EXAMINING RESOURCE ALLOCATION WITHIN U.S. PUBLIC RESEARCH I UNIVERSITIES: AN INCOME PRODUCTION FUNCTION APPROACH

By

Ashley Paul d'Sylva

A Dissertation Submitted to the Faculty of the

CENTER FOR THE STUDY OF HIGHER EDUCATION

In Partial Fulfillment of the Requirements
For the Degree of

DOCTOR OF PHILOSOPHY

In the Graduate College

THE UNIVERSITY OF ARIZONA

1 9 9 8

UMI Number: 9831922

THE UNIVERSITY OF ARIZONA ®
GRADUATE COLLEGE

As members of the Final Examination Committee, we certify that we have read the dissertation prepared by Ashley Paul D'Sylva

entitled Examining Resource Allocation Within U.S. Public Research 1 Universities: An Income Production Function Approach

and recommend that it be accepted as fulfilling the dissertation requirement for the Degree of Doctor of Philosophy

Larry L. Leslie — Date 4/2/98

Gary Rhoades — Date 4/2/98

Dudley Woodard — Date 4/4/98

Date

Date

Final approval and acceptance of this dissertation is contingent upon the candidate's submission of the final copy of the dissertation to the Graduate College.

I hereby certify that I have read this dissertation prepared under my direction and recommend that it be accepted as fulfilling the dissertation requirement.

Dissertation Director — Date
Larry L. Leslie

STATEMENT BY AUTHOR

This dissertation has been submitted in partial fulfillment of requirements for an advanced degree at The University of Arizona and is deposited in the University Library to be made available to borrowers under rules of the Library.

Brief quotations from this dissertation are allowable without special permission, provided that accurate acknowledgment of source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the copyright holder.

SIGNED ______

ACKNOWLEDGEMENTS

I would like to acknowledge the assistance rendered in the preparation of this dissertation by Larry Leslie, Gary Rhoades, and Ron Oaxaca. I am grateful to Larry Leslie for his guidance as a mentor and for his tireless editing of the manuscript, to Gary Rhoades for his support to probe the issues deeper and for the direction he provided, and to Ron Oaxaca who provided specific input into the design and refinement of the regression model used in this study. Additional thanks to Sheila Slaughter who originally started me thinking about these issues and to Doug Woodard for all his help.

DEDICATION

This dissertation is dedicated to my loving wife, Pamela Joan D'Sylva, without whose help, sacrifice, dedication, and prayers this document could not have been completed. Also to my son Benjamin, for helping me to keep everything in perspective.

TABLE OF CONTENTS

TABLE OF CONTENTS -- *Continued*

TABLE OF CONTENTS – *Continued*

LIST OF TABLES

LIST OF TABLES – *Continued*

LIST OF FIGURES

ABSTRACT

In the past 10 years, state financial support for public universities has declined, when measured as a proportion of current-fund revenues. Whether in response to this decline or to satisfy other ends such as personal utility and prestige enhancement, universities and their faculty have sought alternative sources of revenue, mostly through increased research grants and contracts and student tuition and fees. The effects of these revenue changes are observed in the primary operating units of universities, academic departments, which serve as the primary focus of this study.

These changes have promoted concern in recent years that public research universities devote too much of their scarce resources to research at the expense of teaching. Specifically, concerns over teaching productivity and quality abound, especially at the undergraduate level. These concerns have been explained theoretically in terms of faculty preferences to perform research and research-related tasks, over undergraduate instruction--The Economic Theory of the Firm; and in terms of the increasing influence of providers of external revenues upon the behavior of the institutions--Resource Dependency Theory. These two frameworks are used to examine whether changes in departmental revenue support patterns affect undergraduate education at major public research universities.

To test the theories, departmental instructional and research productivity data from the 1994 and 1996 American Association of Universities Data Exchange (AAUDE) are examined. This sample data contains information on 8 public Research I universities, 200 departments, and 1000 data points for 1994, and 6 public Research I universities, 134 departments, and 680 data points for 1996. Seemingly Unrelated Regressions and Piecewise Linear Regressions, following a semi-log specification, are used to estimate the

rate of return to instructional productivity, research productivity, and departmental quality, within the income production function of the departments.

The primary finding was that although some *shifts* in resource allocation were observed to move in a direction that potentially favored research-related endeavors, i.e., graduate instruction and departmental quality, instruction, overall, was most greatly rewarded in the allocation process, and undergraduate instruction more so than graduate instruction.

CHAPTER 1

INTRODUCTION

This study of higher education finance is motivated by the basic problem of economic scarcity. No society or social institution ever possesses resources adequate to satisfy all the wants of its members. The limited supply and relative quality of the classical productive resources of land, labor, and capital lead policy analysts to contemplate the allocation function of economic systems; that is, the unlimited scope of aggregate human wants, along with the limited resources that produce the economic goods and services capable of satisfying these wants, forces choices in the allocation of the scarce resources among alternative uses. When certain goods and services are produced with the scarce resources, the opportunities to produce other goods and services are foregone, assuming there is full employment of resources.

It follows that, because they are subject to these same constraints of resource scarcity and insatiable demand, higher education institutions are forced to make allocation decisions that favor the production of some outputs at the expense of others. University faculty, who compose the largest number of production workers within institutions of higher education (Leslie, 1995), are similarly constrained in the allocating of their finite human resources among the institutional missions (wants) of teaching, research, and public service (James, 1990), the allocation function in economic jargon, being the mathematical relationship describing choices made in expending resources.

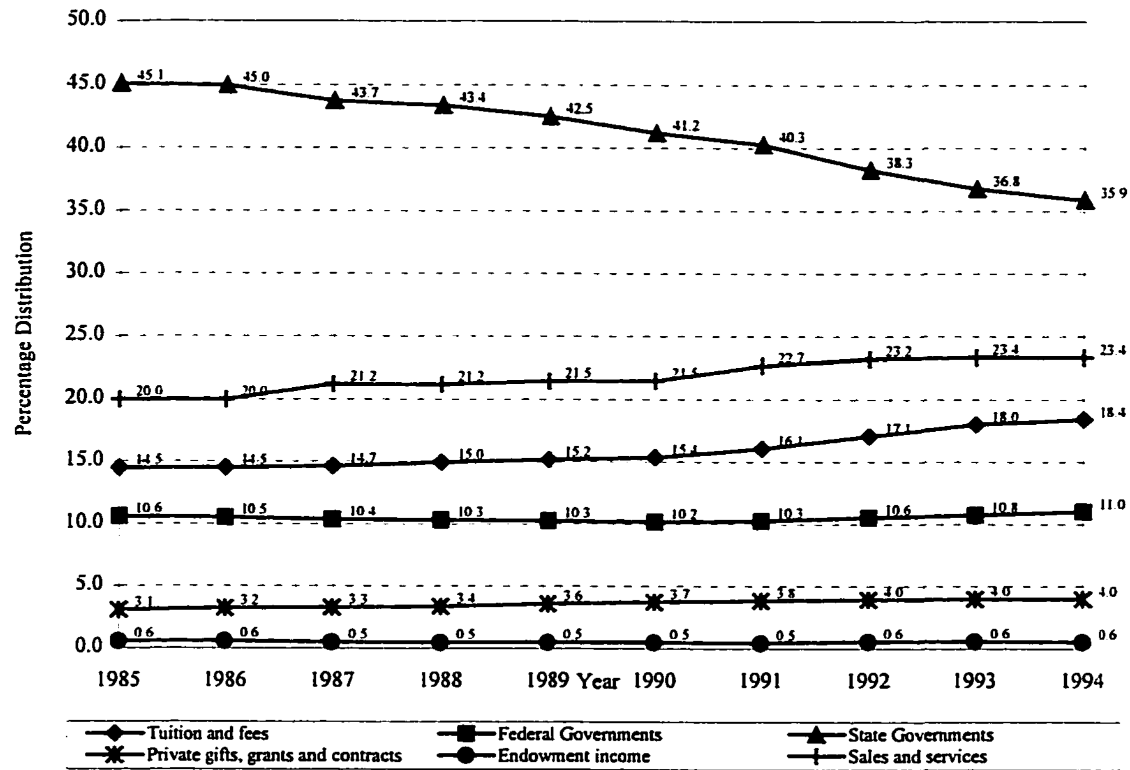
The allocation function for higher education production workers, therefore, is concerned with the problem of how faculty expend their time and effort among the different aspects of the organization's mission.

Statement of the Problem

In recent years much concern has been expressed that university faculty devote too much of their human capital to research at the expense of teaching (e.g., Massy and Wilger, 1992; Fairweather, 1996). Specifically, concerns over teaching productivity and quality abound, especially at the undergraduate level (McPherson and Shapiro, 1993; Zemsky, Massy and Oedel, 1993; Massy, 1996). These concerns come from many individuals and groups: students, administrators, trustees and governing boards, society at large, state funding agencies, and even from some faculty (James ,1990; Fairweather, 1996). The culprit may be changing revenue patterns. Changes in the sources and levels of funds available to universities may affect their allocation function (McPherson and Shapiro, 1993; Slaughter and Leslie, 1997).

Recently revenue changes have been substantial. An analysis of the revenue activities for public institutions of higher education over the 10 year period from 1985 to 1994 reveals a decline in the proportion of current-fund revenue coming from the state, from 45.0% in 1985 to 35.9% in 1994, representing an absolute decrease of 20% (See Figure 1.1).

Figure 1.1. Percentage Distribution of Current-Fund Revenue of Institutions of Higher Education, by Source: 1985 to 1994.



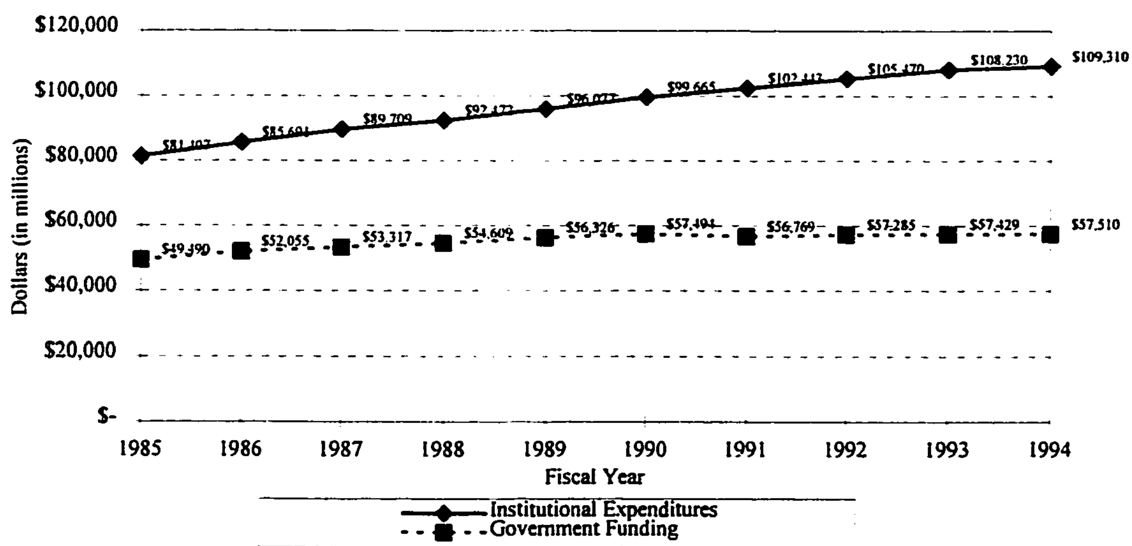
[National Center for Education Statistics (NCES), 1993, pg. 322; 1996, pg. 4]

Froomkin (1990, pg. 195) argued that the proportion of state revenues allocated to higher education diminished throughout the 1980's because "(1) states where economic activity was low reduced their appropriations, (2) states that benefited from the oil boom raised their appropriation very little or not at all, and (3) catch-up increases in low-expenditure Southern states failed to make up for losses elsewhere."

Whether in response to this decline in the proportion of state funding (Slaughter and Leslie, 1997; Ward, 1997), or to satisfy other ends such as personal utility and prestige (James, 1990), universities, and hence faculty, have sought alternative sources of revenue. Mayhew et.al. (1990) document the acceleration in student tuition and fees over the past decade; Kerr (1994), discusses the increased dependency of universities upon stipulated research money provided by government and industry; and Leslie and Rhoades (1995) and Slaughter and Leslie (1997) discuss the search for new revenues via development and endowment money.

Increases from these alternative revenue sources, plus more gradual increases in state support, have bolstered expenditures for the public sector of the higher education system by 24% in real terms over the period from 1985 to 1994. Measured in 1994 constant dollars (GDP Implicit Price Deflator, Appendix 1), this translates into a 21 billion dollar increase, from 88 billion dollars in 1984 to 109 billion dollars in 1994 (NCES, 1996, pg. 5; See Figure 1.2).

Figure 1.2. Federal, State, and Local Government Current-fund Revenue to Public Institution of Higher Education, and Institutional Expenditures of Current-fund Revenue in Public Institutions of Higher Education, in 1994 Constant Dollars: 1985 to 1994.



(NCES, 1993, pg. 332; 1996 pg. 4 and 5)

Despite the declining rate of state government support to higher education, the magnitude of these current-fund revenues has continued to increase in real terms (inflation adjusted) over this period (See Fig. 1.2). Given a set of conditions in which the other revenue sources are fixed, the absolute increases in state support translate into increasing shares of institutional current-fund revenue. However, increases in revenue from alternative sources are not fixed, but rather have outpaced the increases from the state, and therefore, contributed toward the *relative* decline in state government support within the revenue base of these institutions. In short public universities are becoming increasingly reliant upon revenues other than state current-fund appropriations; foremost are tuition and fees and external research grants and contracts. Herein lies the issue fundamental to this study: substituting these alternative funds for diminishing government appropriations can make universities more vulnerable to external control if these alternative funds are more stipulated than the government appropriations they replace.

Many authors argue that these funding changes may create an implicit tension between the instructional and research mission of the university (Volk, 1995; Ward, 1997; Fairweather, 1996; Slaughter and Leslie, 1997). The connections of this tension to public finance and social expectations can be drawn as follows: Given the economic assumption from the classical perspective that education is a quasi-public good (Herber, 1994), higher education should be subsidized by the state to the extent that it provides goods and services that promote the welfare of the state, and therefore, serves the public interest (Tuckman and Chang, 1990). Put in reverse fashion, public subsidies should *not* be used if private resources are adequate to satisfy the public need. In short public allocations are changing and public higher education institutions must seek alternative revenues.

Economists such as Thurrow (1991) argue that in the 21st Century human capital will be the primary economic resource able to increase a society's production possibility curve, or put more simply, raise living standards. The development of human capital through instruction and training, therefore, is the primary function for which universities will be funded by the state. Advancing this argument further, James (1990, pg. 90), in an attempt to estimate the political demand function of universities, poses the question, "What, then, do members of the legislature care about, what are their priorities?" She argues that if they as politicians want to maximize the political gain from their votes, they will care about the quantity of undergraduate students being educated. Thus more political stock will be invested in the numbers of undergraduates being educated at universities than in any other function.

One of the major sources of alternative revenues, however, is grants and contracts, which are sponsored primarily by the Federal Government. Alternatively, research output, not instruction is the primary purpose for which grant and contract revenue is provided. Grant and contract agents may place universities under increasing pressure to choose how they should allocate their finite capital between the teaching and research missions.

A growing number of states, including Arizona, have enacted legislation providing financial incentives for faculty members to teach. The objectives of the Arizona program are

i. to encourage full-time tenure track faculty to increase their teaching loads.
ii. to reward faculty who are already actively engaged in classroom teaching.
iii. to increase the proportion of students who are taught by full, associate and assistant professors. [Joint Legislative Budget Committee (JLBC) Arizona, 1997]

The focus of these programs is to encourage "appropriate" employee behavior. Faculty are considered as state employees who are expected to act in accordance with the wishes of the citizens of the state. The wish of the State, as put by one State legislature, is to "help restore teaching to its rightful place in the hierarchy of faculty activities" (JLBC, 1997, pg. 1). This view is not unique; Massy and Wilger (1992) conclude,

> "State officials believe that many colleges and universities, particularly research institutions, have lost sight of their essential mission--the teaching of undergraduate students--as faculty members spend more time away from the classroom engaged in research and other professional activities" (Massy & Wilger, 1992, pg. 363).

However, the real issue may be the allocation of faculty time *within* the teaching function. The JLBC Report (1997, pg. 3) notes that a major public research university, which participates in the American Association of University Data Exchange (AAUDE), recently reported the percentage distribution of student credit hours by faculty type as follows:

Table 1.1. Distribution of Student Credit Hours by Instructional Rank at a Major Public Research University: 1995-1996.

Type of Faculty	Percent of Total Student Credit Hours Taught		
	LDCH %	UDCH %	GCH %
Full, Associate and Assistant Professors	50.4%	59.6%	82.3%
Other Faculty	27.3%	29.9%	17.7%
Graduate Teaching Assistants	22.3%	10.5%	0.0%

(JLBC, Teaching Incentive Fund Report; 1997, pg. 3)

From the table faculty attention appears to be focused on graduate teaching (tenured and tenure track faculty teach 82.3% of graduates and only 50.4% of undergraduates at this institution); however, this may not necessarily be the case. If the amount of graduate credit hours was small, then faculty could still teach a large percentage of the graduate credit hours while still teaching a substantial number of undergraduate credit hours, albeit a relatively lower percentage. This notwithstanding, the implicit aim of the Arizona and similar teaching incentive programs, arguably, is not just to get tenured and tenure track faculty to teach more, but particularly to teach more undergraduate students.

All this is not to say that teaching and research are independent endeavors, for clearly the extent to which instruction, indeed the curriculum, is relevant and abreast of the latest developments, is a function of research also. The intention of incentives such as those in Arizona is “not to discount the value of research, public service or other useful faculty endeavors” (JLBC, 1997, pg. 1); rather, raising the profile of instruction, particularly undergraduate instruction, is the primary intent of these measures.

So much for the "State" expectation. What is the expectation of the providers of other resources and how does this expectation differ? In contrast to block-grant state funds, the alternative revenue stream of research grants and contracts is often highly stipulated, that is, "restricted." This means that these resources may only be expended to fulfill the purpose for which they were granted, usually *specific* research or *specific* research-related tasks. As the relative proportion of funding from these revenue streams increases, the allocation function of the university changes accordingly; the worry is that increased faculty attention towards research is at the expense of teaching (Slaughter and Leslie, 1997; Ward, 1997).

The second significant source of revenue that is directed primarily towards instruction is tuition and fees. Even if institutions divert state revenues from instruction to research, they may not do so for tuition and fee revenues: Alternatively, the reverse may be true; that is, revenues derived from instruction may be used to support research. The point is that both questions are a public concern: Both state appropriations and tuition are perceived as being used to support research; therefore, both revenues forms should be examined.

Historical Background

Revenues matter. They have an immediate and important effect on the financial status of institutions of higher education (Brinkman, 1990). And revenue changes matter. The changing financial status of institutions has a significant effect on their allocation function, determining in part which economic goods will be produced and in what quantity. What follows is an overview of the changes in these revenue activities for the United States higher education system during the last half century (based upon available data).

Trends in Revenue Sources of Higher Education: 1947 - 1992

From the end of World War II until 1970, the public higher education sector experienced very rapid growth (McPherson and Shapiro, 1993; Hansen and Stampen, 1994). The number of students increased over seven-fold between 1947 and 1970, from 1.1 million in 1947 to 1.6 million in 1956 and eight million in 1974, growing at approximately seven percent per annum (compounded annually) during this 28 year period. Since 1974 the growth rate has decelerated to approximately 1.7% per annum (Fall Enrollments, NCES 1996, pg. 176). Between 1980 and 1984 the number of students in this category was practically stable at 8.9 million, and from 1984 to 1994 the growth rate rose again to 1.7% per annum (Fall Enrollments, NCES 1996, pg. 176).

The growth in enrollments for public higher education, and indeed the higher education system as a whole, was accompanied by spectacular growth in the current-fund revenues, which increased some 162-times in current dollars for the entire system between 1947 and 1994. In 1946 the total current revenues of institutions of higher education were reported to be $1.1 billion (NCES, 1993); in 1994 they were $179 billion (NCES, 1996). In constant prices, the increase was also impressive; the 1946 revenues were estimated to equal $13.6 billion in 1994 prices. Thus the growth in revenues to higher education in real terms was more than 13-fold.

Resources, overall, have kept pace with the fast rate of enrollment growth. Froomkin (1978) documents that the amount spent per full-time equivalent (FTE) student did not change significantly during the period from 1946 to 1974. From 1975 until 1994, the average rate of growth in spending per FTE student followed the growth in enrollments fairly closely, 1.1% per annum versus 1.7%, respectively.

Tuition and fees receipts grew at a more modest pace than both enrollments and current-fund revenues over the period, from $925 million in 1946 (some $11.6 billion in 1994 prices) to 48.6 billion dollars in 1994 (Froomkin, 1990). This translates into a four-fold increase in tuition and fees compared to a six-fold increase in enrollments. It should be noted, however, that while tuition and fees grew from $11.6 billion to $27.5 billion in 1994 prices between 1946 and 1984, a compounded rate of growth equaling 2.2% per annum, from 1984 to 1994 the increase was at an average compound rate of 5% per annum. The growth rate of tuition and fees, therefore, has doubled in the period between 1985 to 1994. For public institutions tuition and fees grew at an annual average rate of 9.2% per annum over this 10 year period, second only to growth in the revenue stream for private gifts, grants, and contracts.

Following World War II, states increased their appropriations to public colleges and universities, enabling state universities to provide the new places for a growing enrollment. State appropriations for the operation of institutions of higher education increased in current dollars from $225 million in 1946 (NCES, 1993, pg. 324) to $37.8 billion in 1994 (NCES, 1996, pg. 2), an increase of over 13-fold in real terms, in constant 1994 dollars.

The fastest growing source of current revenue for institutions, however, was from research and development and related contract work. In 1946 institutions of higher education raised $87 million from this revenue stream, which represented eight percent of their current-fund revenue. In 1994, $31.9 billion of current-fund revenues was derived from unrestricted and restricted, federal, state, and local government grants and contracts, and private gifts, grants, and contracts. This source represented 17% of current-fund revenue, an increase of some 47-fold, in constant 1994 dollars. The revenue stream from private gifts, grants and contracts was the fastest growing single source for public institutions between 1985 and 1994, growing at an average annual rate of 9.4%.

The period between 1968 and 1981 marked a watershed in the financing of higher education (Hansen and Stampen, 1994). To meet the rising demand for higher education and the associated increase in costs, federal funding was sought to expand the system of student financial aid. Leslie (1995) noted that this shift in financing was soon followed by large increases in tuition for public universities so that government subsidies could be directed to those students who demonstrated financial need. These changes were designed to redistribute federal assistance away from institutional support to the support of students.

The wider implications of these changes upon higher education financing are becoming apparent. Leslie (1995) suggests that the changes were indicative of a new direction in higher education financing that went beyond the immediate implications for student aid and tuition policy, or even financing policy. The direction was one of placing institutions of higher education under competitive market pressures in obtaining resources. Clark Kerr attests to the impact these changes have had upon universities, noting, "higher education is becoming more and more a market economy." (Kerr, 1994, pg. 3.)

Effects upon Academic Labor: A Closer Look at the Allocation Function

The debate over the priorities of American faculty members is not an arcane discussion of instruments and indicators; the outcome affects the future of the academic profession. Critics argue that the role of the professoriate is changing from that of trusted, respected professionals dedicated to the pursuit and dissemination of knowledge to members of a self-centered elite who neglect undergraduate teaching to pursue their research interests (Allen, 1996). The common defense by faculty and many University spokespersons, that teaching and research are virtually inseparable, is seen by critics as a misguided Humboltian ideal. David (1997, pg. 160) states that the complaint of undergraduate students in research universities around the world is that "they are taught mainly by graduate students and teaching assistants, while top academics concentrate on the business of research and publication upon which the advancement of their own careers chiefly depends."

This view of faculty is supported in the main by anecdotal evidence rather than rigorous analysis. Many policy-makers, concerned about the fate of higher education during fiscal deprivation, cope with demands for the assessment of faculty workload and productivity under the unproven assumption that each behavioral component of these concepts can be quantified accurately.

Scholars have attempted to shed empirical light on the workload and priorities debate; the evidence presented in the next chapter brings into question assertions of widespread faculty attention toward research at the expense of teaching. Evidence shows that, on average, faculty members devote over 50% of their 52 hour work-weeks to teaching-related tasks, in short, they have responded to budgetary cutbacks by working harder and teaching more. Furthermore, faculty members are more productive than ever and are not neglecting their undergraduate teaching responsibilities (Allen, 1996).

Purpose

The purpose of this study is to estimate the production (allocation) function of public research universities through modeling the income production function of academic departments, by field of science. Specifically, the purpose is to estimate the relative "rate of return" universities assign to teaching productivity and research productivity and to assess whether this return has changed over time. In order to make valid comparisons of work productivity from one time period to the next, the quality of the work must be taken into account; as such, a measure of departmental quality is included in the model. Departments in science, engineering, and mathematics are chosen as the unit of analysis due to the current concern over the quality of undergraduate instruction in these fields (National Science Foundation, 1993).

