometric procedures were incorporated into the study to determine the degree of variation in efficiency and identify sources of inefficiency. They selected four inputs and two outputs for two input-oriented CRS DEA models. Inputs included total number of academic staff, total number of non-academic staff, number of active registered students, and operating expenses other than labor. Outputs included total number of graduates and research income. The first model was run incorporating only the first output and the second model was run incorporating both outputs. Results indicated a need overall for increased research activity and enhanced management of human resources in Greek universities. In Taiwan, Chen and Chen (2011) examined the ability of universities to improve their overall performance and innovation using an output-oriented DEA. They completed CRS and VRS models to study both technical and scale efficiency. The study incorporated three inputs, including the number of students, the number of international members and the number of domestic full time faculty. It also identified five outputs, including the number of graduates, journal articles accepted and published, financial support from the National Science Council, research patents, and the number of cooperating foreign countries. Using these inputs/outputs the majority of universities in Taiwan were inefficient in improving innovation and total quality performance. Based on the analysis they made suggestions for efficiency improvement for each entity and university type to reduce inefficiency and overall costs while improving quality and performance.