For the purpose of this study the allocation function is modeled by the estimation of a revenue function. Revenue functions are part of the family of functions known as *Income Production Functions*. These functions are commonly found in the human capital theory literature, where they are used to estimate the relative importance of variables in the production of income (Ramanathan, 1995). When income is derived from a central allocation source, the relative importance of variables to the production of income is also a measure of their importance in the allocation of that income. Consider the case where the earnings function is estimated for a population of workers at a single factory. Because all workers are all paid from the same central source (the part of the budget the company sets aside for salaries), the relative importance of the variables that impact upon worker incomes are also by definition a measure of how the company decides salaries should be allocated. Therefore, by modeling the income function for these workers, the allocation function for the company is being modeled also [The terms, "allocation function" and "income (revenue) production function," will be used interchangeably from here on in when referring to the university's goals and the department's revenue generating endeavors respectively].

By substituting the department for the individual workers and the university for the factory in the example above, the revenue production function, or income function, is estimated as a means of determining the relative importance of teaching and research productivity among these organizations allocational priorities, i.e., their missions. Further, departmental expenditures of non-restricted funds are used as a proxy measure for revenues derived from the institution's current-funds. Thus the relative importance of teaching and research in generating departmental revenues reflects the relative importance each has in the allocation priorities of the institutions. Unlike teaching, the relative importance of research is estimated conservatively in this model because research expenditures, or more accurately, indirect cost recovery monies, are not included in non-restricted current-funds in the American Association of Universities Data Exchange (AAUDE) data set.

Departmental income in this study is modeled as a function of teaching productivity, research productivity, and departmental quality. To the extent that institutional resource allocation is measured by departmental expenditures of non-restricted funds, the relative effects of these outputs upon the allocation of resources represents one way of measuring the importance of different variables in the resource allocation decision making process (Pfeffer and Salancik, 1974; Dawes, 1974).

The impact of internal decision making on resource allocation for this study is examined with respect to the revenue of academic departments aggregated by academic field of science. The dearth of empirical studies that use the department as the unit of analysis, coupled with the organizational importance of the department and field type in university decision making and resource allocation, represents an important empirical gap that this study addresses (Pfeffer and Salancik, 1974; James, 1990; Massy, 1996; Fairweather, 1996).

Framework

Selection of the decision-making theories that guide resource allocation within institutions of higher education is dependent, in large part, on how these organizations are conceived. Although multiple theories of universities as organizations exist, two prove especially useful for this study of resource allocation in public research universities: *The Economic Theory of the Firm* and *Resource Dependency Theory*. Simply put, the economic theory of the firm conceives of higher education units as rational economic actors. In recent times the economic theory of the firm has been extended to include multi-product, not-for-profit organizations, making its application to universities tenable (e.g., James, 1978). Resource dependency theory lends itself to the study of universities as complex organizations with often diverse constituents and competing goals by emphasizing the political dimension of these organizations and their relationship to the external resource environment (Pfeffer and Salancik, 1978). These two theories offer alternative, though not mutually exclusive, explanations of the bases for resource allocation within institutions of higher education. These two theories and their implications are outlined next.

The Economic Theory of the Multi-Product, Not-For-Profit Firm

The economic theory of the firm (heretofore referred to as the "theory of the firm") is based upon the paradigm that an organization pursues a set of goals to maximize its satisfaction, subject to one or more constraints (Tuckman and Chang, 1990; James, 1990). In the case of not-for-profit organizations, satisfaction is maximized when the organization allocates resources to each goal in such a fashion that no other combination of resources gives rise to a higher level of total utility, given the constraints (James, 1978). The fact that universities are not-for-profit organizations that produce multiple outputs leads to a number of behavioral implications: firstly, that the objectives of decision-makers matter in determining choices and levels of output; secondly, that cost-minimizing factor combinations may not always be chosen; and finally, that cross-subsidization plays an important role. (James, 1990, pg. 78)

However, universities are not-for-profit "Firms" and they are a "special case" within the not-for-profit sector. Unlike profit maximizing organizations that seek to minimize costs, not-for-profit organizations may produce more costly products and services than are optimal from a profit making perspective, in order to satisfy their own preferences. *In short, the major "goal" sought by universities is prestige maximization.* As the (not-for-profit) decision-makers have relatively little discretion over the prices, subsidies, or costs associated with the products and services being delivered, they alter the mix of their organizational products and services to emphasize those that best reflect their preferences (James, 1990).

However, there is a limit in the degree to which these decision-makers can emphasize their preferences, a limit imposed by the fact that the aggregate income of the organization must cover its aggregate costs. Since these decision-makers have preferences of one product or service over another, and because the production of some of the preferred products or services may not cover their own costs, these organizations find themselves taking on profit-making activities that cover the deficit incurred by other activities. This phenomenon is referred to as cross-subsidization (James, 1983).

Overall, the distinguishing characteristic of the theory of the firm, as it may apply to public higher education, is its almost total concentration upon the rational, direct connection of means to ends, resource allocation processes to goals achievement, i.e., prestige maximization.

The External Control of Organizations: Resource Dependency Theory

The importance of goals as a defining characteristic of organizations has been criticized on several grounds: Goals presume a singularity of purpose (Pfeffer and Salancik, 1978); organizations assume that goal setting and choice have an influence over outcomes (Morgan, 1984); the importance of forces external to the organization are neglected (Pfeffer and Salancik, 1978). Resource dependency theory conceives of organizations as coalitions that "alter their purposes and domains to accommodate new interests, sloughing off part of themselves to avoid some interests, and when necessary, becoming involved in activities far afield from their stated central purposes" (Pfeffer and Salancik, 1978, pg. 24). Pfeffer and Salancik see the relationship between resource providers and the organization as a political relationship, because the resource provider holds great power, if not formal authority, over the organization. Recognizing the plurality of goals that exists within organizations, the model allows for the incidence of conflict and bargaining when goals differ.

The process of competing for resources and determining who secures them is central to this framework. As Pfeffer and Salancik state, generally, "organizations will tend to be influenced by those who control the resources they require" (1978, pg. 44). Two factors are important in determining the level of dependence of one organization over another: the relative magnitude of the exchange and the criticality of the resource.

The relative magnitude of the exchange can be assessed by measuring the proportion of resource shares provided. Organizations with a narrow resource base are more susceptible to interorganizational control than those with diversified resources. Criticality of a resource to an organization is measured by the organization's ability to keep functioning in the absence of the resource. Resource importance as defined by this measure is independent of its magnitude.

Pfeffer and Salancik (1978) argue that the importance of a resource to organizational functioning *per se*, is not problematic. Rather, vulnerability is derived from the possibility of changes in resource supply. To ensure the survival of the organization, it is the necessary responsibility of the production units to minimize the possibility of resources becoming scarce. In the case of public universities in the present era, the rational response to the declining rate of state funds has been to increase the share of other revenues in their base, and in so doing, protect their revenue supply.

Whereas the theory of the firm is a relatively straight forward connection of means to ends, resource dependency theory conceives of a much more complex set of relationships. In fairness the theory of the firm has been employed more as an analytical tool then as a fully encompassing theory that explains organizational behavior. Most analysts who have utilized the theory as a basis for testing production functions would never argue that the theory is a complete description of allocation behaviors. Most would recognize, for example, the role of the political behaviors inherent in the resource dependency theory of Pfeffer and Salancik. Nonetheless, the theory of the firm does offer an alternative conception of universities as organizations and specify a set of alternative resource allocation patterns.

Conclusion

Economic theory and resource dependency theory are used to examine resource allocation in this study for three reasons:

i. they offer alternative approaches to derive different testable propositions as to how the allocation function of universities may change.

ii. the need exists for more empirical studies of resource allocation from both perspectives (James, 1990; Slaughter and Leslie, 1997).

iii. changing resource patterns in higher education offer a chance to test the explanatory power of both theories.

Nevertheless, the investigator holds no simple-minded view either that the theories are mutually exclusive or that those who have employed the theory of the firm as a basis for estimating university production functions have assumed that economic theory fully describes organizational behavior. The theories are offered merely to contrast the two perspectives.

Research Questions and Hypotheses

The research questions for the study may be posed as follows:

1. Does the relative weight of research productivity exceed that of teaching productivity in the income production function of academic departments in public Research I universities?
2. Have the relative weights attached to research and teaching productivity changed between academic years 1993-1994 and 1995-1996 in public Research I universities?
3. What is the impact of departmental quality upon the production of departmental income in public Research I universities, and has it changed?

4. Do structural difference exist between the various academic fields of Computing and Mathematics, Life Science, Engineering, Physical Science, and Social Science? And if so, how have they changed over the period of this analysis?

To aid in the evaluation of the relative utility of the two theories in understanding resource allocation, alternative hypotheses are now developed under each theory. The focus in on the changes that may be occurring.

Framework 1: Theory of the Firm

Under this framework the first priority of not-for-profit, multi-product firms, such as universities, is to find a break-even point product mix, so that revenues cover costs; however, this break-even constraint need not apply to each product taken separately. Under the theory the survival priority of public universities is to find a set of profitable activities that attract a clientele and that the faculty are willing to carry out, using a low cost technology. Undergraduate teaching, especially lower division undergraduate teaching, has traditionally served as the profitable activity of U.S. institutions of higher education, along with any low cost programs, undergraduate or graduate, in fields such as business, humanities, social sciences, and some vocationally-oriented programs (James 1990). Thus, the relative importance (as measured by the rate-of-return) of those low-cost, profit producing fields will diminish further within the institution's allocation function, as "profits" in these fields are used to subsidize the high-cost, deficit producing fields.

If profit-making undergraduate education is, in fact, increasingly cross-subsidizing research in public universities, then one would expect a relative decline in the "profit" associated with the production of undergraduate teaching in the revenue function of the department. That is, the university will become more prone to taking money from the production of undergraduate education and giving it to the loss-making endeavors, which may include graduate education and research. Furthermore, because research (it is claimed) in general has greater utility for faculty than does teaching and because it is easier to measure than teaching, and yields more prestige and financial rewards, faculty will be inclined to do more research (James, 1990). Accordingly, universities will increasingly cross-subsidize research from undergraduate teaching, and hence, lower the relative rate of return of undergraduate teaching in the institutions allocation function.

Corollary to this, the relative rate of return for research will increase as the subsidies to it from undergraduate education increase. As graduate students are often used as inputs into the production of research and hence have a complementary effect on research, the relative rate of return attached to graduate instruction will increase also.

These effects are all consistent with the prestige-maximization hypothesis since prestige depends primarily on research, graduate instruction, and in general upon the quality of the unit (James, 1990). These effects give rise to a number of hypotheses:

If faculty, and hence the universities of which they are a part, seek to maximize prestige, then within field groups

I. The rate of return for the production of undergraduate instruction will diminish over time within the revenue production function of departments.

II. The rate of return for the production of graduate instruction will increase over time within the revenue production function of departments.

III. The rate of return for the production of research will increase over time within the revenue production function of departments.

IV. The rate of return for those fields that are subject to low-cost production will decrease over time within the revenue production function of departments.

V. The rate of return for departmental quality will increase over time within the revenue production function of departments.

Framework 2: Resource Dependency Theory

Increasing the share of alternative revenues within the base of public universities has created a greater reliance upon them. This reliance has facilitated an increase in the criticality of these alternative resources to the organization, and furthermore, increased organizational vulnerability to the providers of these resources. With tuition and fees and research grants and contracts being the most significant and the fastest growing of these alternative revenue sources, their criticality to the organization has increased also. Rather than research advancing in importance at the expense of teaching, an alternative conceptualization of resource dependency theory suggests that both research and teaching will increase in importance in the production of departmental revenues.

Pfeffer and Salancik (1974) show that departmental power has a sizable and significant effect upon departmental income production, even greater, in fact, than the effect of the quality of the department. Extending this to the level of the field, those fields that are traditionally powerful will be able to extend their advantage through the internal bargaining process and secure more internal resources. Following this rationale, the importance of departmental quality will be decline, relative to power, in the quest for internal resources, and hence, will have a diminishing rate of return over time within the departmental income production function.

These effects are consistent with the external control of the organization hypothesis which suggests that as the relative share of revenues change within an organization's budget, the behavior of the organization adapts to the meet the needs of the new providers of these resources. These effects give rise to a number of testable hypotheses:

If the change in revenues has made public universities subject to greater control by the providers of these revenues, then within field groups

I. The rate of return for the production of undergraduate instruction will increase over time within the revenue production function of departments.

II. The rate of return for the production of graduate instruction will increase over time within the revenue production function of departments.

III. The rate of return for the production of research will increase over time within the revenue production function of departments.

IV. The rate of return for those fields that are traditionally strong will increase over time within the revenue production function of departments.

V. The rate of return for departmental quality will decrease over time within the revenue production function of departments.

These hypotheses are summarized in the table below. (See Table 1.2)

Table 1.2. Hypothesized Changes in the Relative Weights of Variables within the Revenue Production Function.

	Change in Relative Weight within the Allocation Function	
Variables	Economic Theory	Resource Dependency Theory
Lower Division Credit Hours	-	+
Upper Division Credit Hours	-	+
Graduate 1 Credit Hours	+	+
Graduate 2 Credit Hours	+	+
Sponsored Research Expenditures	+	+
Field Group: Computing & Math	+	+
Engineering	+	+
Life Science	+	+
Physical Science	+	+
Social Science	-	-
Quality	+	-

Ideally, a comprehensive set of measures that directly tests the explanatory power of each theory would be available. In addition to the measures used in this study, these might include direct measures of departmental power, resource criticality, and faculty utility. However, due to the limitations of the data available and the commonality of the effects as hypothesized under both theories, the relative explanatory power of each theory is premised upon the outcomes related to two sets of variables: undergraduate credit hours and departmental quality. The effects of these variables upon internal resource allocation are fundamental to determining which theory possesses the greatest explanatory power. If a negative relationship exists between institutional resource allocation and faculty instructional productivity and a positive relationship between institutional resource allocation and departmental quality, then Pfeffer & Salancik's (1978) resource dependency framework may not offer the best account of organizational responses to the changing fiscal environment. In this case we could reject the explanations provided by this theory in favor of those given by the theory of the firm. In like fashion, if these relationships are reversed we may reject the explanations provided by the theory the firm in favor of those given by resource dependency theory. In actuality elements of both theories may be evident to different degrees within the different field groups.

Design

A multiple regression model that relates institutional resource allocation to measures of departmental output is employed. Departments in the fields of science, engineering and mathematics (National Science Foundation 1993) are chosen as the units of analysis.

Model Specification

The semi-log model is widely used in human capital literature in which theory suggests that the logarithm of earnings or wages be used as the dependent variable. This is a particular strength of the present study. Most previous work has lacked a theoretical basis but rather employed models that simply fit the data best. Employing the semi-log model in the field of higher education, the department is substituted for the individual as the unit of analysis and the earnings of the department are measured by departmental expenditures of non-restricted current-fund revenues. In the present study, non-restricted current-funds are defined as the sum of faculty salaries, support salaries, and service and supply expenditures.

As teaching and research are the primary outputs of faculty labor, suppose the rate of return to an extra credit hour of teaching or an extra dollar of research grants is given by r. Then for the first case, earnings $E_1 = (1+r)E_0$. For two credit hours, this becomes $E_2 = (1+r)^2E_0$. For n credit hours, the generalization is given by $E_n = (1+r)^nE_0$. Taking logarithms of both sides, yields:

$$\ln(E_n) = n\ln(1+r) + \ln(E_0)$$

$$\therefore \quad \ln(E_n) = \beta_1 + \beta_2 n; \text{ [where } \beta_1 = \ln(Eo) \text{ and } \beta_2 = \ln(1+r)]$$

Thus, a semi-log relationship is obtained between departmental earnings and student credit hours. The same relationship holds true for research. The generalized model, therefore, is given by

$$\ln(E) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7$$

where,

X_1 = Lower Division Credit Hours

X_2 = Upper Division Credit Hours

X_3 = Graduate One Credit Hours

X_4 = Graduate Two Credit Hours

X_5 = Sponsored Research Expenditures

X_6 = Faculty Quality

X_7 = Program Effectiveness

In Chapter 3 this generalized model is extended to include departments for all field groups under investigation in this study: computing and mathematics, engineering, life science, physical science, and social science. The system of five equations that are derived are more efficiently estimated using Seemingly Unrelated Regression equations. The transformation of the model is discussed briefly below. The full discussion is provided in the data analysis section of Chapter 3.

Transforming the Model: For a System of 2 Equations

In this overview of the model, the system of equations is simplified to include only two fields. To begin the case for two fields and two parameters is considered in deviation form, where,

$$y_1 = \alpha x + u_1$$
$$y_2 = \beta x + u_2$$

If the error terms in the two equations were uncorrelated, then efficient measures of α and β could be obtained by the application of ordinary least squares estimation on each separate equation (assuming they satisfied all other conditions of the Gauss-Markov theorem), using N observations in each case. However, under the assumption that u_1 and

u_2 are correlated for identical cross-section units, the efficiency of the estimators can be improved by writing the system of equations as one combined equation and applying generalized least-squares estimation. This increases efficiency because there are $2N$ degrees of freedom with which to estimate α and β, rather than N for α and N for β.

In order to write the system as one large equation rather than two smaller equations, it is necessary to distinguish between observations associated with the first equation and observations associated with the second equation. To do so, the observations are relabeled arbitrarily, assigning observations 1 to N to the first equation variables and observations N+1 to $2N$ to the second equation variables. The new variables are defined as follows:

$$y^{\bullet} = \begin{cases} y_{1i}, & if \quad i = 1,\ldots,N \\ y_{2i}, & if \quad i = N+1,\ldots,2N \end{cases} \qquad x^{\bullet} = \begin{cases} x_i, & if \quad i = 1,\ldots,N \\ 0, & otherwise \end{cases}$$

$$z^{\bullet} = \begin{cases} 0, & if \quad i = 1,\ldots,N \\ z_i, & if \quad i = N+1,\ldots,2N \end{cases} \qquad u^{\bullet} = \begin{cases} u_{1i}, & if \quad i = 1,\ldots,N \\ u_{2i}, & if \quad i = N+1,\ldots,2N \end{cases}$$

Also, $\sigma_1^2 = Var(u_1)$ $\qquad \sigma_2^2 = Var(u_2)$ $\qquad \sigma_{12}^2 = Cov(u_1, u_2)$

With this new notation the combined equation is written as

$$y^{\bullet} = \alpha x^{\bullet} + \beta z^{\bullet} + u^{\bullet}$$

Applying the generalized least-squares procedure to this equation yields efficient parameter estimates for α and β. This model is extended in Chapter 3 to include all five fields and all 35 parameters.

Confounding Factors

Brinkman (1981) delineates three categories of higher education cost factors, namely, environment, decision, and volume factors. Operationalized as input prices, input levels, and output levels, these factors alone may account for the variation in non-restricted expenditures. It is necessary to control for these measures across departments in order to delimit their potential confounding effects. That is, if inputs to the production process vary, they will account for a greater share of variance in expenditure by the degree to which the payments for those inputs differ. Since instructional activity is labor intensive, variation in faculty salaries alone will impact upon expenditures independently of other effects. Output level is controlled for in this model. By scaling all quantitative measures by a factor of [1/Full-time Faculty Equivalents (FTE)] the potential confounding results from variations in output levels is largely eliminated.

Given the relatively homogeneous sample of major public research university departments and the competitive national market for faculty, input levels *vis a vis* faculty rank and input prices *vis a vis* faculty salaries are assumed to be constant across institutions for departments in each of the fields selected. Thus on the basis of the homogeneity assumption no attempt is made to control for these environmental and decision factors.

Chapter Summary

Constrained by the economic forces of scarcity and insatiable demand, institutions of higher education are forced to make choices in the allocation of their finite resources across their missions of teaching, research, and public service. Changes in the sources and levels of funds available to universities may affect their allocation functions. In the past ten years, state financial support for public universities has declined, when measured as a proportion of current-fund revenues. Whether in response to this decline or to satisfy other ends such as personal utility and prestige, universities, and hence faculty, have sought alternative sources of revenue mostly though increased tuition and fees and grants and contracts. The effects of these revenue changes "play out" in the primary operating units of universities, academic departments, which serve as the primary focus of the this study.

These changes have prompted concern in recent years that university faculty within public research universities may devote too much of their human capital to research at the expense of teaching. Studies of faculty time allocations seemingly contradict this perception, however, purporting to show that faculty are responding to the fiscal disequilibrium by working harder and teaching more.

Two theories are used to attempt to explain patterns of university resource allocation. The theory of the firm may explain the changing importance of teaching productivity and research productivity by reference to the expense preference and utility maximizing behavior of faculty. This conception of the relative worth of teaching and research within the departmental income production function suggests that the state supported income a department is able to generate may have decreased directly in proportion to the number of undergraduate credit hours generated but increased directly in proportion to the number of graduate credit hours generated, the amount of external research funding acquired, and the quality of the department. Alternatively, resource dependency theory may explain the changes in other ways. Specifically, the amount of state supported income that a department receives may have increased directly in proportion to the number of credit hours generated and the amount of external research funding acquired; but due to the increasing importance of these factors, the "return" to departmental quality may have decreased.

CHAPTER 2

REVIEW OF THE LITERATURE

In this chapter the literature is reviewed in order to develop clearly the approach to answering the questions pursued in the present study, in short, to build the case for examining how departments make choices in the spending/allocation of their resources. The logic of the chapter is as follows.

Because the resources that departments receive, in large part are determined by central administration allocation decisions, examined first are the presumed bases of those decisions: institutional goals. Part two considers the degree to which the stated goals appear to conform to the allocation of resources, as reflected in faculty workload data; that is, the activities of the primary production workers, faculty, should reflect patterns of resource deployment. This, of course, is the nexus of the problem addressed by this study: If allocations fail to conform to goals, there may be something amiss in the resource allocation decision process. The third step is to reflect upon the means or processes resource allocaters decide will best serve institutional goals, specifically, which theoretical approach, the theory of the firm or resource dependency theory, will most likely result in the accomplishment of these goals.

This brings us to selecting the best means of pursuing answers to the question of which theory predominates. These "means" are reflections of the "true" production processes, the production functions actually employed in universities. Thus, part four reviews what others have found in regard to that production process. The purpose of the present study, simply put, is to take the production function research a step farther through an examination of more recent and complete data *at the departmental level.* Through all of this review it is recognized that departmental decisions are, or should be, related directly to the research allocation decisions at the central university level, but it is argued that the choices made at the production level, the departments, reflect the final or ultimate test of how well institutional goals will be served.

2.1. Goals and Priorities for Higher Education

The goals and priorities of institutions of higher education are examined from the frameworks of the theory of the firm and resource dependency theory. The theory of the firm assumes decision makers pursue a set of goals for their satisfaction, subject to one or more constraints (Tuckman and Chang, 1990). In contrast, resource dependency theory argues that while efficiency measures for resource allocation are easy to obtain, they are difficult to interpret . Instead, resource dependency theory suggests that the goals pursued are conditional upon the collective demands of stakeholders, but particularly the demands of those stakeholders who supply the revenues these institutions depend upon. The different interests and goals of these stakeholders are mediated by a process of interest group bargaining and conflict. Efficient resource allocation for one group, say administrators, may not be efficient resource allocation for another group, such as the faculty, both of whom make allocational decisions that reflect, or at least are constrained by, the wishes of resource providers, such as students, parents, and state legislators.

Goals in Higher Education: Theory of the Firm

Whereas the economic perspective has been used to study the goals or preferences of higher education participants theoretically, few studies of an empirical nature have been conducted. Most such studies have distinguished between the preferences of internal and external actors (Garvin, 1980; James, 1990). Typically, the proposed or implied utility function for the institution has assumed either that everyone at the university has an identical team objective function, termed the institution's objective (James 1990), or have "factored in" the utility of only some of the internal stakeholders: typically, administrators and faculty (Garvin, 1980)

Over the years, a considerable literature has developed on the goals for higher education (Tuckman and Chang, 1990). Bowen (1980) claims to have identified more than 1500 different institutional goal statements in historical and contemporary sources. Breneman (1970) argues prestige maximization to be the goal of universities and shows that graduate student admission, retention, and placement decisions to be consistent with this perspective. Garvin (1980) similarly holds that the university's utility is a function of prestige and a number of others agree (Jencks and Reisman, 1968; Mayhew, 1970; Vladeck 1976). Clotfelter (1996), James (1990), and Leslie and Rhoades (1995) argue that Universities, as not-for-profit enterprises, maximize revenues rather than profits to serve clients better and to maximize prestige. Clotfelter (1996) and Leslie and Rhoades (1995) link the dramatic increases in university costs to the pursuit of prestige. In short, prestige maximization has been identified in these and other studies as a common goal that yields utility to the university decision makers.

James (1986) posits that research; graduate training; student quality; and small, advanced classes reflect the university's goal priorities, whereas colleges care more about undergraduates. Decisions about teaching loads at different institutional types and changes in teaching loads through time also are said to give evidence of the increasingly heavy attention to research, especially at universities. A number of faculty reward studies conclude that research productivity is the prime determinant of salary, promotion, and tenure decisions at universities and that teaching is relatively unimportant (Dornbusch, 1979; Fairweather, 1996; Lewis and Becker, 1979; Tuckman, 1979).

These findings are all consistent with the prestige-maximization hypothesis, since prestige is held to depend primarily on the quantity and quality of research, graduate training, and students enrolled. Indeed variables such as research funding, rankings of graduate departments, and undergraduate selectivity are often used as proxies for prestige, which is difficult to measure directly (James, 1990). These findings are consistent with the view expressed by James and Neuberger (1981), who suggest that as not-for-profit institutions, universities spend potential profits on the "consumption of goods" they prefer: quality students, low teaching loads, and small graduate classes. If prestige maximization is taken as the underlying preference of universities, precisely how does this preference impact upon the explicit goals of undergraduate instruction, graduate instruction, and research?

Verry and Davies (1976) argue that the number of student credit hours or of degrees granted may enter into the objective function of universities and that these measures of instruction will yield positive effects if they contribute toward the utility of the institution. If prestige maximization and faculty satisfaction are the underlying goals, then instruction will have a positive effect either if faculty enjoy teaching or if they use students as inputs to research. This being the case, then graduate students are more likely than undergraduate students to have a positive coefficient in the utility function.

Research is included in the faculty utility function for the following reasons: faculty may enjoy spending time doing research, asking questions, and proceeding to answer them as they have been trained to do (Fairweather, 1996); moreover, research enhances institutional and individual visibility, status and prestige; research grants, further increase the resources available to the institution, particularly through indirect cost recovery and faculty time buyouts; and perhaps more altruistically, universities may be motivated by their ideals of expanding society's stock of knowledge.

Although research measurement is problematic, it is not so problematic as measurement of teaching output. The former has been measured by numbers of books published, articles in refereed journals, citations, grants and contracts, and the subjective assessment of experts. The measurement of teaching can only be described as contentious. The relative availability and acceptability of indicators of research quantity and quality probably is another reason for its importance as an output goal.

Priorities in Higher Education: A Resource Dependency Perspective

Moving beyond the assumption that universities operate with a team-utility function working in harmony to achieve some singular set of goals, resource dependency theory conceptualizes universities as coalitions of groups and interests, each with their own preferences and objectives which lead to competing and conflicting demands.

And even the coalitions themselves are multidimensional: there is *no* requirement for the participants to share interests or singular, paramount goals. Anything that justifies a participant's involvement may be sufficient for coalition formation. Organizational participants may come into the coalition when there is some advantage to be gained and leave when that advantage disappears. Gains and costs are defined in terms of individuals, not in terms agreed upon by all.

A large number of interested parties have an effect on university resource allocation decisions. From a meta-analysis of the literature Tuckman and Chang (1990, pg. 55) list 10 significant participant groups within higher education: (1) students, (2) faculty, (3) administrators, (4) state funding agencies, (5) trustees and governing boards, (6) professional and accrediting agencies, (7) society at large, (8) philanthropic organizations, (9) federal funding agencies, and (10) private industry. The goals of four major stakeholders, students, faculty, administrators, and the State, are given in Table 2.1.

Table 2.1. Goals of Four Major Stakeholders in U.S. Higher Education.

Participant Groups	**Major Generic Goals**
Students	• Cognitive learning • Satisfaction and enjoyment • Certification
Faculty Administrators	• Self learning • Student learning • Creation of new knowledge • Recognition and prestige • Student and faculty learning • Growth of the institution • Efficient management of the institution • Professional recognition and prestige
The State	• Protect the rights of citizens in the educational process • Ensure efficient use of state funds • Train citizens to meet state needs

(Tuckman and Chang, 1990, pg. 55)

Clearly, these goals do not all involve the same ends. Sometimes the goals of one group may be in conflict with the goals of another. For example, the goal of the state to ensure efficient resource use for instruction may come into conflict with the goal of the faculty to seek prestige. Consistent with the observation that goals may vary within a single group, students may gain satisfaction and enjoyment from cognitive learning, athletic and arts events, and peer interactions, which may be complementary or may be in conflict when student time allocations are involved and when the various other activities make special demands on student financial resources.

From a resource dependency perspective, therefore, the priorities of the institution are revealed by the prevalence of the wishes certain groups through the process of conflict and interest group bargaining. While the theory of the firm holds that goals are determined, *a priori*, and that the participant groups within the organization work together to maximize these goals, resource dependency argues for a far more "messy" process.

Both resource dependency theory and the theory of the firm, however, share one primary goal for the university: organizational survival. While the theory of the firm proposes a model in which organizational survival is defined as a function of maximizing institutional prestige and faculty satisfaction, resource dependency theory argues that survival is more a function of interdependence among both internal participants and organizations outside organizational boundaries. Pfeffer and Salancik (1978, pg. 40) argue that interdependence exists "whenever one actor does not entirely control all of the conditions necessary for the achievement of an outcome." When these "conditions" are resources, if resources are large relative to the demand for them, there is a reduction in interdependence; however, when resources are scarce, there is an increase in interdependence. Interdependence is a consequence of the open-systems nature of organizations; they must transact with their environment in order to obtain the resources necessary for survival.

Interdependence is not always symmetric (Galbraith, 1967; Pfeffer and Salancik, 1978). Asymmetric relationships exist when the exchange is not equally important to both organizations. Extent of asymmetry is reflected in the degree to which one organization has power over the other. Within organizations for example, not all coalitions are valued equally by those having the power to decide. Those participants who provide resources that are most in demand by other organizational participants come to have substantial influence and control over the organization; one of the inducements for contributing the most critical resources is the ability to control and direct organizational action. The relative power of organizational participants is a function of the dependence of others upon the resources participants provide.

Hackman (1985) examined how power influences the allocation of resources within institutions of higher education. Identifying departments as either core or peripheral, she found that the ability to generate external resources was the primary factor promoting program growth while a loss of power was given as the reason for program decline. Ashar and Shapiro (1988) also found that power was a driving force in resource allocation, where power was defined as a function of workflow rather than centrality.

Scarcity of resources fosters interdependence (Pfeffer and Salancik, 1978) and asymmetries in interdependence create differential power status. The use of power in the resource allocation process leads to the politicization of this process. Pfeffer and Salancik (1974, pg. 137) argue, “Organizations operate as coalitions in many decisions, with subunits contending for resources and with resource allocations being shaped by considerations of relative political strength." Thus the fiscal constraints facing institutions of higher education are conducive to an environment where political power is used to compete for scarce resources.

Balridge (1971) describes three types of organizational models at work within institutions of higher education; the bureaucratic, collegial, and political, of which he argues the political is often the best description of reality. Wildavsky (1968, pg. 193) argues that "if organizations are viewed as political coalitions, budgets are mechanisms through which subunits bargain over conflicting goals". Morgan (1984) goes on to describe resource allocation decisions as a process of interest group bargaining in a political environment, and Bolman and Deal (1986, pg. 320) list five key assumptions of the political framework with respect to resource allocation:

1. Most of the important decisions within organizations involve the allocation of scarce resources.
2. Organizations are coalitions composed of a number of individuals and interest groups.
3. Individuals and interest groups differ in their values, preferences, beliefs, information and perceptions of reality.
4. Organizational goals and decisions emerge from ongoing processes of bargaining, negotiation, and jockeying for position among individuals or groups.
5. As a result of scarce resources and enduring differences, power and conflict are essential features in organizational life.

Bolman and Deal's results are supported by the work of others such as Cohen and March (1974), Etzioni (1964), and Wildavsky (1968). In contrast to the economic view of resource allocation that espouses a singularity of purpose within the institution, this political view assumes a highly competitive and contentious environment among and within institutions (Morgan, 1984).

Given a set of conditions for universities in which resources are scarce, interdependencies within and without the organization exist, interdependencies are asymmetrical, and power differentials prevail, what are the implications for questions about teaching versus research? Leslie (1995), Slaughter and Leslie (1997), and Ward

(1997) argue that as appropriations from states decline in their rate of growth, universities have sought alternative sources of revenues. With research grants and contracts being the fastest growing source of these alternative revenues, universities have come to rely more on this revenue stream; concomitantly resource providers rely, in part, upon the universities to perform these services. But while the interdependency between the university and providers of this revenue has increased, the interdependency has been asymmetrical. In a time of fiscal stress, the providers of these resources have enjoyed the opportunity for greater influence and control over the recipient organizations. Of course other forms of regulatory control have not remained fixed either. Increased federal and state oversight of occupational health and safety, contract compliance, and a number of other organizational practices have augmented the control of these external resource provider further.

Because tuition and fee revenue has increased at a rate only second to that of private gifts, grants, and contracts and because it represents a share of revenues to public universities second only to state funds, the potential interdependency between universities and students has increased also. In past periods when enrollment growth (and thus increased revenues) was high, the interdependency between the students and the university was asymmetrical, and greater power was afforded to the institutions. This was because state subsidies connected to enrollment growth were greater than presently and because institutional marginal costs were less than marginal revenues. However, as enrollment growth has slowed, tuitions have risen, and state grants have diminished, the interdependency between students and the university has increased and should have begun to favor students: an implication not has not traditionally been associated with resource dependency theory.

2.2. Institutional Goals as Reflected in Faculty Workload and Productivity

Is there any empirical evidence that suggests whether the goals of the university, as hypothesized under each of the theoretical frameworks, are being achieved? Part two of this review, considers the degree to which the purported goals of the institutions conform to the allocation of resources, as reflected in faculty workload data.

The re-emergence of concerns over the quality of undergraduate education is expressed in a number of reports, such as *A Nation at Risk (1987)*; *Task Force on the Health of Research (1992);* and *An Exploration of the Nature and Quality of Undergraduate Education in Science, Mathematics and Engineering (1989)*. These reports call for a greater attention to student instruction. The specific issue is whether full-time faculty are giving increased attention to research while delegating their teaching duties to part-time and adjunct faculty and graduate teaching assistants. While not speaking directly to the issue of faculty time and effort preferences, work completed at the National Science Foundation (NSF) for physics, geology, and sociology demonstrate the bases for the public concern and serve as a starting point.

Table 2.21. Proportion of Undergraduate Instruction Provided by Various Faculty Members, by Field and Institution Type: 1990.

	All institutions	Research I & II	Doctorate granting I & II	Comprehensive I & II	Liberal Arts I & II
			(Percentages)		
Geology					
Full-time faculty	79	66	71	81	92
Part-time faculty	9	4	7	13	5
Other faculty	0	0	1	0	0
Teaching Assistants	12	30	21	5	2
Physics					
Full-time faculty	85	59	68	89	90
Part-time faculty	7	4	7	8	6
Other faculty	0	0	0	0	1
Teaching Assistants	8	36	25	3	3
Sociology					
Full-time faculty	82	68	78	83	85
Part-time faculty	15	11	15	17	14
Other faculty	1	1	0	0	0
Teaching Assistants	2	20	6	0	0

(National Science Foundation, 1993, pg. 257)

Table 2.21 shows varying degrees of reliance on the mix of personnel responsible for teaching and how this mix varies by institutional type. On average, full-time faculty account for 82% of undergraduate instruction, part-time faculty contribute over six percent, and undergraduate assistants and adjunct faculty provide the remainder. However, instructional hours taught, show significant variation across institutions, with undergraduates at Research I and II Universities receiving a much larger then average share of instruction from teaching assistants, who provide between 20% and 36% of primary instruction at these institutions, at least for the listed fields.

Table 2.22. Doctoral Scientists and Engineers Employed as Academic Faculty, by Field and Primary Responsibility: 1973-91.

		Primary Responsibility	
Year	Total Employment Number	R&D Percentage	Teaching Percentage
1973	97980	23.0	69.0
1975	111378	22.1	70.7
1977	118559	24.5	63.9
1979	119989	25.3	61.5
1981	130388	24.8	65.6
1983	133909	24.6	62.7
1985	144663	27.0	61.3
1987	149219	31.4	57.6
1989	154300	32.1	56.3
1991	149874	32.7	56.6

(National Science Foundation, 1993, pg. 407)

Other NSF results have served to advance further the perception that faculty "prefer" research over teaching. Data from the *Survey of Doctoral Recipients*, conducted by the NSF (1993), addressed this issue (See Table 2.22). Academic doctoral science and engineering faculty members were asked to describe their primary work responsibility. While the number of respondents reporting either teaching or research as their primary responsibility increased between 1973 and 1991, there was a marked difference in the rate of increase between the two. The number reporting "research" increased by 46%, while those reporting "teaching" increased by only 25%. As seen in Table 2.22, the total percentage of faculty reporting "teaching" as their primary responsibility decreased in share from 69.0% to 56.6% of the total respondents, a decline of 12.4 percentage points. Correspondingly, the number reporting "research" as their primary responsibility increased from 23.0% to 32.7% of the total respondents, an increase of 9.7 percentage points. Many scholars support the implicit message from this table: Faculty resources have been diverted to research at the expense of teaching (James, 1990; Fairweather, 1996; Massy, 1996).

Table 2.23. Percentage Allocation of Faculty Time in Research, Doctoral, and Comprehensive Universities: 1965, 1988, and 1993.

	Teaching	Research	Other
Cartter (1965)	47	24	29
NSOPF (1988)	48.8	21.3	29.9
NSOPF (1993)	44.2	23.7	32.1

[Adapted from Cartter (1965), sample of 106 universities, found in James (1978); National Survey on Post-Secondary Faculty (NSOPF), 424 institutions, figures reported for research universities only, adapted from Fairweather (1996 pg. 26); NSOPF, reported in Allen (1996). Teaching = Undergraduate and Graduate Teaching, Research = Departmental and Sponsored Research, Other = Administration, Service, Consulting and Professional Development]

These tables, however, are not direct reflections of changing faculty priorities; arguably a better measure is faculty time allocations. When faculty time allocations are examined over the 28-year period from 1965 to 1993, it is seen that faculty allocations to both teaching and research have declined, albeit marginally, since 1965. These shifts are due to concomitant shifts upwards of faculty time devoted to "other" activities (See Table 2.23). In fact, the percentage of time allocations to teaching have declined; however, the culprit does not appear to be research. Because these data are subject to self-reporting bias, sampling bias, and differing measures of these activities over time, cautious interpretation is warranted.

Table 2.24. Percentage Allocation of Faculty Time in Research Universities: 1965, 1988, 1993, and 1997.

	Teaching	Research	Other
Parsons and Platt (1965)	47.0	32.0	21.0
National Survey on Post-Secondary Faculty (1988)	42.6	31.4	24
National Survey on Post-Secondary Faculty (1993)	36	33	31
Leslie et.al. (work in progress)	50.8	35.9	13.3

[Adapted from Parsons and Platt (1965), sample of 3 research oriented universities, found in James (1990); National Survey on Post-Secondary Faculty, 424 institutions, figures reported for research universities only, adapted from Fairweather (1996 pg. 26); Leslie, Rhoades and Oaxaca, sample of 9 research I and II universities, NSF sponsored study in progress. Teaching = Undergraduate and Graduate Teaching, Research = Departmental and Sponsored Research, Other = Administration, Service, Consulting and Professional Development]

But the major public criticism is probably directed toward Research Universities, not to all four-year institutions. What do the time allocation data show about the former? Research universities essentially participated in this trend until 1993, except that the changes in teaching and other activities became more pronounced (See Table 2.24).

Recent data by Leslie et.al. (work in progress) for a group of nine public research universities showed increased faculty time allocations to both teaching and research. These most recent figures suggested that in 1997 faculty spent their time more like their colleagues did 29 years prior, with the exception that in 1997 they did more teaching and research, and less of other activities (See Table 2.24). These results exhibited a fan-tailing effect; that is, all three activities converge upon a common allocation of time in 1993 and then diverged back toward 1965 levels.

Table 2.25. Mean Number of Classroom Hours and Student Contact Hours for FTE Faculty in Research Universities.

University	Classroom Hours		Student Contact Hours	
	1987	1992	1987	1992
FTE Faculty	6.2%	7.0%	244	260

[NSOPF 1988 and 1993, found in Allen (1996)]

There are alternative explanations of these results, however. Time allocations *shares* are one thing; but suppose that faculty are working more hours. What then? Indeed, while the percentage of faculty time devoted to teaching in research universities did decline even further from 1988 to 1993, the mean number of classroom hours and student contact hours actually increased (See Table 2.25): Mean number of classroom hours increased by almost 13% and student contact hours by 6.5% over this same period.

The data on faculty allocation of time for all universities, and specifically for research universities, seemingly contradict the perception that faculty are diverting attention to research at the expense of teaching. While it is true that since 1965 the percentage of time faculty spent on research has remained stable (24.0% versus 23.7%), and the percentage of time spent teaching has decreased marginally (47.0% versus 44.2%), more faculty time is being committed to teaching, *even* in Research Universities, which are the target of most public criticism.

Attention to undergraduate teaching also appears to contradict the common perception. Parsons and Platt's study of three research universities (1965) showed that faculty devoted 62% of their instructional time to graduate education and 38% to undergraduate education. Cartter's study of 106 universities (1965) showed that faculty devoted nearly equal proportions of their time to undergraduates and graduates alike, 49% versus 51% respectively. Initial results from Leslie et.al. (work in progress), revealed that faculty from nine major public research universities also devoted about equal amounts of their time to undergraduate and graduate education.

Could it be that faculty time allocations are not really the issue? Is the real issue the efficient and effective deployment of public resources in an era of heightened scarcity? Concerns over faculty attention to undergraduate instruction may result not from a lack of attention to instruction, but rather, from a perception of greater inefficiency in teaching. Indeed, if faculty and the universities of which they are a part are producing less instructional output with the same inputs, resulting in diminished teaching productivity or less instructional output per unit of input (Massy, 1996), then these concerns are warranted. A number of studies have tried to connect the various inputs of higher education to outputs in a mathematical formulation that maximizes the output per unit of input, subject to some constraints. A review of these studies reveals that while universities, and hence faculty, do not operate at the efficient frontier of their production possibility curves (Cohn, 1979; Levin, 1976), there is no consensus of a reduced university or faculty efficiency in the past 30 years (Allen, 1996).

Alternatively, changes in university funding patterns may provide the answer. Although public university percentage revenue has been the greatest in the private gifts, grants, and contracts category between 1985 and 1994, the greatest increase in absolute terms has been in tuition and fees, an increase of almost $8 billion, in 1994 dollars. Thus, the decline in share of state funds to the current-fund revenue of higher education institutions of 6.2 percentage points between 1987 and 1994, has been partly offset by the increase of 4.1 percentage points in the share of tuition and fee revenues. Further, like state appropriations, tuition and fee revenue is not highly stipulated; it can be used for a variety of different institutional purposes. There is no reason to expect that tuition and fee revenue are used any differently from the state appropriations. Considering both increased tuition and fee and research revenues, faculty may not be doing more research and less teaching, but rather, more research and more teaching, as appears to be the case. This appears especially to be true in the case of public research universities, which are the focus of this study.

2.3 Bases of Resource Allocation: How Choices Are Made--The Theory of the Firm versus Resource Dependency Theory.

Goals are reflected by choices (Tuckman and Chang, 1990). Accordingly, this section examines how choices are made within institutions of higher education, that is, the internal decision making processes of universities.

The theory of the firm assumes that the decision-makers take a bundle of available resources and allocates these resources in a way that maximizes the decision makers satisfaction. An implicit assumption of those who seek to apply this model directly to the university setting is that increases in the resources devoted to institutional goals cause increases in output, and these increases in output in turn translate into increases in the satisfaction of the decision-makers. Rather than assuming that internal decisions guide resource allocation decisions, the resource dependency model assumes that choice is governed by external forces because organizations are not self-contained nor self-sufficient. It is this reliance upon the environment that makes the external control of organizations both possible and probable.

Morgan (1984) categorizes the steady stream of theories and practices related to resource allocation decision making over the past three decades as being rooted in a "rational calculation" paradigm or "market interaction" paradigm. This characterization effectively captures the difference between the theory of the firm, which presumes the economically rational pursuit of self-interest, and organizational theories such as resource dependency theory, which often focus on power and political process. These paradigms suggest alternative ways for making resource allocation decisions. A review of the literature on the decision making processes is presented for each of the theoretical frameworks employed in this study: the theory of the firm and resource dependency theory.

Decision-Making Processes: The Theory of the Firm Perspective

If the university objective is to maximize prestige for the institution as a whole, then under the theory of the firm, institutional resources should be allocated so that in equilibrium the marginal prestige added by the last dollar spent is equalized across departments (James, 1990). Equalizing marginal prestige across departments ensures the greatest return of profits to the university (tuition in excess of cost), because prestige is linked to the institutions'ability to attract students. Tenure and other long-term contracts may prevent this equilibrium from being reached for a long period of time when the external environment changes and total budgets are stable or contracting. However, the movement will always be in the direction of equalizing marginal prestige across departments.

Referring back to the basic objective function of universities, which James (1986) argues places priority on research, graduate training, and institutional quality, this movement toward allocating resources to equalize marginal prestige among departments suggests that those departments doing more research, and those teaching more graduate students will have greater access to institutional resources. In order to continue satisfying and attracting students--one of the major sources of revenue to universities--enrollments must enter into the allocation process. However, this effect is limited if undergraduate enrollments are unresponsive to departmental allocations and depend instead on other factors such as the support for facilities, for institutional ambiance, and on reputation of the campus (James, 1990). Furthermore, undergraduate tastes among departments may shift from year to year while many departmental resources are committed on a long-term basis, i.e., to tenured faculty. Alternatively, graduate enrollments, which are department specific and are a direct source of prestige, may be expected to garner a greater "return" in the allocation process.

In fact, empirical evidence demonstrates that enrollments influence departmental budgets, with graduates earning a higher reward than undergraduates (James, 1990; Slaughter work in progress). Along similar lines departments with strong graduate and research programs are less likely to lose resources when institutional resources decline (Pfeffer and Moore, 1980; Hoenack, et.al., 1986). Departments that can attract scholars who can capture research grants will also have an additional claim on resources because they expand institutional revenues and hence prestige.

Academic disciplines may be arranged in a hierarchy with high-status departments bringing greater prestige to the institution than low-status departments (Alpert, 1985). In general universities will tend to favor departments where status weights are large. These higher-status departments include those with high reputational rankings, those that are central to the mission of the university, and those having a strong job market for their graduate students. While these status weights vary by department they are relatively constant across universities and constitute an important force leading toward uniform priorities (James, 1990). If these weights are an accurate approximation of the relative social importance of different departments, the allocation system is effective; if not, it is distorted and will lead to a sub-optimal allocation of resources.

In sum to make decisions about allocations among departments, the university needs information regarding the marginal prestige derived from the addition of university resources. With prestige measured as a function of graduate teaching, research, and quality, these factors will be predominant in the institutions allocation function and take priority over other factors, such as undergraduate teaching productivity.

Decision-Making Processes: A Resource Dependency Perspective

When organizations such as universities engage in exchanges and transactions with other groups or organizations, they are subject to a number of external constraints. To prosper the focal organization must respond to the demands of external organizations with which it interacts. It is this dependence on the environment that makes organizational control more a function of external than internal forces.

In the study of inter-organizational control, a number of authors have argued that interdependence is a necessary condition for exerting influence (Jacobs, 1974; Blau, 1963). As early as 1950, authors such as Hawley noted that power accrued to those organizations who controlled the resources necessary to the functioning of others. Pfeffer and Salancik (1978, pg. 44) concurred with these results, remarking "in general organizations will tend to be influenced by those who control the resources they require."

Thompson (1967, pg. 31) argued that organizational dependence was a function of its need for resources, and the number of providers of those resources. Conversely, Blau (1964) considered those factors which contributed toward independence and concluded that three factors were most important: the possession of strategic resources, having alternative resource providers, and the ability to use coercive force to take the necessary resources.

Extending the discussion to include intra-organizational power, Hickson (1971), notes that power accrued to those in the organization able to reduce organizational uncertainty. Pfeffer and Salancik (1974) examining resource allocation within a single university, concluded that the power of a department in an organization was a function of the amount of important resources contributed by the department.

In the formulation of both inter- and intra-organizational dependence the concept of resource importance is present. Firstly, with respect to resource importance Pfeffer and Salancik (1978) contend two dimensions foster dependence: the relative magnitude of the resource exchange, and the criticality of the resource. Leslie (1995), and Slaughter and Leslie (1997) suggest that the increase in relative magnitude of funds from research grants and contracts in the revenue base of public universities fosters a greater dependence between the universities and the providers of these funds. Furthermore, as the share of state funds to the current-fund revenue declines, the revenues from these research grants and contracts increasingly are used to support activities formerly supported by the state, such as for the support of graduate students, administrative functions, and increasingly for equipment and supplies. Slaughter and Leslie (1997) concluded that not only have these resources increased in relative magnitude, they have increased in criticality also.

As a consequence of the increased importance ascribed to research grant and contract revenues, universities are subject to greater control by the providers of this resource. Accordingly, Slaughter and Leslie (1997) suggest that the priority of research will increase among the various goals of the university, perhaps even at the expense of undergraduate education. However, extending this rationale to the revenue stream of tuition and fees, the case can be made that the priority given to undergraduate education may have stabilized or possibly even increased, as students are, undisputedly, one of the most critical resources for a university.

2.4. How Goals are Approached: Production Functions in Higher Education

Production function research can reveal the actual relationships between functions and allocations, or between decision making and goals. The production function mathematically defines the relationship between the employment of scarce inputs, such as faculty time, to the production of outputs, such as student learning. This section reviews the economics of education literature concerning the higher education production function. The results from a large number of sources are synthesized and presented in order to determine what is known about the character and form of the higher education production function.

Higher Education Production Functions: The General Form

The production function in higher education seeks to represent the process whereby a university transforms inputs, typically labor and capital, into outputs (Hopkins 1990). To specify the function precisely requires the ability

a) to identify and quantify all relevant inputs and outputs, and

b) to describe the relationship between inputs and outputs in mathematical terms.

Massy and Hopkins (1981) specify the general form of the production function:

where, $\mathbf{Y} = (Y_1, Y_2, \ldots, Y_m)$ is a vector of outputs, and

$\mathbf{X} = (X_1, X_2, \ldots, X_n)$ is a vector of inputs.

The production process is described by one or more production functions of the type

$$F(\mathbf{Y}, \mathbf{X}) = 0.$$

The output measures relate to the three primary outputs of higher education institutions: the transmission of knowledge, teaching; the creation of knowledge, research; and the application of knowledge to solve societal problems, public service. Major public research universities in the U.S. embody all three of these missions and, hence, have a plurality of outputs.

Hopkins and Massy (1981) point out that the intangible features of both the inputs and the outputs of the higher education production process are as important as the more tangible, quantifiable ones. Examining the production function for educational outcomes, the authors argue that a quantitative measure like the number of student course enrollments is not comprehensive enough to serve as the basis for analysis. Indeed, from the point of view of students already enrolled in a program, quality factors may be the only material variables. They go on to identify a set of tangible and intangible factors, which Hopkins (1990) categorizes further as input and output variables (See Table 2.3).

Table 2.3. Identification of Inputs and Outputs of Higher Education.

	Tangible	Intangible
Inputs	1. New students matriculating	1. Quality and diversity of matriculating students
	2. Faculty time and effort	2. Quality of effort put forth by faculty
	3. Student time and effort	3. Quality of effort put forth by students
	4. Staff time and effort	4. Quality of effort put forth by staff
	5. Buildings and equipment	5. Quality, age, and style of buildings; age and quality of equipment
	6. Library holdings and acquisitions	6. Quality of library holdings and acquisitions
	7. Endowment assets	
Outputs	1. Student enrollment in courses	1. Quality of education obtained
	2. Degrees awarded	2. Quality of education obtained
	3. Research awards, articles, and citations	3. Quality and quantity of research
	4. Services rendered to the general public	4. Quality of services rendered
		5. Goodwill
		6. Reputation

(Hopkin 1990, pg. 13)

No research to date has successfully characterized the production function in terms as precise as the set of input and output variables listed in the table above. The imprecision of the models developed thus far can be attributed to our poor understanding of the technologies of instruction, research and public service. Furthermore, the tools for estimating the requisite functional forms and coefficients are inadequate to the task. Finally, if the concept of a true production function is accepted as one which is based on an optimal technology, that is, one that achieves maximum levels of outputs for a given set of inputs, then no data exist that are adequate to estimate such a model. As Levin (1976) points out, there is no reason to believe that the educational enterprise has been operating on the efficient frontier of production possibilities; in fact, there are many reasons to believe that it has not. Thus, even if the true and complete functional form could be specified, the model could not be estimated accurately from existing data.

It is apparent, then, that all efforts directed at specifying and estimating the higher education production function have provided less than satisfactory or only partial results, even though there are a great many such efforts reflected in the literature. The more notable and informative of these efforts are summarized below.

Production Functions for Instruction

Most of the research to date has been carried out in the instructional domain although the interactions of instruction and research have been considered (public service are excepted). The studies, which are reviewed below, are categorized according to the predominant level of analysis, that is, whether the model is intended to represent the instructional production process of an entire institution, a single academic department, or the learning process of an individual student. Accordingly, the models and results in this section may be most applicable to those institutions where teaching is the primary mission.

At the institutional level, the grossest form of the production function can be represented by unit-cost ratios, such as dollar expenditures for instruction per student credit hour. Such ratios are often used as crude productivity indices (Wallhaus 1975). In these instances, the sole measure of input is taken as cost and the sole measure of output is taken as credit hours. The implicit production function assumes a single-efficient-point technology with constant returns to scale, being of the form

$$y = ax,$$

where, x = total expenditures on instruction, and y = number of student credit hours. Failure to take into account the university's research objective and the assumption of a single-point-technology with constant returns to scale, severely limits the applicability and credibility of this model (Hopkins, 1990).

A somewhat different approach to estimating the instructional production function for a single university is given by Oliver and Hopkins (1976). By introducing a time dimension, these authors portray the production process as a network of cohort flows in which students enter at various levels, remain for a certain period of time and then either graduate or drop out. One of the larger limitations of this model is that the flow network is assumed to be in equilibrium, that is, the flow rates of student cohorts along with all behavioral and technological constraints are fixed from one year to another.

An interesting application of production-theory at the departmental level was given by Breneman (1976), who sought to explain Ph.D. degree-granting behavior of academic departments in a single university. A simple input-output structure was used to describe the Ph.D. production process. Breneman studied variations in the parameters, success rate of matriculants, average length of time to degree, and average length of time to drop out. He assumed that these parameters were easily manipulated by faculty in response to the following conditions: departmental prestige, demand for the Ph.D. output, and the amount of resources provided to the department. His primary hypothesis was that faculty concern over the prestige of their department limited the production of Ph.D.'s in situations of limited demand for the product, regardless of the enrollment level, since prestige was related directly to the placement of graduates in other top schools. Although Breneman cited a variety of evidence in support of his theory, the evidence was certainly not conclusive. In addition, the use of departments from a single prestigious university limited the applicability of his conclusions.

Last is a brief review of production models that use the individual student as the unit of analysis. For these models, educational output is measured in terms of the level of student achievement in one or more categories, or in terms of the change in level of student achievement that results from the schooling process. Here student achievement is typically measured in terms of standardized test scores. Within this category of models two sub-categories exist: those that relate student achievement to school and non-school related inputs, and those that relate investment to student time.

During the 1960's and the 1970's, the desire to estimate the effect of primary and secondary schooling on achievement was the cause of a great deal of work. Despite numerous attempts to relate various achievement measures to student, environmental, and school characteristics, however, the results were often contradictory and inconclusive. The common problem of these attempts was the still limited understanding of all the inputs and their inter-relationship in the teaching process. This work was summarized and subjected to extensive critique by Cohn (1979), Hanushek (1979), Lau (1979) and Levin (1976). Without the proper specification of the variables and functional relationships for this process, the formulation of an appropriate production function was still not possible.

This approach was applied directly to higher education in two instances, and the criticisms were the same. Astin (1968) attempted to relate social backgrounds and ability levels of college students and measures of the quality of institutions attended to achievement on the Graduate Record Examination (GRE), and after controlling for student ability and background, found no institutional effect upon GRE scores. Manahan (1983) performed a similar study on a smaller scale, using data obtained from a single class at a single institution, and found some positive association between changes in test scores and a measure of instructional quality. As was the case for primary and secondary schools, no adequate production function for individual student learning was derived.

Becker (1983) and Polachek, et.al. (1978) pursued models of the second type: They attempted to relate student achievement to investments of student time. Becker's production function used a measure of pre-course aptitude, along with time allocated to the course, as inputs. Polachek, et.al., used three input variables: pre-course aptitude, time allocated to classroom instruction, and studying outside of class. Applying their model to a single class of freshmen students, Polachek et.al. generated some interesting results on the marginal product of one hour of study versus one hour spent in class; however, they failed to take into account any variations in the quality of the output of instruction.

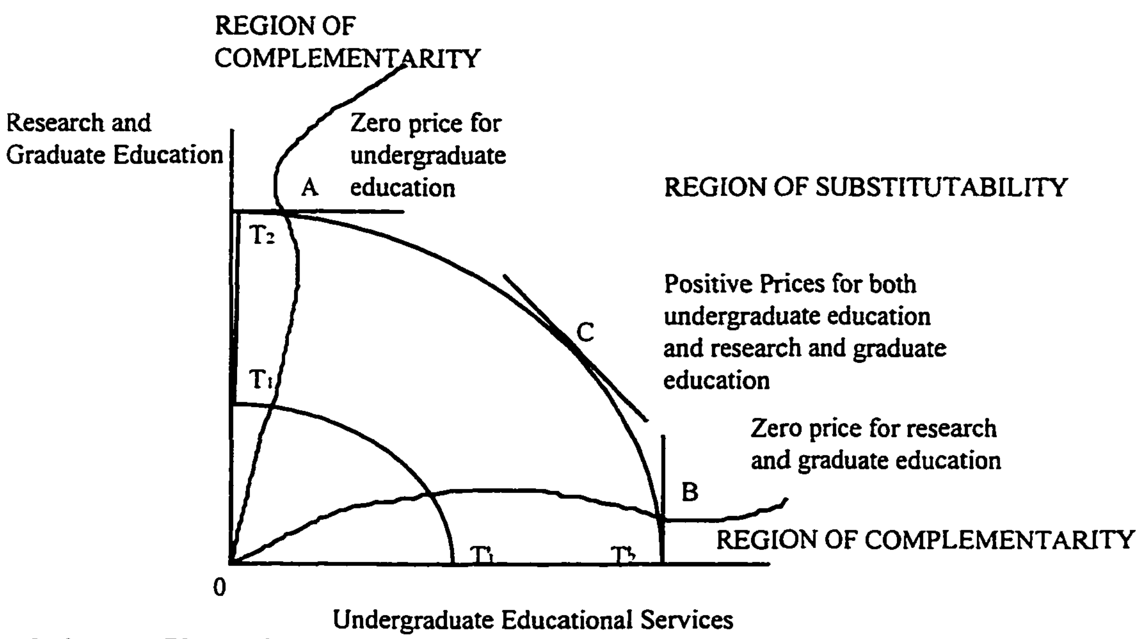
More recent studies focused on the substitution possibilities of new technologies in the individualized instruction process. Lewis, et.al. (1985) reported some evidence on the substitutability of computer-aided-instruction for independent study time, in terms of students gaining mastery over a fixed set of course materials. These authors went on to report that practically no current data existed on the cost effectiveness of this instructional method over any others.

Joint Production of Teaching and Research

Although no studies were found that attempted to estimate the production function of research alone, a number of studies were found that dealt with the joint production of teaching and research. Models that incorporate the presumed interactions between instructional and research activities of faculty and students are almost certainly necessary to describe accurately the production function of the research university.

A simple theoretical framework was provided by Nerlove (1972), who examined the joint production of undergraduate education and graduate education with research. He suggested that the production possibility curve is of the shape as seen in Figure 2.41.

Figure 2.41. Combinations of Undergraduate Education and of Research and Graduate Education Showing the Regions of Complementarity and the Region of Substitutability.



(Nerlove 1972, pg. 31)

This curve shows a region, close to each axis, in which the two outputs are postulated to be complementary to one another: that is, more output of both is possible given the fixed resource restraint. In a larger region in the middle of the figure, the two outputs act as substitutes; that is, increments in the production of one is accompanied by decrements in the production of the other. The outputs depicted along the axes of Figure 2.41 are intended to be measured in "quality adjusted" units, so that increases in output occur whenever quantity or quality increase.

One important inference from this model is that teaching and research are more efficiently produced within the same, rather than in separate institutions. This conclusion follows from the complementarity supposedly exhibited between teaching and research when either activity is largely subordinate to the other. Indeed, this concept of complementarity is seen to lie at the core of the research university.

Recent studies by Ward (1997) and Hasbrouk (1997) have suggested a significant, yet modest positive relationship between teaching and research productivity for academic departments and institutions, respectively. Examining departments in 160 universities and colleges in the U.S., Ward found that as research spending per FTE faculty member increased, undergraduate class sections offered by the department increased also. Hasbrouk, in a national study at the institutional level, showed that for the 10 year period from 1983 to 1993, as private gift, grant, and contract revenues per FTE student increased, instructional expenditures per FTE student increased also. Both these studies argued a positive relationship between increased research productivity and teaching productivity, productivity being defined as a greater level of output per unit of input.

Ward's and Hasbrouk's results, however, were not definitive. In a related, though less extensive study, Gander (1995) estimated the joint production for a sample of 31 departments at a single university. Introducing an added measure of faculty size, he found that teaching productivity falls and research productivity increases as faculty size increases.

One possible interpretation of these apparently contradictory results is that the institution from Gander's study is operating in the region of substitutability, while those from Ward's and Hasbrouk's are more in the region of complementarity; however, there is no reason to believe that either teaching or research are largely subordinate to one another, a condition Nerlove defines as pre-requisite to complementarity occurring.

Although still relatively scarce in the literature, empirical studies of joint production are now appearing more often. Two early attempts by Southwick (1969) and by Sengupta (1975) had little success in fitting a model to data on input and output measures from 68 land-grant universities. In 1995 Gander experienced considerably more success, reporting an overall R^2 of 91%, with coefficients significant at the 5% level or better. Johnes' 1996 study employing a joint production function for research and teaching for a sample of 50 British universities also reported a good data fit, with all coefficients significant at better than 1%.

Of course, even in these studies, where the models have a good fit to the data, there is no guarantee that the results represent the efficient frontier of production possibilities (Hopkins 1990). In fact, following the reasoning advanced by Levin (1976), there is suspicion that these functions only model the inefficiencies of the current system.

Another approach to modeling the joint production process is through formulating economic models of individual faculty behavior. One such model, by Becker (1975), presents a professorial decision making model for the purpose of exploring alternative plans to raise teaching quality. In this paper it is assumed that professors allocate their time between teaching (T_1), research (T_2), and leisure activities (T_3) to maximize a utility function $U = U(Q_1, Q_2, Q_3)$, where, Q_1, Q_2 and Q_3 represent, teaching output, research output, and leisure consumption, respectively. The output variables are assumed to be linear functions of the time allocations and, in the case of leisure time only, of income (Y). An expression for a professor's production possibility for a fixed amount of total time (T) is given by,

$$T = h_1 Q_1 + h_2 Q_2 + h_3 Q_3 .$$

From this expression the terms of trade among Q_1 and the respective signs of the coefficients h_1 and h_2 indicate whether teaching and research are economic complements or substitutes. To date Becker has not tested his model empirically.

Following the work of Becker, Sengell et.al. (1996) empirically examined faculty time allocation decisions for a sample of some 1400 faculty from 480 U.S. universities and colleges. Their findings suggest that increasing teaching productivity in the short term by raising teaching loads may not insure that teaching productivity is increased over the long term. In fact, the strategy may have the long term effect of reducing the overall time commitment of the faculty to the university. The authors suggest that to the extent research activities augment an individual's human capital, these investments of time in research endeavors tend to increase a faculty member's effective work life. In other words the substitution of research for teaching may in fact promote an individual faculty member's overall productivity in the long term. To this extent, teaching and research are not complementary economic goods, but rather directly compete for faculty time.

A number of researchers have attempted to model the exact nature of the interaction between teaching and research; yet none have succeeded in quantifying the joint production relationship in a way that permits the drawing of conclusive results. To date a lack of understanding of the technologies of research and teaching, coupled with a system that is operating well "within" (less than) the efficient frontier of its production possibility, precludes the formulation of a precise and efficient production possibility curve for teaching and research.

Economies of Scale in Higher Education

Finally, there are the studies of economies of scale in the higher education production function. Although most studies focus on instruction only, neglecting the multi-product nature of the university, several new studies (Cohn et.al., 1989; Degroot et.al., 1991; Dundar and Lewis, 1995) do add explicit research output measures.

More than 25 years ago, the Carnegie Commission on Higher Education (1971) explored the relationship between institutional size and costs per student using a national data base of colleges and universities. The data revealed a general decline in unit costs with increasing size; this trend was especially pronounced for institutions with enrollments of under 1, 000, but generally increasing returns to scale over a broad range of institutional sizes.

Radner and Miller (1975) extended this work in a longitudinal study of faculty-student ratios as a function of institutional size. Results obtained from a national data set for undergraduate institutions only, showed definite increasing returns to scale up to an enrollment level of between three and four thousand students. These increasing returns to scale were more pronounced in private institutions than in public ones.

Brinkman (1981) also reported the existence of economies of scale in higher education with respect to instruction, and Brinkman & Leslie (1986) found evidence for economies of scale from a detailed meta-analysis of the existing research.

Cohn, et.al. (1989) found economies of scope (the cost savings accruing to firms producing two or more outputs jointly as against specializing in the production of a single output) in both public and private institutions, with private institutions showing more pronounced ray economies of scale (measurement of the overall economies of scale) than did their public counterparts. Product specific economies of scale (those economies of scale that are differentially exhibited for specific multi-product outputs, such as undergraduate education, graduate education, and research), however, were only observed within the public institutions and there only for research and graduate teaching.

Degroot et.al., (1991) examined 147 American doctorate granting universities and found evidence of considerable economies of scale, as well as economies of scope, related to the joint production of undergraduate and graduate instruction. Contradicting the finding of Cohn et.al. that ray-economies of scale were more pronounced in private institutions, the authors argued that public or private status was not significant for the explanation of variable costs. From a consideration of the marginal costs of the outputs, the authors suggested that graduate education and faculty research were subsidized by undergraduate education.

Nelson and Heverth (1992), on the other hand, found no economies of scale or scope at the departmental level if class size was controlled: They noted that failure to control for class size upwardly biased the results. Significantly, the authors also found that research expenditures increased the cost of undergraduate education. Or put another way, undergraduate education served to subsidize research, a finding that was consistent with the findings of Degroot. et.al. (1991).

Dundar and Lewis (1995) analyzed departments across 18 public research universities by field type and found both economies of scale and scope. They argued that, as a result of the existence of ray economies of scale, most departments within public research institutions gained efficiencies through the expansion of both their teaching and research outputs. These findings, they argued, indicated that there were cost advantages associated with the joint production of departmental teaching and research.

Nelson and Heverth withstanding, there is considerable evidence of economies of scale for instruction, and growing evidence for economies of scale for research, in institutions of higher education. This evidence is found both in studies using the institution and the department as the unit of analysis. The results are mixed, however, as to whether teaching and research are complementary activities in the university setting. Nelson and Heverth, and Degroot. et.al., conclude that there are no cost advantages to be had through the joint production of departmental teaching and research, but rather that undergraduate teaching serves to subsidize research. Dundar and Lewis, on the other hand, find clear complementarities between the two, and argue for the joint production of the two at the department level in order to achieve greater efficiencies.

The literature on production functions is relevant to this study of higher education resource allocation because it provides information on how scarce inputs, such as faculty time, are employed to produce outputs like teaching and research. Efficient production involves the utilization of inputs from the set of production possibilities represented by the applicable production function, in such a way as to maximize the value of the outputs achieved. Poor understanding of the technologies of teaching and research, coupled with the intangible nature of the inputs and outputs, however, make it difficult to define, yet alone control for, the production functions of universities. Accordingly, faculty possess significant discretion over the nature and quantity of instructional and research outcomes. These outcomes, then, may well be just as much a reflection of choices made by faculty, as well as administrators and others outside the university, as they are a function of some well defined, universal production process.

The choices seemingly made by academic personnel are not unconstrained, however. To succeed, every organization must be responsive to the demands facing it. Universities are usually concerned with the demands of students and outside funding agents. Public universities normally are even more concerned with the demands of their state legislatures. Faculty decisions are also affected by internal university governance structures, which encourage individual faculty to pursue stated or implied institutional goals. Faculty salaries and unit budgets may, for example, be based in significant part upon research productivity, even in institutions whose funding is determined largely by their enrollments.

Academic personnel often have considerable discretion to pursue their goals, a condition that raises two important questions: (1) What are these goals? (2) How do they compare with those of the other constituent groups within higher education? Framing these goals from the perspectives of resource dependency theory and economic theory, provides alternative conceptions of institutional priorities. Recognizing these priorities is fundamental to understanding what impact they might have (if any) on the allocation function.

Chapter Summary

Four related, though distinct bodies of literature, were reviewed for this study of resource allocation within institutions of higher education: the literature of (1) goals and priorities for higher education, (2) faculty workload and productivity, (3) decision making processes within higher education, and (4) higher education production functions. These four literatures were importantly related to this study for the following reasons.

Goals and priorities should be connected to resource allocation decisions. The theory of the firm assumes a decision maker who pursues a set of goals that maximizes his or her satisfaction; satisfaction is realized when the decision maker allocates resources to each goal so that no other combination of resources gives rise to a greater level of utility (Tuckman and Chang, 1990). Extended to the case where there are multiple decision makers and multiple goals, resource dependency theory suggests that the relationship between resource allocation and outputs is one way of measuring the relative importance of competing goals within an organization (Pfeffer and Salancik 1974). Both theories require an understanding of how goals "play out" in the resource allocation process. A review of this literature identifies the different parties involved in the resource allocation process and the major goals normally attributed to each.

Second is the literature concerning faculty workload data. The degree to which the stated goals appear to conform to the allocation of resources is a test of how goals are manifest. Generally, the data support the thesis that faculty in public universities are responding to the fiscal disequilibrium by working harder and teaching more, not substituting research for teaching.

Third was the literature on how choices are made within institutions of higher education.

Finally, the literature on production functions was examined. The production function mathematically defines the relationship between the employment of scarce inputs to the production of outputs. To the extent that the production of different outputs is joint, that is, the outputs are produced more efficiently together than they are separately, then joint production should be reflected in the allocation function. An understanding of the basic production functions of universities must precede any analysis of how resources are allocated--as presumably the allocation of scarce resources should be employed in a way that maximizes the value of the outputs achieved.

In the next chapter the methods of this study are detailed. A discussion of how to model the resource allocation process is pursued, focusing specifically on estimating the "rate of return" for the various factors of teaching productivity, research productivity, and departmental quality. Hypotheses generated from both theoretical frameworks are tested in order to determine the explanatory power of both theoretical frameworks.

CHAPTER 3

METHODS

The purpose of this study is to estimate the rate of return for research productivity, teaching productivity, and departmental quality in the allocation function of public research universities and to test whether these returns have changed over the period of this study. If changes in the institutions resource dependencies drive internal resource allocations, then the rate of return for these variables should reflect the priorities of those upon whom the universities are dependent. Alternatively, if internal factors drive this process, then the optimization of inputs with respect to the utility function of the institutions will dictate the relative return for the outputs of teaching, research, and departmental quality.

The prioritization of the research and teaching outputs within the allocation function of public research universities is the issue; accordingly, the problem then becomes one of how to measure those priorities. One viable measure of priorities in higher education is the allocation of faculty time among the various work related tasks: teaching, research, and public service. These workload studies, however, do not directly take into account the role of the department in determining how faculty spend their time. Other studies of resource allocation within higher education (Berg and Hoenack, 1987; Verry and Davies, 1976) have found that the relative weight attached to outputs differ materially across academic departments and disciplines, and as such, using only institutional level data can be misleading, too. Since aggregating institutional outputs may lead to unreliable conclusions, Tierney (1980), and others have called for separate analyses to be conducted by department. This study moves beyond most other studies of its type by using the fundamental university organizational unit, the department, as the unit of analysis across a range of public research universities.

The specification of an income production function for departments, of course, is not independent of the allocation function for the institution as a whole; that is, for example, the importance departments attach to teaching productivity in order to capture departmental revenue also reflects the importance attributed to teaching productivity by those who allocate resources at the institutional level. Actual expenditure data are used as a proxy for institutional allocations. Wildavsky (1968) suggests that if budgets are a record of whose priorities are to prevail in the budgetary process, then expenditures are a record of whose priorities *actually prevail* in the end; use of expenditure data patterns is warranted and even preferred to an examination of budgetary data.

Variables

The dependent variable for the income production model is all the state supplied non-restricted current-fund expenditures of the department. This is an important difference in comparison with previous studies. The expenditures of the department include faculty and support salaries, computer and equipment expenditures, and services and supplies, essentially the total departmental inputs employed for the production of outputs in an academic year.

Input Variables

The expenditures of departmental inputs are specified as follows:

$$y = \sum_{i=1}^{5} C_i$$

y = total departmental annual expenditures, and

C_1= total departmental annual faculty wages and fringe benefits,

C_2 = total departmental annual salaries and fringe benefits of support staff,

C_3 = total annual departmental expenditures for services and supplies,

C_4 = total annual departmental expenditures for equipment,

C_5 = total annual departmental expenditures for computers.

Output variables

This study focuses on the teaching and research outputs of higher education. Although the importance of public service as an institutional output is recognized, no reliable measures for this dimension exist; thus, public service almost always is eliminated from production function analyses. Student credit hours at four teaching levels, lower division, upper division, graduate one, and graduate two, are used as proxies for teaching output. This utilization of student credit hours as teaching output proxies is noteworthy because in most other studies numbers of students or graduates have been used. Student numbers are less preferable proxies because the associated expenditures (e.g., service courses taken outside the department) are not specific to the individual departments (Dundar and Lewis, 1995). Student credit hours produced by each department clearly reflect more accurately the teaching outputs of departments.

Research outputs usually are specified as the number of articles published, number of patents granted, or the number of technological innovations developed (Gander, 1995; Dundar and Lewis, 1995); however, no such outputs are available in the AAU data. Instead, total restricted research expenditures are taken as a measure of research output. (Even if the data did exist, their usefulness is questionable: patents take two or three years to be awarded, journals and books are often not published in the same year as they are submitted, and so on.)

The five outputs of for the income function of this study are specified as

X_1=annual departmental lower division credit hours,

X_2=annual departmental upper division credit hours,

X_3=annual departmental graduate one (masters) credit hours,

X_4=annual departmental graduate two (doctoral) credit hours,

X_5=annual departmental sponsored research expenditures.

Quality of output variables

Output quality is an important consideration in examining departmental production. But how is quality to be measured? Two measures of quality were selected, based largely on normative practice and data availability: scholarly quality of the program faculty and effectiveness of the program in educating research scholars. The measures captured elements of both teaching and research outputs of the department although the first related more to research outcomes and the second more to teaching. These measures were obtained from a national study by the National Research Council (NRC) at 3,600 research doctoral programs at over 279 institutions in 41 fields of study (Goldberger et.al., 1995). Each program was evaluated by an average of 50 faculty respondents from the same field. The assessment of the "scholarly quality of program faculty" was based on measures or scholarly publication and peer review. The assessment of the "program effectiveness in educating research scholars and scientists" was based on measures of faculty accessibility, the department curricula, the instructional and research facilities, the quality of graduate students, the performance of graduates, and other departmental factors that were believed to contribute to a program's effectiveness. The values for "scholarly quality of program faculty" and "program effectiveness in educating research scholars and scientists" ranged from zero to five, with zero signifying "not sufficient for doctoral education" and five signifying "distinguished". Raters were required to designate no more than five programs as "distinguished". For each program a mean rating was calculated; programs were then rank-ordered within fields on each of these two measures (Goldberger et.al., 1995).

Data

The major data source for this study was the American Association of Universities Data Exchange (AAUDE). Data on expenditures (income) and teaching output (student credit hours at the four instructional levels) were drawn from the latest complete AAUDE set, 1993-1994 and from 1995-1996. These data were supplemented by data collected in site-visits to AAUDE member institutions over the spring semester of 1997. The two AAUDE data sets enabled comparisons over time, although missing data made comparisons problematic. For the sake of brevity, from here on the data sets simply are referred to as AAUDE data from academic year (AY) 1994 and AY 1996. Dundar and Lewis (1995) hold that the AAUDE departmental data are valid and reliable estimates of expenditures and enrollments for the leading research and doctoral granting universities in the Nation.

The sub-sample of institutions selected from the AAUDE for this study, therefore, was limited to those public research universities and departments for whom complete data were available for AY 1994 and AY 1996. The University of Maryland, for example, which reported non-restricted expenditures for 78 departments in AY 96, only reported restricted expenditures for 38 departments in the same year. Such restrictions yielded a sub-sample of 8 major public research universities and 200 departments in AY 94 and 6 institutions and 136 departments in AY 96.

Expenditures and student credit hour production data were taken from 31 types of constituent departments across five departmental fields: Computing and Mathematics, Engineering, Life Science, Physical Science, and Social Science. The following departments were included :

	AY 1994	AY 1996
Computing and Mathematics	• Computer Science	• Computer Science
	• Mathematics	• Mathematics
	• Statistics	• Statistics
Engineering	• Aerospace	• Aerospace
	• Chemical	• Chemical
	• Civil	• Civil
	• Electrical	• Electrical
	• Industrial	• Industrial
	• Material Science	• Mechanical
	• Mechanical	• Nuclear
	• Nuclear	
Life Science	• Agriculture	• Agriculture
	• Biochemistry	• Biology
	• Biology	• Entomology
	• Botany	• Forestry
	• Entomology	• Horticulture
	• Forestry	• Microbiology
	• Horticulture	• Plant Pathology
	• Microbiology	
	• Plant Pathology	
Social Science	• Anthropology	• Anthropology
	• Economics	• Economics
	• Education	• Education
	• Geography	• Political Science
	• Political Science	• Psychology
	• Psychology	• Sociology
	• Sociology	
Physical Science	• Astronomy	• Astronomy
	• Chemistry	• Chemistry
	• Geology	• Geology
	• Physics	• Physics

Empirical data on the quality of graduate programs were taken form the National Research Council's (1995) assessment of research doctorate programs in the United States.

Data Analysis

A multiple regression model relating institutional resource allocation to measures of departmental output for academic units in the sciences is employed. As noted in Chapter 1, the semi-log model is widely used in human capital literature in which theory suggests that the logarithm of earnings or wages be used as the dependent variable. When this model is applied to the field of higher education in the present study, the department is substituted for the individual as the unit of analysis and the earnings of the department is measured by its expenditures of non-restricted research money. The generalized model is given by

$$\ln(E) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \varepsilon$$

where,

X_1 = Lower Division Credit Hours

X_2 = Upper Division Credit Hours

X_3 = Graduate One Credit Hours

X_4 = Graduate Two Credit Hours

X_5 = Sponsored Research Expenditures

X_6 = Faculty Quality

X_7 = Program Effectiveness

Specifying this model for each of the fields of science in this study yields a system of 5 equations given by

$$\underset{(T_i \times 1)}{\mathbf{Y}_1} = \underset{(T_i \times 8)}{\mathbf{X}_1} \underset{(8 \times 1)}{\Gamma_1} + \underset{(T_i \times 1)}{\varepsilon_1}$$

$$\underset{(T_i\, l \times 1)}{\mathbf{Y}_2} = \underset{(T_i \times 8)}{\mathbf{X}_2} \underset{(8 \times 1)}{\Gamma_2} + \underset{(T_i \times 1)}{\varepsilon_2}$$

$$\underset{(T_i \times 1)}{\mathbf{Y}_3} = \underset{(T_i \times 8)}{\mathbf{X}_3} \underset{(8 \times 1)}{\Gamma_3} + \underset{(T_i \times 1)}{\varepsilon_3}$$

$$\underset{(T_i \times 1)}{\mathbf{Y}_4} = \underset{(T_i \times 8)}{\mathbf{X}_4} \underset{(8 \times 1)}{\Gamma_4} + \underset{(T_i \times 1)}{\varepsilon_4}$$

$$\underset{(T_i \times 1)}{\mathbf{Y}_5} = \underset{(T_i \times 8)}{\mathbf{X}_5} \underset{(8 \times 1)}{\Gamma_5} + \underset{(T_i \times 1)}{\varepsilon_5}$$

where,

1 = Engineering

2 = Natural Science

3 = Math & Computing

4 = Physical Science

5 = Social Science

and

$$\Gamma = \begin{bmatrix} \beta_0 \\ \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \\ \beta_5 \\ \beta_6 \\ \beta_7 \end{bmatrix}, \text{ and again, } \quad \mathbf{X}_i = \begin{bmatrix} \mathrm{X}_{i,0} = \text{constant} \\ X_{i,1} = \text{lower division credit hours} \\ X_{i,2} = \text{upper division credit hours} \\ X_{i,3} = \text{graduate one credit hours} \\ X_{i,4} = \text{graduate two credit hours} \\ X_{i,5} = \text{sponsored research expenditures} \\ X_{i,6} = \text{quality of faculty} \\ X_{i,7} = \text{program effectiveness} \end{bmatrix}$$

For any system of equations that are seemingly independent and are estimated separately, the problems of heteroscedasticity and nonzero covariances of disturbances may occur. Murphy (1973) demonstrates this problem by using an example of a system of equations dealing with gross corporate investment as determined by expected profits, retained earnings, capital stock, and an interest rate for several different corporations. If the varying data elements are obtained over the same time period, it is likely that the same underlying factors in the economy, factors which are not specified in the equation, are affecting the disturbance terms consistently in each regression. This situation may be called contemporaneous covariance of disturbances and has the effect of making OLS estimates of the coefficients in each equation inefficient. Models in which this problem commonly arises include those explaining earnings, incomes, migration patterns, etc., for subgroups of the population such as different age cohorts, different races, or different sexes. Because the models in the present study include all of the afore-mentioned conditions for which heteroscedasticity and non-zero covariance of disturbance terms are a concern, Seemingly Unrelated Regression (SUR) was employed.

Transforming the Model: For a System of Equations

A solution can be obtained if the data are pooled from each regression. In this combined set of ($5 \times N$) observations, the coefficient vector is extended to ($5 \times K$) components with the first K corresponding to $\Gamma_{1,}$ and each successive group of K corresponding to $\Gamma_{2,}$ $\Gamma_{3,}$ $\Gamma_{4,}$ and $\Gamma_{5,}$, respectively. However, because the size of the sample for the field of Mathematics and Computing was small, and because SUR estimation usually requires equal sample sizes per equation, the field of Mathematics and Computing and Physical Science were collapsed into a single field, labeled Physical Science. The new model to be estimated, therefore, is denoted by

$$\mathbf{Y}_i = \mathbf{X}_i\beta_i + \mathbf{u}_i$$

This may be written in shorthand as $\mathbf{Y} = \mathbf{X}\beta + \mathbf{u}$, or

$$\begin{bmatrix} \mathbf{Y}_1 \\ \mathbf{Y}_2 \\ \mathbf{Y}_3 \\ \mathbf{Y}_4 \end{bmatrix} = \begin{bmatrix} \mathbf{X}_1 & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{X}_2 & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{X}_3 & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{X}_4 \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \end{bmatrix} + \begin{bmatrix} \mathbf{u}_1 \\ \mathbf{u}_2 \\ \mathbf{u}_3 \\ \mathbf{u}_4 \end{bmatrix}$$

where,

$$\mathbf{Y} = (4T \times 1 \text{ matrix})$$

$$\mathbf{X} = 4T \times \left(\sum_{i=1}^{4} K_i \right) = (4T \times 32) \text{ matrix}$$

$$\beta = \left(\sum_{i=1}^{4} K_i \right) \times 1 = (32 \times 1) \text{ matrix}$$

$$\mathbf{u} = (4T \times 1) \text{ matrix}$$

According to the assumptions of the seemingly unrelated regression model, there is no autocorrelation within equations, but contemporaneous (cross-equation) covariance does exist. That is,

$$E\left(\mathbf{u}_i\mathbf{u}_j^{'}\right)=\begin{bmatrix}\sigma_{ij} & 0 & \cdots & 0\\ 0 & \sigma_{ij} & \cdots & 0\\ \cdots & \cdots & \cdots & \cdots\\ 0 & 0 & \cdots & \sigma_{ij}\end{bmatrix}=\sigma_{ij}\mathbf{I}$$

where $\mathbf{I}$ is a 4 × 4 identity matrix. The relationship applies to the covariances between two arbitrary equations in the system of four equations. This is generalized in matrix form as

$$\Omega = E(\mathbf{u}\mathbf{u}^{'}) = \begin{bmatrix} E(\mathbf{u}_1\mathbf{u}_1^{'}) & E(\mathbf{u}_1\mathbf{u}_2^{'}) & \cdots & E(\mathbf{u}_1\mathbf{u}_4^{'})\\ E(\mathbf{u}_2\mathbf{u}_1^{'}) & E(\mathbf{u}_2\mathbf{u}_2^{'}) & \cdots & E(\mathbf{u}_2\mathbf{u}_4^{'})\\ E(\mathbf{u}_3\mathbf{u}_1^{'}) & E(\mathbf{u}_3\mathbf{u}_2^{'}) & \cdots & E(\mathbf{u}_3\mathbf{u}_4^{'})\\ E(\mathbf{u}_4\mathbf{u}_1^{'}) & E(\mathbf{u}_4\mathbf{u}_2^{'}) & \cdots & E(\mathbf{u}_4\mathbf{u}_4)\end{bmatrix}$$

Substituting $E\left(\mathbf{u}_i\mathbf{u}_j^{'}\right)$ into Ω yields:

$$\Sigma \otimes \mathbf{I}$$

$$\text{where } \Sigma = \begin{bmatrix}\sigma_{11} & \sigma_{12} & \cdots & \sigma_{14}\\ \sigma_{21} & \sigma_{22} & \cdots & \sigma_{24}\\ \sigma_{31} & \sigma_{32} & \cdots & \sigma_{34}\\ \sigma_{41} & \sigma_{42} & \cdots & \sigma_{44}\end{bmatrix}.$$

All the information about error covariance is contained in the Ω matrix. The most efficient estimation of the parameters is obtained by applying generalized least squares to estimate the model as follows:

$$\hat{\beta} = (\mathbf{X}'\Omega^{-1}\mathbf{X})^{-1}(\mathbf{X}'\Omega^{-1}\mathbf{Y})$$

$$\text{with} \quad E[(\hat{\beta}-\beta)(\hat{\beta}-\beta)'] = (\mathbf{X}'\Omega^{-1}\mathbf{X})^{-1}.$$

In actuality the elements of Ω must be estimated. This is accomplished by using the residuals obtained when OLS estimation is applied to each of the four equations in the system:

$$\hat{\sigma}_{ii} = \frac{\hat{\mathbf{u}}_i\hat{\mathbf{u}}_i'}{T-K_i}$$

$$\hat{\sigma}_{ij} = \frac{\hat{\mathbf{u}}_i\hat{\mathbf{u}}_j'}{\sqrt{(T-K_i)((T-K_j)}}$$

$$\hat{\mathbf{u}}_i = \mathbf{Y} - \mathbf{X}_i\hat{\beta}_i$$

Transformation of the Data

The data have been transformed in a number of different ways to meet the specification of the different models and correct for any inherent statistical problems such as heteroscedasticity. An overview of these transformations are discussed in order to facilitate an accurate interpretation of the results.

Transformation 1: Semi-Log Transformation

A semi-log relationship is obtained between departmental earnings and student credit hours. The same relationship holds true for research. The beta coefficients in this model may be interpreted as the marginal effects of the independent variables X upon ln$E$. Differentiating both sides with respect to n yields

$$\beta_2 = \frac{d(\ln E)}{dX} = \frac{1}{E}\frac{dE}{dX}.$$

The term (dE/E) can be interpreted as the change in E divided by E. When multiplied by 100, this gives the percentage change in E per unit change in X. Therefore, β_2 multiplied by 100, gives the rate of return in earnings for a one unit increase in X.

Transformation 2: Per Full-time Equivalent Faculty Member

Brinkman (1981) delineates 3 categories of higher education cost factors, namely, environment, decision and volume factors. Operationalized as input prices, input levels and output levels, these factors alone may account for the variation in non-restricted expenditures. Controlling for these measures across departments, therefore, is necessary to delimit the potential confounding effect. For example, if outputs to the production process vary, they will account for a greater share of the variance in the dependent variable to the degree the levels of those outputs differ. Output levels are controlled for in this model by constructing a measure of FTE faculty on the dimensions of 'Total Departmental Faculty Salary' and 'Mean Field Faculty Salary'. The estimation of FTE faculty was required as this measure was not reported in the AAUDE data set. All quantitative measures are scaled by a factor of (1/FTE), thereby eliminating the potentially confounding results from differing output levels; therefore, the coefficients should be interpreted as the rate of return per FTE faculty member (A table of the mean values of the raw data and FTE transformed data appear in Appendix 2).

Transformation 3: Eliminating Multicollinearity

Although estimates derived in the presence of multicollinearity are efficient and unbiased, standard errors of the estimated measures are generally higher and t-statistics lower, possibly to the point of insignificance. As the variables Lower Division Credit Hours (LDCH) and Upper Division Credit Hours (UDCH), and, Scholarly Quality of the Program Faculty (QUALITY) and Program Effectiveness in Educating Research Scholars and Scientists (EFFECTIVE) were highly correlated for both periods (0.963, 0.986), the decision was made to collapse them into two variables representing Undergraduate Credit Hours (UGCH) and departmental quality and effectiveness, termed Departmental Standing (STANDING). In order to keep the measures of teaching productivity symmetric, the variables Graduate One Credit Hours (G1CH) and Graduate Two Credit Hours (G2CH) were also collapsed into a single variable, representing total graduate credit hour production: Graduate Credit Hours (GCH). The result was that instead of the seven independent variables initially proposed, only five (including the constant) were utilized (See Figure 4.1).

Figure 3.1. Variable Transformations.

Variables Proposed	Variables Utilized
Lower Division Credit Hours Upper Division Credit Hours	Undergraduate Credit Hours
Graduate 1 Credit Hours Graduate 2 Credit Hours	Graduate Credit Hours
Research Productivity	Research Productivity
Departmental Quality Departmental Effectiveness	Departmental Standing

The new variables may be defined in the following way:

Undergraduate Credit Hours (UGCH) = The annual total of lower and upper division credit hours per faculty member, where lower and upper division credit hours are combined (For a definition of student credit hours see Appendix 3).

Graduate Credit Hours (GCH) = The annual total of graduate one and graduate two credit hours per faculty member, where graduate one and two credit hours are combined.

Research Productivity (RESEARCH) = The annual total of sponsored research expenditures per faculty member, where sponsored research expenditures are derived from the sources of public and private research gifts, grants, and contracts.

Departmental Standing (STANDING) = The mean of the departments rating on the combined measures of quality and effectiveness. This measure pertains to the departments overall quality.

Transformation 4: Controlling for Heteroscedasticity

In carrying out the White's test for heteroscedasticity, it is assumed that the variance of the error term is a linear function of a number of independent variables, in particular, squares and cross-products of the variables in the regression models. This suggests that the following Weighted Least Squares (WLS) procedure be used to control for within equation heteroscedasticity:

1. Estimate the equations by Ordinary Least Squares regression.
2. Compute the residuals $\hat{u}$ and their squares $\hat{u}^2$.
3. Regress $\ln(\hat{u}^2)$ against a constant, the independent variables, the independent variables squared, and their cross products.
4. From the predicted variances of $\ln(\hat{u}^2)$, obtain $\hat{\sigma}$ by exponential transformation.
5. Weight the dependent and independent variables by $1/\hat{\sigma}$.

(Ramanathan 1995, pg.434.)

The estimates of the coefficients have the same interpretation as in the original model. However, the transformed variables do not possess the same meaning as the original data, and as such descriptive statistics in the heteroscedasticity transformed model do not pertain to the original model.

The four equations for 1994 and 1996 were estimated separately by WLS procedure and subjected to the White's Heteroscedasticity Test (See Appendix 4) for which the null hypothesis of homoscedasticity failed to be rejected in each case (p=0.01), except for the field of Social Science in 1996. To this end, the hypothesis that heteroscedasticity is present is rejected and within equation homoscedasticity is assumed, for all but the field of Social Science in 1996.

Transformation 5: Piecewise Linear Regression using a Dummy Variable Approach

A number of the hypotheses in this study tested whether the relationship between the dependent variable and the independent variables changed between time periods. To this end two different linear relationships were hypothesized between both time periods. Piecewise linear regression utilized the dummy variable approach to model nonlinear relationships that could be approximated by two linear relationships (Fisher, 1970; Ramanathan, 1995). To illustrate this technique, consider the abridged version of the model for a single field given by

$$\ln E = \alpha + \beta X_1 + \gamma X_2 + \vartheta X_3 + u,$$

in which

E = departmental expenditures,

X_1 = teaching productivity,

X_2 = research productivity, and

X_3 = departmental quality.

A dummy variable is defined as follows

$$D_1 = \begin{cases} 1, & \text{if } 1996 \\ 0, & \text{if } 1994 \end{cases}$$

To test whether the structures for the two periods are different, the specification must assume the following: $\alpha = \alpha_0 + \alpha_1 D_1$, $\beta = \beta_0 + \beta_1 D_1$, $\gamma = \gamma_0 + \gamma_1 D_1$, $\vartheta = \vartheta_0 + \vartheta_1 D_1$

Substituting these into the first equation, yielded the following equation:

$$\ln E = \alpha_0 + \alpha_1 D_1 + \beta_0 X_1 + \beta_1 D_1 X_1 + \gamma_0 X_2 + \gamma_1 D_1 X_2 + \vartheta_0 X_3 + \vartheta_1 D_1 X_3 + u.$$

Therefore the estimated models were as follows:

for 1994 $\quad \ln E = \hat{\alpha}_0 + \hat{\beta}_0 X_1 + \hat{\gamma}_0 X_2 + \hat{\vartheta}_0 X_3,$

for 1996 $\quad \ln E = \alpha_0 + \alpha_1 D_1 + \beta_0 X_1 + \beta_1 D_1 X_1 + \gamma_0 X_2 + \gamma_1 D_1 X_2 + \vartheta_0 X_3 + \vartheta_1 D_1 X_3.$

By comparing these relations a number of hypotheses can be tested. For instance , the hypothesis that $\alpha_1 = \beta_1 = \gamma_1 = \vartheta_1 = 0$ indicates that there is no structural change whatsoever between time periods, assuming the error variance is the same in AY 1994 and AY 1996. A t-test on β_1 will test whether the rate of return for teaching productivity is the same between 1994 and 1996. This model is extended to each of the four field groups in this study.

Wald Test of Coefficient Restrictions

The Wald test deals with hypotheses involving restrictions on the coefficients of the explanatory variables. A meaningful explanation of the Wald test cannot be given without the use of matrix algebra. In the linear model $y = X\beta + \varepsilon$, a set of linear restrictions under test may be expressed as

$$H_0: R\beta = r$$

where R is a known matrix of order q by k and r is a known vector of q elements, q being a positive integer less than k, denoting the number of restrictions being tested. To perform a Wald test only the unrestricted model is estimated. To illustrate this test the least squares vector, $b = (X'X)^{-1}X'y$, is computed. The vector $Rb - r$ then measures the discrepancy between Rb and the hypothetical vector $r = RB$. If the elements in this vector are small, little doubt is cast on the null hypothesis. Conversely, if they are large, there is doubt about H_0. The Wald statistic for testing H_0 is

$$W = (Rb - r)'[RVar(b)R']^{-1}(Rb - r)$$

where *Var(b)* indicates the variance-covariance matrix of the least squares estimator.

Under stringent conditions W has $\chi^2(q)$ distribution, if H_0 is true. However, *Var(b)* is not known exactly, and must be estimated, the disturbance in the relation may not be normally distributed; and the regressors may not be fully independent of the disturbance term. Under these complications a very useful large sample result can be utilized, namely that

$$W = (Rb - r)'[s^2R(X'X)^{-1}R']^{-1}(Rb - r)$$

is asymptotically distributed as $\chi^2(q)$ under H_0. In this result we see that *Var(b)* has been replaced by its least squares estimate $s^2(X'X)^{-1}$. It may be shown that

$$(Rb - r)'[s^2R(X'X)^{-1}R']^{-1}(Rb - r) = \tilde{u}'\tilde{u} - u'u$$

Thus using

$$\frac{u'u}{T-k} = s^2$$

the resulting test statistic is given by

$$W = \frac{\tilde{u}'\tilde{u} - u'u}{s^2}$$

The Wald test procedure can be applied to equations estimated by least squares, two-stage least squares, nonlinear least squares, logit, probit, and system estimators such as SUR. The Wald test was utilized in the first two models estimated in this analysis to test for the following linear restrictions on coefficients under the null hypothesis:

i. the joint significance of all the variables in the income production function for each field of academic science;

ii. the joint significance of undergraduate and graduate teaching productivity; and,

iii. the equality between the effect of undergraduate and graduate teaching productivity, and teaching and between research productivity.

In the third analysis, in which the data from both time periods are pooled, the Wald test is used to test for between time period changes on the afore-mentioned restrictions.

In summary, the semi-log model employed in this study is widely used in the human capital theory literature to specify the earning functions of individuals; in this study the department was substituted for the individual, and the income production function for the department was estimated. A system of four equations was obtained, for which OLS estimates of the coefficients might have been inefficient due to the existence of cross-equation covariance of the error terms; thus SUR was employed to estimate the best linear unbiased estimates of the coefficients.

In order to test for structural differences in the model across the two time periods, AY 1994 and AY 1996, the Wald test was employed. This allowed testing of the equality of all the coefficients for both models. A special case of the Wald test was employed to test for structural differences across time-periods in the subsets of the model. This enabled the equality of subsets of the coefficients to be tested across both models. The Wald test was also used to test for equality between subsets of the coefficients for the model for a given period of time. Finally, two-tailed t-tests were used to test for the significance of individual variables.

Limitations

A number of possible problem areas emerge with respect to the data and to the design of this model. No attempt is made to control for different costs of inputs to the different departments within or across institutions. This may have a biasing effect: As noted by De Groot et.al. (1991), the main resources for departmental production in public universities are the faculty and administrative staff, and these costs do vary across departments. Unfortunately, the data sets do not permit an estimate of average departmental wage rates and imputation of such wage rates from national data poses other problems. However, since the labor markets for faculty and administrators at major public research universities are very competitive, it may be satisfactory to assume that wages are constant across this sample of institutions. Nevertheless, the size of any bias cannot be known.

Second, Dundar and Lewis (1995) note that there are no absolute measures of quality or quantity of educational outcomes. Although *value-added* measures of teaching and research are probably the best measures of quality, it is very difficult to obtain such direct measures across institutions. Accordingly, in the present study proxies for quality are employed, as were the proxy variables of student credit hours and sponsored research expenditures in the case of quantity. But the quality proxies employed here have other limitations. Many public universities have considerable differentiation in the quality of their undergraduate and graduate programs (Jones et. al., 1982; Dundar and Lewis, 1995). Many, for example, may have an open access policy at the undergraduate level, while being highly selective at the graduate level in order to obtain the best and most able graduate students. Further, the reputational measures of the NRC are subjective, depending on the perception of the raters. While there tends to be strong agreement among raters about which programs are the strongest and which are the weakest, there is considerably less agreement about programs in the middle range. Two other limitations are of note. First the relative effect of research on departmental revenues may be underestimated because departments receive revenues for research from funds other than the non-restricted component of the current-fund, such as from indirect cost recovery. Second, public service is excluded from the analysis. This omission may bias the estimators for research and teaching.

Summary

This study builds upon the work of others (Hasbrouk, 1997; James, 1990; Slaughter and Leslie, 1997; Pfeffer and Salancik, 1978; Ward, 1997) who have sought to identify the factors driving resource allocation in "Western" and U.S. higher education. A number of hypotheses were derived from two theoretical frameworks: the theory of the firm and resource dependency theory. These hypotheses pertained to the relative importance of teaching productivity, research productivity, and measures of quality within the resource allocation function of public universities. To estimate the relative effects of these variables upon the departments' income production function, a generalized semi-log model was developed. When applied to the four field groups examined in this study, this model yielded a system of four equations. These equations were estimated using seemingly unrelated regression techniques, in order to control for the potentially confounding effect of contemporaneous covariance. To test the hypotheses under consideration, two traditional statistical tests were employed: the Wald Test and the two-tailed t-test.

CHAPTER 4

FINDINGS

To assess the hypotheses and propositions posed in this study, three variations of the SUR model were estimated. All three models utilized the Seemingly Unrelated Regression approach to control for heteroscedasticity between equations. The first model, however, did not control for heteroscedasticity within equations, yielding biased and inefficient results.

The first model yielded only the overall goodness of fit for the underlying semi-log specification used in all three models. Model 1 was estimated separately for the 1994 and 1996 data. Model 2 utilized the Weighted Least Squares transformation to control for within equation heteroscedasticity. In this model, the variance of the error term was assumed to be a linear function of the independent variables, in particular of their squares and cross products. To guarantee that the predicted variances were positive, the logarithm of the squared residuals was used within the auxiliary regression. This was equivalent to specifying multiplicative heteroscedasticity. The estimates from WLS estimates in this SUR model were efficient and unbiased, and therefore were used to test hypotheses among coefficients within each time period. Model 2 was also estimated separately for the 1994 and 1996 data.

Model 3 tested for structural change in the relationship between the dependent variable and independent variables from the first time period, 1994, to the second, 1996.

The test was conducted using Fisher's dummy variable technique, which was utilized for two reasons: Firstly it offered the flexibility to test as many or as few coefficients as was necessary, and secondly it pooled the data, increasing the efficiency of the results. The estimates from this model were also efficient and unbiased, and were used to test hypotheses across time periods. Model 3 was estimated for the pooled sample of 1994 and 1996 data.

The findings are presented, by year, for each of the fields of science, for each of the three models. Firstly, an examination of the overall goodness of fit statistics from Model 1 are discussed. This is followed by an examination of the estimation from the SUR of Model 2, where within period hypotheses are tested using the Wald test. Finally, the results of the SUR equations from Model 3 were considered in order to test between period hypotheses, using the 2 tailed t-test and the Wald test. After the results are considered by field of science, the results for the overall research questions and hypotheses are examined. This inductive approach is taken in order to build bases for answering the questions and evaluating the hypotheses.

1994 Findings

We begin with the results from 1994, in each case presenting first the uncorrected findings, in order to examine the "goodness of fit", and then to the important findings, the corrected results.

Life Sciences

An "uncorrected" Seemingly Unrelated Regression estimated the relative effects of teaching productivity, research productivity, and departmental quality upon the criterion variable ln(NRE) for a system of 4 equations in which $n = 200$ (Appendix 5).

Table 4.1. 1994 Heteroscedasticity Uncorrected SUR Results for the Life Sciences.

$\ln(NRE)_{94(1)} = \beta_{94(1,1)} + \beta_{94(1,2)}[UGCH] + \beta_{94(1,3)}[GCH] + \beta_{94(1,4)}[RE] + \beta_{94(1,5)}[STANDING]$			
Observations: 50			
R-squared	0.995105	Mean dependent var	16.24841
Adjusted R-squared	0.99467	S.D. dependent var	23.25204
S.E. of regression	1.697567	Sum squared resid	129.678

For the field of Life Sciences (n=50), the squared multiple correlation coefficient, denoted by R^2, was 0.9951, meaning that the predictor variables accounted for a high proportion of variability in the criterion variable. Adjusting for the degrees of freedom in the equation, the adjusted squared multiple correlation coefficient, denoted by $\overline{R}^2$ was 0.9947 (See Table 4.1). Due to heteroscedasticity, however, the estimates from this model are not efficient; thus we turn to the results from Model 2.

When within equation heteroscedasticity was controlled for in Model 2 (See Appendix 5) by the application of the estimated weighted least squares transformation, the SUR estimates yielded the best linear unbiased estimates (BLUE). Table 4.2 reports the estimated coefficients and their associated t-statistics; these results were unbiased, consistent, and efficient.

Table 4.2 . 1994 Results of Hypothesis Testing for the Life Sciences.

	Null Hypothesis:	Wald	t-test	Decision Rule (α=0.10)
1.	$\beta_{94(1,2)} = 0$ $\beta_{94(1,3)} = 0$ $\beta_{94(1,4)} = 0$ $\beta_{94(1,5)} = 0$	53115.7 ***		Reject Null Hypothesis
2.	$\beta_{94(1,2)} + \beta_{94(1,3)} = 0$	85.53419***		Reject Null Hypothesis
3.	$\beta_{94(1,1)} = 0$		0.07412 (0.519)	Fail to Reject Null Hypothesis
4.	$\beta_{94(1,2)} = 0$		0.185755*** (6.792)	Reject Null Hypothesis
5.	$\beta_{94(1,3)} = 0$		0.119059*** (5.915)	Reject Null Hypothesis
6.	$\beta_{94(1,4)} = 0$		0.790358*** (100.927)	Reject Null Hypothesis
7.	$\beta_{94(1,5)} = 0$		0.008551** (2.314)	Reject Null Hypothesis
8.	$\beta_{94(1,2)} = \beta_{94(1,3)}$	3.645975*		Reject Null Hypothesis
9.	$\beta_{94(1,2)} + \beta_{94(1,3)} = \beta_{94(1,4)}$	149.834***		Reject Null Hypothesis

* Significant at the 0.10 confidence level;
** Significant at the 0.05 confidence level;
*** Significant at the 0.01 confidence level.

The null hypothesis that all the coefficients, less the constant, in the Life Science equation were jointly equal to zero was rejected $\chi^2_{4,0.01)} = 53115.7$. This lead to the conclusion that at least one of the β's was not zero. Decomposing this analysis further, revealed that undergraduate teaching productivity and graduate teaching productivity were also jointly significant $\chi^2_{(1,0.01)} = 85.53$. Furthermore, all of the coefficients were individually statistically significant at α=0.05 or better, except for the constant term (See Table 4.2).

The hypothesis that rate of return for undergraduate teaching productivity was equal to the rate of return for graduate teaching productivity (heretofore the rate or return is implicitly assumed within the hypotheses) failed to be rejected at α=0.05, but was significant at α=0.10, with $\chi^2_{(1)} = 3.65$. From this it could be concluded that the rate of return for an extra credit hour of undergraduate instruction per faculty member (18.58%), was greater than the rate of return for an extra credit hour of graduate instruction per faculty member (11.91%), a difference of 6.67%.

The hypothesis that undergraduate and graduate teaching productivity together were equal to research productivity also was rejected $\chi^2_{(1,0.01)} = 149.83$; specifically, the rate of return for an additional credit hour of teaching per faculty member (30.49%) was less than the rate of return for an additional unit of research per faculty member (79.04%) (See Table 4.2).

Engineering

For the field of Engineering (*n*=50), when within equation heteroscedasticity was not controlled for, R^2 was 0.9750 and $\bar{R}^2$ was 0.9727, indicating strong explanatory power of the model (See Table 4.3).

Table 4.3. 1994 Heteroscedasticity Uncorrected SUR Results for Engineering.

$\text{Ln (NRE)}_{94(2)} = \beta_{94(2,1)} + \beta_{94(2,2)}[\text{UGCH}] + \beta_{94(2,3)}[\text{GCH}] + \beta_{94(2,4)}[\text{RE}] + \beta_{94(2,5)}[\text{STANDING}]$			
R-squared	0.974981	Mean dependent var	7.917903
Adjusted R-squared	0.972757	S.D. dependent var	7.126412
S.E. of regression	1.176241	Sum squared resid	62.25939

The corrected results (Model 2) were as follows.

Table 4.4. 1994 Results of Hypothesis Testing for Engineering.

Null Hypothesis:	Wald	t-test	Decision Rule (α=0.10)
1. $\beta_{94(2,2)} = 0$ $\beta_{94(2,3)} = 0$ $\beta_{94(2,4)} = 0$ $\beta_{94(2,5)} = 0$	7245.2***		Reject Null Hypothesis
2. $\beta_{94(2,2)} + \beta_{94(2,3)} = 0$	57.15257***		Reject Null Hypothesis
3. $\beta_{94(2,1)} = 0$		-0.19495** (-2.128)	Fail to Reject Null Hypothesis
4. $\beta_{94(2,2)} = 0$		1.271175*** (12.318)	Reject Null Hypothesis
5. $\beta_{94(2,3)} = 0$		-0.07529 (-0.600)	Fail to Reject Null Hypothesis
6. $\beta_{94(2,4)} = 0$		0.42341*** (5.939)	Reject Null Hypothesis
7. $\beta_{94(2,5)} = 0$		0.007846* (1.726)	Reject Null Hypothesis
8. $\beta_{94(2,2)} = \beta_{94(2,3)}$	65.4506***		Reject Null Hypothesis
9. $\beta_{94(2,2)} + \beta_{94(2,3)} = \beta_{94(2,4)}$	11.44843***		Reject Null Hypothesis

* Significant at the 0.10 confidence level; ** Significant at the 0.05 confidence level; *** Significant at the 0.01 confidence level.

The null hypothesis that all the coefficients, less the constant, in the Engineering equation were jointly equal to zero was rejected $\chi^2_{(4,0.01)} = 7245.2$, leading to the conclusion that at least one of the β's was not zero. Further decomposition of the analysis, revealed that undergraduate teaching productivity and graduate teaching productivity were also jointly significant $\chi^2_{(1,0.01)} = 57.15$. Furthermore, all of the coefficients were individually statistically significant at α=0.10 or better, except for the coefficient of graduate teaching productivity (See Table 4.4).

The hypothesis that undergraduate teaching productivity was equal to graduate teaching productivity was rejected $\chi^2_{(1,0.01)} = 65.45$: The rate of return for an extra credit hour of undergraduate instruction per faculty member (127.12%), was greater than the rate of return for an extra credit hour of graduate instruction per faculty member (-7.53%). The difference in this case was substantial, with an additional unit of undergraduate teaching per FTE faculty yielding 134.65% more departmental income than an additional unit of graduate teaching per FTE faculty.

The hypothesis that undergraduate and graduate teaching together were equal to research was rejected $\chi^2_{(1,0.01)} = 11.45$. The rate of return for an additional credit hour of teaching per faculty member (119.59%) was greater than the rate of return for an additional unit of research per faculty member (42.34%).

Physical Science

For the field of Physical Sciences (n=50), Model 1 yielded an R^2 of 0.99989 and an $\overline{R}^2$ of 0.99986, indicating strong explanatory power of the model (See Table 4.5).

Table 4.5. 1994 Heteroscedasticity Uncorrected SUR Results for the Physical Sciences.

$\ln(NRE)_{94(3)} = \beta_{94(3,1)} + \beta_{94(3,2)}[UGCH] + \beta_{94(3,3)}[GCH] + \beta_{94(3,4)}[RE] + \beta_{94(3,5)}[STANDING]$			
Observations: 50			
R-squared	0.999895	Mean dependent var	10.24023
Adjusted R-squared	0.999886	S.D. dependent var	43.31407
S.E. of regression	0.462055	Sum squared resid	9.607283

The corrected results were as follows. The null hypothesis that all the coefficients, less the constant, in the Physical Sciences equation were jointly equal to zero was rejected $\chi^2_{(4,0.01)} = 72051517.0$, again leading to the conclusion that at least one of the β's was not zero. Again, undergraduate teaching productivity and graduate teaching productivity were also jointly significant $\chi^2_{(1,0.01)} = 79.19$, and all of the coefficients were individually statistically significant at α=0.05 or better (See Table 4.6).

Table 4.6. 1994 Results of Hypothesis Testing for the Physical Sciences.

	Null Hypothesis:	Wald	t-test	Decision Rule (α=0.10)
1.	$\beta_{94(3,2)} = 0$ $\beta_{94(3,3)} = 0$ $\beta_{94(3,4)} = 0$ $\beta_{94(3,5)} = 0$	72051517 ***		Reject Null Hypothesis

Table 4.6. (Cont.) 1994 Results of Hypothesis Testing for the Physical Sciences.

	Null Hypothesis:	Wald	t-test	Decision Rule (α=0.10)
2.	$\beta_{94(3,2)} + \beta_{94(3,3)} = 0$	79.19608***		Reject Null Hypothesis
3.	$\beta_{94(3,1)} = 0$		0.174439*** (3.771)	Fail to Reject Null Hypothesis
4.	$\beta_{94(3,2)} = 0$		1.954455*** (22.528)	Reject Null Hypothesis
5.	$\beta_{94(3,3)} = 0$		-0.85622*** (-9.963)	Fail to Reject Null Hypothesis
6.	$\beta_{94(3,4)} = 0$		0.126452** (2.388)	Reject Null Hypothesis
7.	$\beta_{94(3,5)} = 0$		0.003695** (2.254)	Reject Null Hypothesis
8.	$\beta_{94(3,2)} = \beta_{94(3,3)}$	541.225***		Reject Null Hypothesis
9.	$\beta_{94(3,2)} + \beta_{94(3,3)} = \beta_{94(3,4)}$	30.36473***		Reject Null Hypothesis

* Significant at the 0.10 confidence level;
** Significant at the 0.05 confidence level;
*** Significant at the 0.01 confidence level.

The hypothesis that the rate of return for undergraduate teaching productivity and graduate teaching productivity was equal, was rejected $\chi^2_{(1,0.01)} = 541.22$, which suggested that the rate of return for an extra credit hour of undergraduate instruction per faculty member (195.45%), was greater than the rate of return for an extra credit hour of graduate instruction per faculty member (-85.62%). Once again the difference in this case was substantial, with undergraduate teaching productivity yielding 281.07% more departmental income than did graduate teaching productivity.

The hypothesis that undergraduate and graduate teaching together are equal to research is rejected $\chi^2_{(1,0.01)} = 30.36$: The rate of return for an additional credit hour of teaching per faculty member (109.83%) clearly was greater than the rate of return for an additional unit of research per faculty member (12.64%). See Table 4.6.

Social Science

For the field of Social Sciences (n=50), Model 1 R^2 was 0.9926 and $\overline{R}^2$ was 0.9920, once again indicating strong explanatory power of the model (See Table 4.7).

Table 4.7. 1994 Heteroscedasticity Uncorrected SUR Results for the Social Sciences.

$\ln(NRE)_{94(4)} = \beta_{94(4,1)} + \beta_{94(4,2)}[UGCH] + \beta_{94(4,3)}[GCH] + \beta_{94(4,4)}[RE] + \beta_{94(4,5)}[STANDING]$			
Observations: 50			
R-squared	0.992687	Mean dependent var	5.019789
Adjusted R-squared	0.992036	S.D. dependent var	4.448238
S.E. of regression	0.396954	Sum squared resid	7.090768

The corrected results showed that the coefficients, less the constant, in the Social Sciences jointly were not equal to zero, and thus the null hypothesis was rejected $\chi^2_{(4,0.01)} = 25515.5$, leading to the conclusion that at least one of the β's was not zero. Undergraduate teaching productivity and graduate teaching productivity were also jointly significant $\chi^2_{(1,0.01)} = 67.38$, but only undergraduate teaching productivity and research productivity were individually significant ($t_{94(4,2)}$=7.89, $t_{94(4,4)}$=2.61; α=0.01). See Table 4.8.

Table 4.8. 1994 Results of Hypothesis Tests for the Social Sciences.

	Null Hypothesis:	Wald	t-test	Decision Rule (α=0.10)
1.	$\beta_{94(4,2)} = 0$ $\beta_{94(4,3)} = 0$ $\beta_{94(4,4)} = 0$ $\beta_{94(4,5)} = 0$	25515.5***		Reject Null Hypothesis
2.	$\beta_{94(4,2)} + \beta_{94(4,3)} = 0$	67.37851***		Reject Null Hypothesis
3.	$\beta_{94(4,1)} = 0$		0.146296 (1.594)	Fail to Reject Null Hypothesis
4.	$\beta_{94(4,2)} = 0$		1.117036*** (7.892)	Reject Null Hypothesis
5.	$\beta_{94(4,3)} = 0$		0.155347 (0.841)	Fail to Reject Null Hypothesis
6.	$\beta_{94(4,4)} = 0$		0.263902*** (2.616)	Reject Null Hypothesis
7.	$\beta_{94(4,5)} = 0$		-0.00096 (-0.464)	Reject Null Hypothesis
8.	$\beta_{94(4,2)} = \beta_{94(4,3)}$	14.6084***		Reject Null Hypothesis
9.	$\beta_{94(4,2)} + \beta_{94(4,3)} = \beta_{94(4,4)}$	10.64808***		Reject Null Hypothesis

* Significant at the 0.10 confidence level;
** Significant at the 0.05 confidence level;
*** Significant at the 0.01 confidence level.

The hypothesis that undergraduate teaching productivity was equal to graduate teaching productivity was rejected $\chi^2_{(1,0.01)} = 14.60$; that is, the rate of return for an extra credit hour of undergraduate instruction per faculty member (111.70%) was greater than the rate of return for an extra credit hour of graduate instruction per faculty member (15.53%). Once again the difference in this case was substantial, with undergraduate teaching productivity yielding 96.17% more departmental income than graduate teaching productivity (See Table 4.8).

The hypothesis that undergraduate and graduate teaching together were equal to research was rejected $\chi^2_{(1,0.01)} = 10.65$, and it could be concluded that the rate of return for an additional credit hour of teaching per faculty member (127.23%) was greater than the rate of return for an additional unit of research per faculty member (26.39%).

1996 Findings

We turn next to the results for 1996, in each case presenting first the uncorrected findings, in order to examine the "goodness of fit", and then to the important findings, the corrected results.

Life Science

The R^2 and $\overline{R}^2$ values for the field of Life Science (n=34) were again large at 0.9947 and 0.9940, respectively (See Table 4.9).

Table 4.9. 1996 Heteroscedasticity Uncorrected SUR Results for the Life Sciences.

$\ln(NRE)_{96(1)} = \beta_{96(1,1)} + \beta_{96(1,2)}[UGCH] + \beta_{96(1,3)}[GCH] + \beta_{96(1,4)}[RE] + \beta_{96(1,5)}[STANDING]$			
R-squared	0.994771	Mean dependent var	1.993555
Adjusted R-squared	0.994049	S.D. dependent var	2.189208
S.E. of regression	0.168879	Sum squared resid	0.827079

The corrected results were that coefficients in the Life Sciences equation, less the constant, were jointly equal to zero, and the null hypothesis was rejected $\chi^2_{(4,0.01)} = 10349.2$. Undergraduate teaching productivity and graduate teaching productivity were also jointly significant $\chi^2_{(1,0.01)} = 17.463$ and all of the coefficients were individually statistically significant at α=0.05 or better, except for the intercept and the coefficient of graduate teaching productivity (See Table 4.10 and Appendix 6).

Table 4.10. 1996 Results of Hypothesis Testing for the Life Sciences.

	Null Hypothesis:	Wald	t-test	Decision Rule (α=0.10)
1.	$\beta_{96(1,2)} = 0$ $\beta_{96(1,3)} = 0$ $\beta_{96(1,4)} = 0$ $\beta_{96(1,5)} = 0$	10349.2***		Reject Null Hypothesis
2.	$\beta_{96(1,2)} + \beta_{96(1,3)} = 0$	17.46281***		Reject Null Hypothesis
3.	$\beta_{96(1,1)} = 0$		0.012417 (0.333)	Fail to Reject Null Hypothesis
4.	$\beta_{96(1,2)} = 0$		0.410855*** (3.914)	Reject Null Hypothesis
5.	$\beta_{96(1,3)} = 0$		0.014357 (0.103)	Fail to Reject Null Hypothesis

Table 4.10. (Cont.) 1996 Results of Hypothesis Testing for the Life Sciences.

Null Hypothesis:	Wald	t-test	Decision Rule (α=0.10)
6. $\beta_{96(1,4)} = 0$		0.674893*** (14.467)	Reject Null Hypothesis
7. $\beta_{96(1,5)} = 0$		0.001246** (2.116)	Reject Null Hypothesis
8. $\beta_{96(1,2)} = \beta_{96(1,3)}$	3.122357*		Reject Null Hypothesis
9. $\beta_{96(1,2)} + \beta_{96(1,3)} = \beta_{96(1,4)}$	2.858989*		Reject Null Hypothesis

* Significant at the 0.10 confidence level;
** Significant at the 0.05 confidence level;
*** Significant at the 0.01 confidence level.

The hypothesis that undergraduate teaching productivity was equal to graduate teaching productivity, too, was rejected $\chi^2_{(1,0.1)} = 3.12$; the rate of return for an extra credit hour of undergraduate instruction per faculty member (41.08%) was greater than the rate of return for an extra credit hour of graduate instruction per faculty member (1.43%). In contrast to the difference of 6.67% in the 1994 data, the difference in this case was substantial, with undergraduate teaching productivity yielding 39.65% more departmental income than did graduate teaching productivity.

The hypothesis that undergraduate and graduate teaching together were equal to research was rejected $\chi^2_{(1,0.1)} = 2.86$. In contrast to the 1994 result, the rate of return for an additional credit hour of teaching per faculty member (42.51%) was greater than the rate of return for an additional unit of research per faculty member (0.12%). See Table 4.10.

Engineering

For the field of Engineering (n=34), when within equation heteroscedasticity was not controlled for, R^2 was 0.9925 and $\overline{R}^2$ was 0.9914, more, consistent evidence of the strong explanatory power of the model (See Table 4.11).

Table 4.11. 1996 Heteroscedasticity Uncorrected SUR Results for Engineering.

$\ln(NRE)_{96(2)} = \beta_{96(2,1)} + \beta_{96(2,2)}[UGCH] + \beta_{96(2,3)}[GCH] + \beta_{96(2,4)}[RE] + \beta_{96(2,5)}[STANDING]$			
R-squared	0.992500	Mean dependent var	22.30969
Adjusted R-squared	0.991465	S.D. dependent var	11.9525
S.E. of regression	1.104231	Sum squared resid	35.36043

The corrected results were that undergraduate teaching productivity and graduate teaching productivity were jointly significant $\chi^2_{(1,0.01)} = 6.75$. Furthermore, all of the coefficients were individually statistically significant at α=0.05 or better, except for the intercept and the coefficient of graduate teaching productivity (See Table 4.12).

Table 4.12. 1996 Results of Hypothesis Testing for Engineering.

	Null Hypothesis:	Wald	t-test	Decision Rule (α=0.10)
1.	$\beta_{96(2,2)} = 0$ $\beta_{96(2,3)} = 0$ $\beta_{96(2,4)} = 0$ $\beta_{96(2,5)} = 0$	8284.64***		Reject Null Hypothesis
2.	$\beta_{96(2,2)} + \beta_{96(2,3)} = 0$	6.753469***		Reject Null Hypothesis
3.	$\beta_{96(2,1)} = 0$		-0.00679 (-0.552)	Fail to Reject Null Hypothesis

Table 4.12. (Cont.) 1996 Results of Hypothesis Testing for Engineering.

	Null Hypothesis:	Wald	t-test	Decision Rule (α=0.10)
4.	$\beta_{96(2,2)} = 0$		0.326625*** (3.479)	Reject Null Hypothesis
5.	$\beta_{96(2,3)} = 0$		0.281842 (1.212)	Fail to Reject Null Hypothesis
6.	$\beta_{96(2,4)} = 0$		0.677151*** (6.656)	Reject Null Hypothesis
7.	$\beta_{96(2,5)} = 0$		0.00063** (2.396)	Reject Null Hypothesis
8.	$\beta_{96(2,2)} = \beta_{96(2,3)}$	0.028275		Fail to Reject Null Hypothesis
9.	$\beta_{96(2,2)} + \beta_{96(2,3)} = \beta_{96(2,4)}$	0.041972		Fail to Reject Null Hypothesis

* Significant at the 0.10 confidence level
** Significant at the 0.05 confidence level
*** Significant at the 0.01 confidence level

Unlike the 1994 result, the hypothesis that undergraduate teaching productivity was equal to graduate teaching productivity failed to be rejected $\chi^2_{(1,0.01)} = 0.03$; the rate of return for an extra credit hour of undergraduate instruction per faculty member (32.66%) was not significantly different than the rate of return for an extra credit of graduate instruction per faculty member (28.18%). See Table 4.12.

The hypothesis that undergraduate and graduate teaching together were equal to research failed to be rejected at any reasonable level $\chi^2_{(1)} = 0.04$. The rate of return for an additional credit hour of teaching per faculty member (60.85%) was not statistically significantly different from the rate of return for an additional unit of research per faculty member (67.71%). This result contrasted with that from 1994, that showing the rate of return for teaching (119.58%) to be significantly more than the rate of return for research (42.34%).

Physical Science

For the field of Physical Sciences (n=34), again R^2 and $\bar{R}^2$ approached 1.0 (See Table 4.13).

Table 4.13. 1996 Heteroscedasticity Uncorrected SUR Results for the Physical Sciences.

ln $(NRE)_{96(3)} = \beta_{96(3.1)} + \beta_{96(3.2)}[UGCH] + \beta_{96(3.3)}[GCH] + \beta_{96(3.4)}[RE] + \beta_{96(3.5)}[STANDING]$			
R-squared	0.999509	Mean dependent var	42.88232
Adjusted R-squared	0.999441	S.D. dependent var	77.23761
S.E. of regression	1.826604	Sum squared resid	96.75796

The corrected results revealed that undergraduate teaching productivity and graduate teaching productivity were jointly significant $\chi^2_{(1,0.01)} = 361.64$; likewise, all of the coefficients except for the intercept were individually statistically significant at α=0.05 or better (See Table 4.14).

Table 4.14. 1996 Results of Hypothesis Testing for the Physical Sciences.

	Null Hypothesis:	Wald	t-test	Decision Rule (α=0.10)
1.	$\beta_{96(3,2)} = 0$ $\beta_{96(3,3)} = 0$ $\beta_{96(3,4)} = 0$ $\beta_{96(3,5)} = 0$	73664.7***		Reject Null Hypothesis
2.	$\beta_{96(3,2)} + \beta_{96(3,3)} = 0$	361.6406***		Reject Null Hypothesis

Table 4.14.(Cont.) 1996 Results of Hypothesis Testing for the Physical Sciences.

	Null Hypothesis:	Wald	t-test	Decision Rule (α=0.10)
3.	$\beta_{96(3,1)} = 0$		-0.01351 (-1.414)	Fail to Reject Null Hypothesis
4.	$\beta_{96(3,2)} = 0$		0.660964*** (5.371)	Reject Null Hypothesis
5.	$\beta_{96(3,3)} = 0$		1.205234*** (14.875)	Reject Null Hypothesis
6.	$\beta_{96(3,4)} = 0$		0.129424** (2.357)	Reject Null Hypothesis
7.	$\beta_{96(3,5)} = 0$		-0.00058*** (-4.965)	Reject Null Hypothesis
8.	$\beta_{96(3,2)} = \beta_{96(3,3)}$	8.766109***		Reject Null Hypothesis
9.	$\beta_{96(3,2)} + \beta_{96(3,3)} = \beta_{96(3,4)}$	134.693***		Reject Null Hypothesis

* Significant at the 0.10 confidence level
** Significant at the 0.05 confidence level
*** Significant at the 0.01 confidence level

The hypothesis that undergraduate teaching productivity was equal to graduate teaching productivity was rejected $\chi^2_{(1,0.01)} = 8.78$; the rate of return for an extra credit of undergraduate instruction per faculty member (66.09%), was less than the rate of return for an extra credit of graduate instruction per faculty member (120.52%). Once again the difference in this case was substantial although in the opposite direction of the 1994 results; an additional unit of graduate teaching yielded 54.43% more departmental income than an additional unit of undergraduate teaching in 1994.

As was the case in 1994, it was concluded that the rate of return for an additional credit hour of teaching per faculty member (187.48%) was greater than the rate of return for an additional unit of research per faculty member (129.42%), although the difference in this case appears to have diminished (See Table 4.14).

Social Science

R^2 and $\overline{R}^2$ values again approach 1.0 (See Table 4.15).

Table 4.15. 1996 Heteroscedasticity Uncorrected SUR Results for the Social Sciences.

$\ln(NRE)_{96(4)} = \beta_{96(4.1)} + \beta_{96(4.2)}[UGCH] + \beta_{96(4.3)}[GCH] + \beta_{96(4.4)}[RE] + \beta_{96(4.5)}[STANDING]$			
R-squared	0.998365	Mean dependent var	1.101681
Adjusted R-squared	0.99814	S.D. dependent var	0.88852
S.E. of regression	0.038324	Sum squared resid	0.042594

From Model 2 it was shown that undergraduate teaching productivity and graduate teaching productivity were jointly significant $\chi^2_{(1,0.01)} = 374.42$; all of the coefficients except for the intercept and quality coefficient were individually statistically significant at α=0.05 or better (See Table 4.16). However, because the assumption of within equation homoscedasticity was rejected for the 1996 data from this field, hypothesis tests may no longer be valid (See Appendix 4). Nonetheless, the data were transformed using estimated generalized least squares to obtain consistent and asymptotically efficient estimates of the parameters. Accordingly, the results of the hypothesis tests are presented, predicated upon cautious interpretation.

Table 4.16. 1996 Results of Hypothesis Testing for the Social Sciences.

	Null Hypothesis:	Wald	t-test	Decision Rule (α=0.10)
1.	$\beta_{96(4,2)} = 0$ $\beta_{96(4,3)} = 0$ $\beta_{96(4,4)} = 0$ $\beta_{96(4,5)} = 0$	25587.6***		Reject Null Hypothesis
2.	$\beta_{96(4,2)} + \beta_{96(4,3)} = 0$	374.416***		Reject Null Hypothesis
3.	$\beta_{96(4,1)} = 0$		-0.00594 (-0.622)	Fail to Reject Null Hypothesis
4.	$\beta_{96(4,2)} = 0$		0.927867*** (17.541)	Reject Null Hypothesis
5.	$\beta_{96(4,3)} = 0$		0.632964*** (8.396)	Reject Null Hypothesis
6.	$\beta_{96(4,4)} = 0$		0.101633** (2.342)	Reject Null Hypothesis
7.	$\beta_{96(4,5)} = 0$		-3.17E-05 (-0.132)	Fail to Reject Null Hypothesis
8.	$\beta_{96(4,2)} = \beta_{96(4,3)}$	8.318443***		Reject Null Hypothesis
9.	$\beta_{96(4,2)} + \beta_{96(4,3)} = \beta_{96(4,4)}$	138.9936***		Reject Null Hypothesis

* Significant at the 0.10 confidence level
** Significant at the 0.05 confidence level
*** Significant at the 0.01 confidence level

The rate of return for an extra credit hour of undergraduate instruction per faculty member (92.78%) was greater than the rate of return for an extra credit hour of graduate instruction per faculty member (63.29%), as was the case in 1994. Once again the difference in this case was substantial, with undergraduate teaching productivity yielding 29.49% more departmental income than graduate teaching productivity (See Table 4.16).

As was the case in 1994, the hypothesis that undergraduate and graduate teaching together were equal to research was rejected $\chi^2_{(1,0.01)} = 138.99$, and it could be concluded that the rate of return for an additional credit hour of teaching per faculty member (156.08%) was greater than the rate of return for an additional unit of research per faculty member, which is not significantly different from 0 (See Table 4.16).

1994 and 1996 Pooled Results

The third model utilized a dummy variable approach on pooled data for 1994 and 1996 in order to model changes between the two years. Not surprisingly, the estimates for individual coefficients were very similar between the unpooled and pooled models (See Appendix 7). The 1994 and 1996 coefficients changed marginally, primarily because of the different estimation procedure and possibly because of the increased sample size of the pooled data (See Appendix 8). The only coefficient that was significant in the pooled analysis that was not significant in the unpooled analysis was the constant for the Social Science field.

The change in significance for the coefficients of the 1996 results in the pooled versus unpooled analyses was more pronounced. This was due to the different tests employed to evaluate the hypotheses, i.e. a two-tailed t-test on a single coefficient for the unpooled data versus a Wald test on a linear combination of coefficients for the pooled data. For example, consider the null hypothesis that undergraduate teaching, for the field of Engineering, equaled zero: $H_0: \beta_{96(2,2)} = 0$. Testing this hypothesis using the unpooled results amounted to a t-test of the coefficient, $\beta_{96(2,2)}$. The t-statistic (3.479) was significant at α=0.01, and therefore the null hypothesis was rejected in favor of the alternative hypothesis that $\beta_{96(2,2)}$ was significantly different from zero, with a rate of return which equaled 32.66%. When the same test was performed on the pooled set of data, it became a test of the linear combination of coefficients, for which the null hypothesis was given by $H_0: \beta_{94\&96(2,2)} + \beta_{94\&96(DV2)} = 0$, where DV was a dependent variable that equaled 1 if 1996; 0 if 1994. This was evaluated using a Wald test that yielded a $\chi 2$ statistic (32.308) which was also significant at α=0.01. Once again the null hypothesis was rejected and the conclusion was made that the rate of return for undergraduate teaching productivity was equal to approximately 36.34%. The two results were similar in this case, however, as the test on the pooled results for 1996 required twice as many regression coefficients to test the same hypothesis: the loss of degrees of freedom reduced the power of the test. As such, six coefficients were not significant in the pooled 1996 analysis that were significant in the unpooled 1996 analysis. Therefore, the results from the 1996 pooled analysis yielded a more conservative basis for rejecting the null hypothesis.

The coefficients that represent β_{UGCHDV}, β_{GCHDV}, β_{REDV}, and $\beta_{STANDINGDV}$ measured the differential in departmental earnings between 1994 and 1996. The joint hypotheses, that $\beta_{UGCHDV} = \beta_{GCHDV} = \beta_{REDV} = \beta_{STANDINGDV} = 0$ for each of the four equations, proposed that the relationships were identical between the two time periods. The hypothesis that the rate of return for teaching productivity changed over time was tested by a Wald test on the equation $\beta_{UGCHDV} + \beta_{GCHDV} = 0$. The hypotheses that the rate of return for research productivity and departmental quality changed over time was tested by a t-test on the coefficients β_{REDV} and $\beta_{STANDINGDV}$.

Life Science

The null hypothesis that the change in coefficients, excluding the constants, between 1994 and 1996 for the Life Sciences equation were jointly equal to zero was rejected $\chi^2_{(4,0.01)} = 87160.1$. Decomposing this analysis further, however, revealed that the changes in undergraduate teaching productivity and graduate teaching productivity were not jointly significant $\chi^2_{(1,0.01)} = 0.002$. In fact, despite being jointly significant, none of the coefficients were statistically significant individually at α=0.10 or better (See Table 4.17).

Table 4.17. Pooled Results for Hypothesis Testing in the Life Sciences.

	Null Hypothesis:	Wald	t-test	Decision Rule (α=0.10)
1.	$\beta_{94\&96(1,2)} = 0$ $\beta_{94\&96(1,3)} = 0$ $\beta_{94\&96(1,4)} = 0$ $\beta_{94\&96(1,5)} = 0$	87160.1***		Reject Null Hypothesis
2.	$\beta_{94\&96(1,2)} + \beta_{94\&96(1,3)} = 0$	0.001866		Fail Reject Null Hypothesis
3.	$\beta_{94\&96(1,1)} = 0$		-0.08904 (-0.215)	Fail to Reject Null Hypothesis

Table 4.17. (Cont.) Pooled Results for Hypothesis Testing in the Life Sciences.

	Null Hypothesis:	Wald	t-test	Decision Rule (α=0.10)
4.	$\beta_{94\&96(1,2)} = 0$		0.08066 (0.072)	Fail to Reject Null Hypothesis
5.	$\beta_{94\&96(1,3)} = 0$		-0.12751 (-0.085)	Fail Reject Null Hypothesis
6.	$\beta_{94\&96(1,4)} = 0$		-0.04355 (-0.087)	Fail to Reject Null Hypothesis
7.	$\beta_{94\&96(1,5)} = 0$		-0.00645 (-0.934)	Fail to Reject Null Hypothesis
8.	$\beta_{94\&96(1,2)} = \beta_{94\&96(1,3)}$	0.007559		Fail to Reject Null Hypothesis
9.	$\beta_{94\&96(1,2)} + \beta_{94\&96(1,3)} = \beta_{94\&96(1,4)}$	4.38E-06		Fail to Reject Null Hypothesis

* Significant at the 0.10 confidence level
** Significant at the 0.05 confidence level
*** Significant at the 0.01 confidence level

The hypothesis that the change in the coefficient for undergraduate teaching productivity was equal to the change in the coefficient for graduate teaching productivity also failed to be rejected also $\chi^2_{(1,0.01)} = 0.007$. Although the point estimate of the change in the rate of return for an extra credit hour of undergraduate instruction per faculty member (8.07%), was not significantly different from the change in the rate of return for an extra credit hour of graduate instruction per faculty member (-12.75%), they varied by more than 20%.

The hypothesis that the change in the rate of return from undergraduate and graduate teaching together were equal to research failed to be rejected $\chi^2_{(1,0.01)} = 0.00004$; therefore, it may be concluded that the change in the rate of return for an additional credit hour of teaching per faculty member (-4.68%) was not significantly different than the change in the rate of return for an additional unit of research per faculty member (-4.35%), neither of which were significantly different from zero. Similarly, the change in the rate of return to departmental quality also failed to differ significantly between the two periods (-0.64%). See Table 4.17.

Engineering

The null hypothesis that the change in coefficients, excluding the constants, between 1994 and 1996 for the Engineering equation were jointly equal to zero was rejected $\chi^2_{(4,0.01)} = 47.9$. This suggested that the changes in at least one of the coefficients was non-zero. Further decomposition revealed, however, that undergraduate teaching productivity and graduate teaching productivity were not jointly significant $\chi^2_{(1,0.01)} = 1.84$. The coefficients for the changes in the constant, undergraduate teaching productivity, and departmental quality were all individually statistically significant at α=0.05 or better [$t_{94\&96(2,1)}$=(2.34), $t_{94\&96(2,1)}$=(-5.68), $t_{94\&96(2,1)}$=(-1.85)]; however, the coefficients for the change in research productivity and departmental quality were not significant (See Table 4.18).

Table 4.18. Pooled Results for Hypothesis Testing in Engineering.

	Null Hypothesis:	Wald	t-test	Decision Rule (α=0.10)
1.	$\beta_{94\&96(2,2)} = 0$ $\beta_{94\&96(2,3)} = 0$ $\beta_{94\&96(2,4)} = 0$ $\beta_{94\&96(2,5)} = 0$	47.9***		Reject Null Hypothesis
2.	$\beta_{94\&96(2,2)} + \beta_{94\&96(2,3)} = 0$	1.839742		Fail to Reject Null Hypothesis
3.	$\beta_{94\&96(2,1)} = 0$		0.195558** (2.338)	Reject Null Hypothesis
4.	$\beta_{94\&96(2,2)} = 0$		-0.90019*** (-5.684)	Reject Null Hypothesis
5.	$\beta_{94\&96(2,3)} = 0$		0.419405 (1.230)	Fail to Reject Null Hypothesis
6.	$\beta_{94\&96(2,4)} = 0$		0.20015 (1.292)	Fail to Reject Null Hypothesis
7.	$\beta_{94\&96(2,5)} = 0$		-0.00757** (-1.853)	Reject Null Hypothesis
8.	$\beta_{94\&96(2,2)} = \beta_{94\&96(2,3)}$	11.10435***		Reject Null Hypothesis
9.	$\beta_{94\&96(2,2)} + \beta_{94\&96(2,3)} = \beta_{94\&96(2,4)}$	1.795686		Fail to Reject Null Hypothesis

* Significant at the 0.10 confidence level
** Significant at the 0.05 confidence level
*** Significant at the 0.01 confidence level

The hypothesis that the change in the coefficient for undergraduate teaching productivity was equal to the change in the coefficient for graduate teaching productivity was rejected $\chi^2_{(1,0.01)} = 11.10$: The change in the rate of return for an extra credit hour of undergraduate instruction per faculty member (-90.02%) was significantly less than the change in the rate of return for an extra credit hour of graduate instruction per faculty member (41.94%).

The hypothesis that the change in the rate of return from undergraduate and graduate teaching together were equal to research failed to be rejected $\chi^2_{(1,0.01)} = 1.79$, leading to the conclusion that the change in the rate of return for an additional credit hour of teaching per faculty member (-48.07%) was not significantly different from the change in the rate of return for an additional unit of research per faculty member (20.01%). Again, differences in the point estimates were noteworthy, however (See Table 4.18).

Physical Science

Testing the null hypothesis that the change in coefficients, excluding the constants, between 1994 and 1996 for the Physical Sciences equation were jointly equal to zero was rejected $\chi^2_{(4,0.01)} = 1876.1$. Undergraduate teaching productivity and graduate teaching productivity were jointly significant $\chi^2_{(1,0.01)} = 19.47$. In fact all the coefficients for change were individually statistically significant at α=0.05 or better, except for the coefficient for research productivity (See Table 4.19).

Table 4.19. Pooled Results for Hypothesis Testing in the Physical Sciences.

Null Hypothesis:	Wald	t-test	Decision Rule (α=0.10)
1. $\beta_{94\&96(3,2)} = 0$ $\beta_{94\&96(3,3)} = 0$ $\beta_{94\&96(3,4)} = 0$ $\beta_{94\&96(3,5)} = 0$	1876.1***		Reject Null Hypothesis
2. $\beta_{94\&96(3,2)} + \beta_{94\&96(3,3)} = 0$	19.47027***		Reject Null Hypothesis
3. $\beta_{94\&96(3,1)} = 0$		-0.18424*** (-3.225)	Reject Null Hypothesis
4. $\beta_{94\&96(3,2)} = 0$		-1.28539*** (-8.630)	Reject Null Hypothesis
5. $\beta_{94\&96(3,3)} = 0$		2.045962*** (16.286)	Reject Null Hypothesis
6. $\beta_{94\&96(3,4)} = 0$		-0.00067 (-0.008)	Fail to Reject Null Hypothesis
7. $\beta_{94\&96(3,5)} = 0$		-0.00425** (-2.119)	Reject Null Hypothesis
8. $\beta_{94\&96(3,2)} = \beta_{94\&96(3,3)}$	240.1385***		Reject Null Hypothesis
9. $\beta_{94\&96(3,2)} + \beta_{94\&96(3,3)} = \beta_{94\&96(3,4)}$	9.251383***		Reject Null Hypothesis

* Significant at the 0.10 confidence level
** Significant at the 0.05 confidence level
*** Significant at the 0.01 confidence level

The hypothesis that the change in the coefficient for undergraduate teaching productivity was equal to the change in the coefficient for graduate teaching productivity was rejected $\chi^2_{(1,0.01)} = 240.17$: The change in the rate of return for an extra credit hour of undergraduate instruction per faculty member (-128.53%) was significantly less than the rate of return for an extra credit hour of graduate instruction per faculty member (204.59%).

The hypothesis that the change in the rate of return from undergraduate and graduate teaching together are equal to research was rejected $\chi^2_{(1,0.01)} = 9.25$: The change in the rate of return for an additional credit hour of teaching per faculty member (76.05%) was significantly greater than the change in the rate of return for an additional unit of research per faculty member (-0.07%). See Table 4.19.

Social Science

The null hypothesis that the change in coefficients, excluding the constants, between 1994 and 1996 for the Social Sciences equation were jointly equal to zero failed to be rejected $\chi^2_{(4,0.01)} = 1.5$, however, once again, caution is warranted when interpreting the results of hypothesis tests using that pertain to the 1996 data for Social Science. This notwithstanding, none of the changes in the coefficients were significantly different from zero; in fact, none of the coefficients for change were individually statistically significant either, at α=0.05 or better.

Table 4.20. Pooled Results for Hypothesis Testing in the Social Sciences.

	Null Hypothesis:	Wald	t-test	Decision Rule (α=0.10)
1.	$\beta_{94\&96(4,2)} = 0$ $\beta_{94\&96(4,3)} = 0$ $\beta_{94\&96(4,4)} = 0$ $\beta_{94\&96(4,5)} = 0$	1.5		Fail to Reject Null Hypothesis
2.	$\beta_{94\&96(4,2)} + \beta_{94\&96(4,3)} = 0$	0.009323		Fail to Reject Null Hypothesis
3.	$\beta_{94\&96(4,1)} = 0$		-0.16564 (-0.487)	Fail to Reject Null Hypothesis
4.	$\beta_{94\&96(4,2)} = 0$		-0.21334 (-0.114)	Fail Reject Null Hypothesis
5.	$\beta_{94\&96(4,3)} = 0$		0.487455 (0.183)	Fail Reject Null Hypothesis
6.	$\beta_{94\&96(4,4)} = 0$		-0.15471 (-0.101)	Fail to Reject Null Hypothesis
7.	$\beta_{94\&96(4,5)} = 0$		0.001346 (0.158)	Fail to Reject Null Hypothesis
8.	$\beta_{94\&96(4,2)} = \beta_{94\&96(4,3)}$	0.037819		Fail to Reject Null Hypothesis
9.	$\beta_{94\&96(4,2)} + \beta_{94\&96(4,3)} = \beta_{94\&96(4,4)}$	0.009689		Fail to Reject Null Hypothesis

* Significant at the 0.10 confidence level
** Significant at the 0.05 confidence level
*** Significant at the 0.01 confidence level

The hypothesis that the change in the coefficient for undergraduate teaching productivity was equal to the change in the coefficient for graduate teaching productivity failed to be rejected $\chi^2_{(1,0.01)} = 0.037$. Though clearly less (based on the point estimates), the change in the rate of return for an extra credit of undergraduate instruction per faculty member (-21.33%) was not significantly different than the rate of return for an extra credit of graduate instruction per faculty member (48.74%).

The hypothesis that the change in the rate of return from undergraduate and graduate teaching together were equal to research failed to be rejected $\chi^2_{(1,0.01)} = 0.01$. An additional credit hour of teaching per faculty member (27.41%) did not yield significantly more (or less) return than an additional unit of research per faculty member (-15.47%). See Table 4.20.

Chapter Summary

Income production functions were estimated for departments in the fields of Life Science, Engineering, Physical Science, and Social Science for a sample of public, research one universities. Seemingly Unrelated Regressions were utilized to estimate the coefficients on systems of equations separately for the years 1994 and 1996, and together on a pooled sample of data from both years (See Appendix 8). To ensure that the high goodness of fit statistics, as measured by R^2, were not the result of spurious correlations caused by the transformation of the data, SUR estimates were calculated for the pre FTE and GLS transformed data for both AY 1994 and AY 1998 (See Appendix 9). In each case the goodness of fit statistics remained very high, validating the results for the transformed data. The answers to the research questions are as follows.

Addressing the Research Questions and Hypotheses

1. Does the rate of return for research productivity exceed that of teaching in the income production function of academic departments in public Research 1 universities ?

For the fields of Engineering, Physical Science, and Social Science the rate of return for teaching productivity was significantly greater than the rate of return for research productivity in 1994 (See Table 4.21).

4.21. The Rate of Return for Teaching Productivity versus The Rate of Return for Research Productivity for 1994 & 1996.

Field	Teaching Productivity		Research Productivity		Wald Test on $H_0: \beta(2) + \beta(3) = \beta(4$	
	1994	1996	1994	1996	1994	1996
Life Science	30.49%***	42.51%***	79.04%***	67.48%***	149.83***	2.85*
Engineering	119.59%***	60.84%***	42.34%***	67.71%***	11.44***	0.04
Physical Science	109.83%***	186.61%***	12.65%**	12.94%**	30.36***	134.69***
Social Science	127.23%***	156.07%***	26.39%***	10.16%**	10.64***	138.99***

* Significant at the 0.10 confidence level;
** Significant at the 0.05 confidence level;
*** Significant at the 0.01 confidence level.

The rate of return for research productivity significantly exceeded that of teaching productivity only for the field of Life Science in 1994. In 1996, the results were somewhat different. While teaching productivity was significantly greater than research productivity for the field of Life Science, no significant differences existed for the fields of Engineering and Social Science (See Table 4.21).

Examining the point estimates, we see that the yield for teaching productivity actually increased in three of the four field, between 1994 and 1996, while the return from research productivity declined in two fields and was stable in a third. Further, the return from teaching still was greater in 1996 for two fields than was the return from research; in the other two cases, the point estimates were relatively close together.

2. Have the relative weights attached to research productivity and teaching productivity significantly changed between academic years 1994 and 1996 in public Research 1 universities?

   i. Undergraduate Teaching Productivity exhibited a consistently positive and significant relationship with departmental income production in the 1994 unpooled analysis for all field groups (See Table 4.22).

Table 4.22. The Rate of Return to Undergraduate Teaching Productivity by Field; 1994 and 1996.

Field	**Undergraduate Teaching Productivity**		
	1994	**1996**	**Δ 1994-1996**
Life Science	18.58%**	41.08%***	8.07%
Engineering	127.12%***	32.66%***	-90.02%***
Physical Science	195.45%***	66.09%***	-128.54%***
Social Science	111.70%***	92.78%***	-21.33%

* Significant at the 0.10 confidence level;
** Significant at the 0.05 confidence level;
*** Significant at the 0.01 confidence level.

The same was true in the 1996 unpooled analysis also, although the rate of return for undergraduate teaching appeared to be less for the fields of Engineering, Physical Science, and Social Science and greater for Life Science (See Table 4.22). The change in the rate of return, as measured in the pooled analysis, revealed that the changes in the return to undergraduate teaching were only significant for Engineering and Physical Science.

ii. Graduate Teaching Productivity exhibited a greater variation among fields than did undergraduate teaching (See Table 4.23).

Table 4.23. The Rate of Return to Graduate Teaching Productivity by Field; 1994 and 1996.

Field	Graduate Teaching Productivity		
	1994	**1996**	**Δ 1994-1996**
Life Science	11.91%***	1.43%	-12.75%
Engineering	-7.53%	28.18%	41.94%
Physical Science	-85.62%***	120.52%***	204.59%***
Social Science	15.53%	63.29%***	48.74%

* Significant at the 0.10 confidence level
** Significant at the 0.05 confidence level
*** Significant at the 0.01 confidence level

In 1994 graduate teaching productivity yielded a significantly positive relationship with Life Science, a significantly negative relationship with Physical Science, and no significant relationship with Engineering or Social Science. The 1996 results revealed a significantly positive relationship between graduate teaching productivity and departmental income production for the fields of Physical Science and Social Science, and no significant relationship for the fields of Life Science or Engineering. Point estimates of all yields were not positive, however. The change in the rate of return, as measured by the pooled analysis, was significant only for Physical Science, for which the rate of return to graduate teaching increased by some 206.14% (See Table 4.23).

iii. Research Productivity showed a consistently positive and significant relationship with departmental income production for all fields in 1994 (See Table 4.24).

Table 4.24. The Rate of Return to Research Productivity by Field; 1994 and 1996.

Field	Research Productivity		
	1994	**1996**	**Δ 1994-1996**
Life Science	79.04%***	67.48%***	-4.35%
Engineering	42.34%***	67.71%***	20.01%
Physical Science	12.64%**	12.94%**	-0.07%
Social Science	26.39%***	10.16%**	-15.47%

* Significant at the 0.10 confidence level
** Significant at the 0.05 confidence level
*** Significant at the 0.01 confidence level

Research Productivity also showed a consistently positive and significant relationship with departmental income production for all fields in 1996. No significant changes occurred in the rate of return to research productivity between time periods, as measured by the pooled analysis, for all of the fields (See Table 4.24).

Although the results appeared to indicate relationships that were unique to particular field groupings, some general trends were observed. Firstly, undergraduate teaching productivity and research productivity always exhibited a significantly positive effect upon the production of departmental income. These effects seemed to have declined, however, over time for most of the fields. Secondly, graduate teaching productivity was not always significantly related to the production of departmental income. In 1994 when this relationship was significant it was positive in one case and negative in another; in 1996 when this relationship was significant it was positive in both cases.

3. What is the impact of departmental quality upon the production of departmental income in public Research 1 universities, and has it changed?

Caution is needed when interpreting the effect of the quality measure upon the production of departmental income because the quality of a department is negatively related to its national rank score; i.e., the higher the magnitude of its ranking, the lower the supposed quality. Therefore, the rate of return for the quality measure should be interpreted as the percentage change in the departmental revenues per unit "decrease" in the quality score of the department. Thus, decrements in departmental quality exhibited a consistently positive and significant effect upon the production of income in 1994 for the fields of Life Science, Engineering, and Physical Science; it was not significant for the field of Social Sciences. In 1996 decrements in departmental quality were still positive and significant for the fields of Life Science and Engineering, but negative and significant for the field of Physical Science (See Table 4.25).

Table 4.25. The Rate of Return to Departmental Quality by Field; 1994 to 1996.

Field	Departmental Quality		
	1994	1996	Δ 1994 and 1996
Life Science	0.86%**	0.12%**	-0.64%
Engineering	0.78%*	0.06%**	-0.76%**
Physical Science	0.37%**	-0.06%***	-0.42%**
Social Science	-0.09%	0.00%	0.13%

* Significant at the 0.10 confidence level
** Significant at the 0.05 confidence level
*** Significant at the 0.01 confidence level

The change in the rate of return for departmental quality, as measured by the pooled analysis, was negative and significant for the fields of Engineering and Physical Science, (-0.76%) and (-0.42%) respectively (See Table 4.25).

From these results we may conclude that while decreased departmental quality has had a positive effect upon the production of departmental income, it's effect has changed, having moved in the direction to reward quality.

4. Do structural difference exist between the various academic fields of Life Science, Engineering, Physical Science, and Social Science? And if so, how have they changed over the period of this analysis?

The rate of return, as determined by the aggregate of all the coefficients in the income production function for the four field groups is given in Table 4.26.

Table 4.26. Summary of Coefficients in the Income Production Function for all Fields; 1994 & 1996.

FIELD	INTERCEPT	UGCH	GCH	RESEARCH	STANDING	TOTAL RATE OF RETURN
	1994	**1994**	**1994**	**1994**	**1994**	**1994**
Life Science	7.41%	18.58%**	11.91%***	79.04%***	8.55%**	125.49%
Engineering	-19.49%**	127.12%***	-7.53%	42.34%***	7.85%*	150.29%
Physical Science	17.44%***	195.45%***	-85.62%***	12.64%**	3.69%**	143.60%
Social Science	14.63%	111.70%***	15.53%	26.39%***	-0.09%	168.16%
	1996	**1996**	**1996**	**1996**	**1996**	**1996**
Life Science	1.24%	41.08%***	1.43%	67.48%***	0.12%**	111.35%
Engineering	-0.68%	32.66%***	28.18%	67.71%***	0.06%**	127.93%
Physical Science	-1.35%	66.09%***	120.52%***	12.94%**	-0.06%***	198.14%
Social Science	-0.59%	92.78%***	63.29%***	10.16%**	-0.003%	165.63%

* Significant at the 0.10 confidence level
** Significant at the 0.05 confidence level
*** Significant at the 0.01 confidence level

When the equality of the aggregate rate of return was tested (Appendix 10) among field groups for 1994, the results were as follows (Table 4.26): The rate of return for Social Science (168.16%) was greater than Engineering (150.29%), Physical Science (143.60%), and Life Science (125.49%). However, no significant differences existed among the aggregate rates of return for the three fields, Engineering, Physical Science, and Life Science.

Testing the equality of the aggregate rate of return among field groups for 1996 (See Appendix 10), yielded the following results (See Table 4.26): The rate of return for the field of Physical Science (198.14%) was significantly greater than Social Science

(165.63%), and both were significantly greater than Engineering (127.93%) and Life Science (111.35%). No significant difference existed between the aggregate rate of return for Engineering and Life Science (See Table 4.28).

Finally, testing the hypothesis that the 1994 coefficients were equal to the 1996 coefficients for each field yielded the following results:

Table 4.27. Wald Test on the Equality of the Coefficients across Time Periods for all Fields: 1994 to 1996.

Field	$\sum \beta_{94}$	$\sum \beta_{96}$	H_0: $\sum \beta_{1994} = \sum \beta_{1996}$ [Wald Test (χ^2_8)]	Decision Rule (α=0.10)
Life Science	125.49%	111.35%	0.08576	Fail to reject H_0
Engineering	150.29%	127.93%	0.243387	Fail to reject H_0
Physical Science	143.60%	198.14%	33.8552***	Reject H_0
Social Science	168.16%	165.63%	0.001034	Fail to reject H_0

* Significant at the 0.10 confidence level
** Significant at the 0.05 confidence level
*** Significant at the 0.01 confidence level

The ranking of fields based upon the aggregate rate of return have changed over the period of this study. The field of Physical Science was the only field to experience any significant changes in its aggregate rate of return between time periods: 143.60% in 1994 to 198.14% in 1996, an increase of 54.54 percentage points. This resulted in the Physical Sciences being ranked above the Social Sciences in the aggregate rate of return for 1996. Engineering and Life Science still remained significantly lower than Social Science in the 1996 analysis, and of course were lower than Physical Science also.

The hypotheses posed in chapter one of this study, suggested that the relationships from each of the theoretical frameworks would appear as follows (See Table 4.30).

Table 4.28. Hypothesized Changes in the Relative Weights of Variables within the Revenue Production Function.

	Life Science		Engineering		Physical Science		Social Science	
Hypothesized Δ Rate of Return	**RDT**	**TF**	**RDT**	**TF**	**RDT**	**TF**	**RDT**	**TF**
Undergraduate Credit Hours	+	-	+	-	+	-	+	-
Graduate Credit Hours	+	+	+	+	+	+	+	+
Research Productivity	+	+	+	+	+	+	+	+
Departmental Quality	-	+	-	+	-	+	-	+

(RDT = Resource Dependency Theory; TF = Theory of the Firm)

In comparison, the results from the present study revealed the following changes (See table 4.29).

Table 4.29. Actual Changes in the Relative Weights of Variables within the Revenue Production Function: 1994 and 1996.

Δ Rate of Return	**Life Science**	**Engineering**	**Physical Science**	**Social Science**
Undergraduate Credit Hours	8.07%	-90.02%***	-128.54%***	-21.33%
Graduate Credit Hours	-12.75%	41.94%	204.59%***	48.74%
Research Productivity	-4.35%	20.01%	-0.07%	-15.47%
Departmental Quality	-0.64%	-0.76%*	-0.42%*	0.13%

* Significant at the 0.10 confidence level;
** Significant at the 0.05 confidence level;
*** Significant at the 0.01 confidence level

Although only five of the variables were significant (excluding the constant terms) in the pooled analysis that measured change between the time periods, four of the significant changes related to variables that were key in differentiating between the effects of the alternative frameworks used in the present study: these variables were undergraduate teaching productivity and departmental quality. While the four results changed in the direction hypothesized by the theory of the firm, i.e., diminished returns to undergraduate instruction and increased returns to departmental quality, the context within which these changes occurred, i.e., higher returns to instruction than research in both years, high returns to undergraduate instruction in both years, and mostly negative returns to quality in both years, support the arguments developed from resource dependency theory. The implications of these findings are discussed in Chapter 5.

CHAPTER 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This was a study of resource allocation in public research one universities. Specifically, this study examined the relative rate of return universities realized from teaching productivity, research productivity, and departmental quality for academic departments within the fields of Life Science, Engineering, Physical Science, and Social Science. The bases of resource allocation used by the institutions, i.e., their allocation function, was modeled by the estimation of the departments income production functions. This chapter contains a summary of the theoretical frameworks, research questions, and methods, followed by a discussion of the major conclusions and implications of the study. Suggestions for further research conclude this chapter.

Summary of Theoretical Frameworks

The two theoretical frameworks used in this study, resource dependency theory and the theory of the firm, offer two alternative explanations of resource allocation within institutions of higher education. In summary the model derived from the theory of the firm assumes that an organization pursues a set of goals to maximize its satisfaction subject to one or more constraints (Tuckman and Chang, 1990; James, 1990). In the case of not-for-profit organizations, satisfaction is maximized when the organization allocates resources to its goal in such a fashion that no other combination of resources gives rise to a higher level of total utility, given the constraints (James, 1978).

Unlike profit maximizing organizations that seek to minimize costs to reduce expenditures, not-for-profit organizations may produce more costly products and services than are optimal from a profit making perspective. Decision-makers, in fact, tend to satisfy their own preferences. As the decision-makers have relatively little discretion over the prices, subsidies, or costs associated with the products and services being delivered, the major way they can increase institutional benefits is by altering the mix of products and services.

There are limits, however, to which the decision-makers can respond to their preferences, limits imposed by the fact that the aggregate income of the organization must cover its aggregate costs. Because the decision-makers within the organization have particular tastes, preferring to deliver one product or service over another, and because some of the preferred services may not cover their own costs, these organizations find themselves taking on profit making activities that cover the deficits incurred by other activities. This phenomenon illustrates cross-subsidization (James, 1983).

The importance of goals as a defining characteristic of organizations has been criticized on several grounds: this framework presumes a singularity of purpose (Pfeffer and Salancik, 1978); it assumes that goal setting and choice have an influence over outcomes (Morgan, 1984); and it neglects forces external to the organization (Pfeffer and Salancik, 1978). An alternative conception of organizations conceives of them as coalitions that "alter their purposes and domains to accommodate new interests, sloughing off part of themselves to avoid some interests, and when necessary, becoming involved in activities far afield from their state central purposes" (Pfeffer and Salancik, 1978, pg. 24). Under this model, which is derived from resource dependency theory, the political dimension of the organization is emphasized. Recognizing the plurality of goals that exist, the resource dependency model allows for the incidence of conflict and bargaining when goals differ.

The process of competing for resources and the determination of who secures those resources is central to the resource dependency framework. By examining the relationship of resource allocation to organizational control within the framework of resource dependency theory, Pfeffer and Salancik contend that in general, "organizations will tend to be influenced by those who control the resources they require" (1978, pg. 44). Two factors are important in determining the level of dependence of one organization over another: the relative magnitude of the exchange and the criticality of the resource.

The relative magnitude of the exchange is the proportion of resource shares provided. Organizations with a narrow resource base are more susceptible to external control than those with a diversified base of resources. A critical resource is one that is necessary for the organization to keep functioning. Resource criticality, by definition, is independent of resource magnitude.

Pfeffer and Salancik (1978) argue that the importance of a resource to organizational functioning, *per se*, is not problematic but that vulnerability may result from the possibility of change in the supply of the resource. To ensure the survival of the organization it is necessary that the production units minimize the possibility of resources becoming scarce. In the case of public universities, declining shares of state fund revenues may have promoted the universities to increase the share of other revenues in their base.

Summary of Method

This study examined the effect of teaching productivity, research productivity, and departmental quality upon departmental income production. The unit of observation was academic departments in a sample of research one universities in the United States. The analysis estimated the effect of undergraduate student credit hours per faculty member, graduate student credit hours per faculty member, sponsored research expenditures per faculty member, and departmental rankings upon a conservative measure of departmental "income," which was measured by non-restricted current-fund expenditures. Four research questions were posed and subsequently answered:

1. Does the relative weight of research productivity exceed that of teaching in the income production function of academic departments in public Research 1 universities ?
2. Have the relative weights attached to research and teaching significantly changed between academic years 1993-1994 and 1994-1996 in public Research 1 universities?

3. What is the impact of departmental quality upon the production of departmental income in public Research 1 universities, and has it changed?
4. Do structural difference exist between the various academic fields of Life Science, Engineering, Physical Science, and Social Science? And if so, how have they changed over the period of this analysis?

To answer these questions, three systems of equations comprised of four equations each, were estimated. Each equation followed a log linear model, in which the earnings of the department were related to the exogenous variables: teaching productivity, research productivity, and departmental quality. To control for within equation heteroscedasticity, the data were transformed by estimated generalized least squares. To control for between equation heteroscedasticity, or contemporaneous covariance, Seemingly Unrelated Regression was employed to estimate the coefficients.

Models one and two were used to estimate the parameters for the data separately in 1994 and 1996. In general each equation in the model was specified as

$$\ln(E) = \beta_1 + \beta_2 X_1 + \beta_3 X_2 + \beta_4 X_3 + \beta_5 X_4$$

where,

X_1 = Undergraduate Student Credit Hours Per FTE Faculty Member

X_2 = Graduate Student Credit Hours Per FTE Faculty Member

X_3 = Sponsored Student Research Expenditures Per FTE Faculty Member

X_4 = Departmental Student Standing Rankings

The system of four equations specified in the model were given by

$$\underset{(T\times 1)}{\mathbf{Y}_1} = \underset{(T\times 5)}{\mathbf{X}_1}\ \underset{(5\times 1)}{\Gamma_1} + \underset{(T\times 1)}{\varepsilon_1}$$

$$\underset{(T\times 1)}{\mathbf{Y}_2} = \underset{(T\times 5)}{\mathbf{X}_2}\ \underset{(5\times 1)}{\Gamma_2} + \underset{(T\times 1)}{\varepsilon_2}$$

$$\underset{(T\times 1)}{\mathbf{Y}_3} = \underset{(T\times 5)}{\mathbf{X}_3}\ \underset{(5\times 1)}{\Gamma_3} + \underset{(T\times 1)}{\varepsilon_3}$$

$$\underset{(T\times 1)}{\mathbf{Y}_4} = \underset{(T\times 5)}{\mathbf{X}_4}\ \underset{(5\times 1)}{\Gamma_4} + \underset{(T\times 1)}{\varepsilon_4}$$

Where,

1 = Life Science
2 = Engineering
3 = Physical Science and Math, and
4 = Social Science

$$\Gamma_n = \begin{matrix}\beta_1\\ \beta_2\\ \beta_3\\ \beta_4\\ \beta_5\end{matrix}$$

Model 3, utilized the Piecewise Linear approach to estimate the separate linear relationships for pooled 1994 and 1996 data. The dummy variable technique was used to model the nonlinear function, which was comprised of two different linear functions. For each equation in the model

$$\ln(E) = \beta_I + \beta_{II}X_1 + \beta_{III}X_2 + \beta_{IV}X_3 + \beta_V X_4$$

where,

X_1 = Undergraduate Student Credit Hours Per FTE Faculty Member

X_2 = Graduate Student Credit Hours Per FTE Faculty Member

X_3 = Sponsored Research Expenditures Per FTE Faculty Member

X_4 = Departmental Standing Rankings

A dummy variable was defined so that

$$D_1 = \begin{cases} 1, & \text{if } 1996 \\ 0, & \text{if } 1994 \end{cases}$$

To test whether the structures for the two periods were different, the specification assumed the following:, $\beta_I = \beta_1 + \beta_2 D_1$, $\beta_{II} = \beta_3 + \beta_4 D_1$, $\beta_{III} = \beta_5 + \beta_6 D_1$,

$$\beta_{IV} = \beta_7 + \beta_8 D_1, \qquad \beta_V = \beta_9 + \beta_{10} D_1$$

Substituting these into the equation above yielded the following equation:

$$\ln(E) = \beta_1 + \beta_2 D_1 + \beta_3 X_1 + \beta_4 D_1 X_1 + \beta_5 X_2 + \beta_6 D_1 X_2 + \beta_7 X_3 + \beta_8 D_1 X_3 + \beta_9 X_4 + \beta_{10} D_1 X_4 + u$$

In general, the system of 4 equations was given by

$$\underset{(T \times 1)}{\mathbf{Y}_1} = \underset{(T \times 5)}{\mathbf{X}_1} \underset{(5 \times 1)}{\Gamma_1} + \underset{(T \times 1)}{\varepsilon_1}$$

$$\underset{(T \times 1)}{\mathbf{Y}_2} = \underset{(T \times 5)}{\mathbf{X}_2} \underset{(5 \times 1)}{\Gamma_2} + \underset{(T \times 1)}{\varepsilon_2}$$

$$\underset{(T \times 1)}{\mathbf{Y}_3} = \underset{(T \times 5)}{\mathbf{X}_3} \underset{(5 \times 1)}{\Gamma_3} + \underset{(T \times 1)}{\varepsilon_3}$$

$$\underset{(T \times 1)}{\mathbf{Y}_4} = \underset{(T \times 5)}{\mathbf{X}_4} \underset{(5 \times 1)}{\Gamma_4} + \underset{(T \times 1)}{\varepsilon_4}$$

Where,

1 = Life Science
2 = Engineering
3 = Physical Science and Math , and
4 = Social Science

$$\Gamma_n = \begin{matrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \\ \beta_5 \\ \beta_6 \\ \beta_7 \\ \beta_8 \\ \beta_9 \\ \beta_{10} \end{matrix}$$

The data sets for these analyses were taken from the American Association of Universities Data Exchange (AAUDE) 1994 and 1996 files for non-restricted and sponsored research expenditures, and from site visits to universities. This AAU database contained detailed departmental measures of student credit hour production, non-restricted expenditures, and restricted research expenditures. The final sample for 1994 consisted of 8 public Research I universities, 200 departments, and 1000 data points. The final sample for 1996 consisted of 6 public Research I universities, 134 departments, and 680 data points.

Conclusions

The fundamental approach taken in this study was to estimate an income production function for departments within the fields of Life Science, Engineering, Physical Science, and Social Science. At the outset of this paper, the argument was put forth that when the majority of income is derived from a single source, i.e., from non-restricted current-fund revenues, then the income production function is also a model of the allocation function of the organization. Put another way, it is a model that reveals those priorities to which the organization is committed fiscally. In concluding this study, a number of observations can be made regarding the effects of the variables measuring teaching productivity, research productivity, and departmental quality upon the dependent variable, departmental income, and to what degree these effects fit the alternative frameworks of resource dependency theory and the theory of the firm.

Model Specification and Goodness of Fit

In forming conclusions and generalizations from these results, it was important to establish the validity of the estimates from the models employed. For each year and in each field the model exhibited a consistently high adjusted squared multiple correlation coefficient ($R^2 \geq 97.5\%$). In the unpooled analyses, 15 of the 20 coefficients were significant in 1994 and 13 of the 20 coefficients were significant in 1996. In the pooled analysis for 1994 and 1996, 7 of the 20 coefficients were significant, indicating statistically significant changes between time periods.

These strong goodness of fit measures, coupled with the control of within and between equation heteroscedasticity, ensured that the model produced the best, linear, unbiased, estimates obtainable; because the requirements of the Gauss-Markhov Theorem were met, confidence could be placed in the results of the estimates obtained and in the ensuing hypothesis tests (except, perhaps, for the field of Social Science in 1996).

Elimination of multicollinearity between the two measures of undergraduate credit hours and the two measures of graduate credit hours was accomplished by aggregating these measures; this process resulted in a loss of some precision in the model but bolstered the significance of the results by reducing standard errors.

Teaching Productivity

The perception that instruction has been displaced by research as the priority in the allocation function of public universities was not supported by the results. Teaching productivity (as measured by the aggregate of undergraduate and graduate instruction) exhibited a significantly positive relationship with departmental income production in both time periods. In the 1994 unpooled analysis, teaching productivity exhibited a greater effect upon departmental income production than did research productivity for all fields (excluding the Life Sciences in which teaching productivity yielded a significantly lower effect than research productivity). In the 1996 unpooled analysis, teaching productivity had a significantly greater effect than research productivity in the fields of Life Science and Physical Science, but was not significantly different (higher *or* lower) from research productivity for the fields of Engineering or Social Science. Based upon these findings, one of the major conclusions of this study was that departments from the fields examined, could, and did, increase their revenues by increasing their instructional productivity, or more simply put, by teaching more. In fact, unlike graduate instruction, undergraduate instruction consistently increased departmental current-fund revenues for departments from all fields in both periods of time. Furthermore, the average rate of return for undergraduate education over both years exceeded that for graduate education for all fields (See Appendix 8); therefore, departments that focused upon the production of instruction, and specifically undergraduate instruction, consistently yielded more current-fund departmental revenues than departments that focused more on research. These results, in conjunction with the faculty time allocation data presented in Chapter 2, contradicted the perception that universities were neglecting instruction, particularly undergraduate instruction, by allocating more fiscal resources, including faculty time, to research. In fact the opposite appeared to be true; in 1994 the rate of return for instruction exceeded that for research in departments from three of the four fields; in 1996 the rate of return for instruction exceed that for research in two of the four fields but was not significantly different from research in the others; in both 1994 and 1996 the rate or return for instruction, especially undergraduate instruction, was significant and positive for all fields. Of course this result is mitigated by excluding from the sample, departments that only did graduate education.

Unfortunately, the results for changes between 1994 and 1996 are less encouraging: The results of the pooled analysis showed that the rate of return for undergraduate instruction significantly decreased between 1994 and 1996 for the fields of Engineering and Physical Science (-90.02% and -128.54% respectively) but did not change significantly for the other two fields (Social Science had a decline of (-21.33%) and Life Science had an increase of (8.07%), though neither of these changes were significant at any reasonable level of α). Interestingly, for the Physical Sciences there was a commensurate positive change in the rate of return for graduate instruction (204.59%), which elevated graduate instruction to be the single most important (current-fund) revenue generating variable for departments within this field. (Although not significant, the change for graduate instruction in the field of Engineering was also positive and quite large--41.94%.)

How do these results fit with the alternative theoretical frameworks used in this study? In Chapter One it was shown, or argued, that faculty in 1997 public research universities were spending more time teaching then they were ten years ago (See Table 2.2), that they were spending as much time on teaching undergraduates as they were on graduates; and that they were doing so primarily because they were resource dependent: They come to rely more heavily on student tuition and fee revenues as the rate of state support declined. As students became a more critical resource provider, a concomitant upward shift in the level of faculty attention towards student instruction was expected. However, this would only occur if the increased resources from students were being allocated to the departments as departmental teaching productivity rose. An alternative hypothesis, derived from the Theory of the Not-for-Profit Firm (James, 1990), suggested utility maximization was what drove the allocation of resources, and that undergraduate education only entered into the utility function of faculty to the degree that the profits that were generated from it could be transferred to support more desirable endeavors such as research.

The results have shown clearly that teaching "matters" within the departments revenue production function when aggregated by field type, and therefore, that teaching also "matters" within the institution's allocation function. Furthermore, undergraduate teaching matters, having yielded a consistently positive effect upon the production of departmental income. These results support the resource dependency perspective that teaching is rewarded because resource shares from students and the state are great in relative magnitude. Additionally, despite the short period of time over which change was measured, the rate of return to teaching productivity, in general, either increased (Physical Science) or did not change significantly between years. Once again, these results seem to fit the hypotheses derived from resource dependency theory. In contrast, however, the rate of return for *undergraduate* teaching productivity either significantly declined (Engineering and Physical Science) or did not change significantly between 1994 and 1996. Departments in Engineering and Physical Science were getting significantly less "return" from the institution for teaching undergraduates.

The latter result supports the theory of the firm hypothesis that profit-making undergraduate instruction increasingly are being "taxed," presumably to support other loss making endeavors that yield greater utilities to institutional decision-makers. As suggested by the theory of the firm, those endeavors that yield greater utility may be graduate instruction, research, and departmental quality. The results suggest that there is an increase in the rate of return for graduate instruction, at least in one of the fields examined. Furthermore, the rate of return to departmental quality also has increased significantly for Engineering and Physical Science (the rate of return for Life Science also increased, but this change was not significant).

These results suggested that for some fields, particularly Engineering and Physical Science, undergraduate instruction, though still important in the revenue production function of departments, was increasingly being "taxed". As the "return" to undergraduate instruction diminished, the "return" to graduate instruction and departmental quality has increased, at least in some cases. Undergraduate instruction, therefore, may have cross-subsidized graduate instruction and activities that promoted department quality, such as research. Although no evidence was found to support the argument that undergraduate instruction was being used to cross-subsidize research directly, to the extent that graduate instruction entered into the production of research, and to the extent that research was an activity that contributed to departmental quality, revenues from undergraduate instruction may have been used to support research indirectly. The increased influence upon resource allocation decisions that undergraduate students were hypothesized to have possessed, may not have been realized because students have little "economic" ability to influence resource allocation decisions; furthermore, they have great difficulty organizing. The costs of coordinated action may have acted as a barrier to students exercising their "control." In effect, these costs, may have promoted a form of "free-rider" behavior, causing students to take the attitude "let someone else do it!"

Research Productivity

The effect of instruction upon departmental income was greater than the effect of research for some fields, and equal to the effect of research for others. This was not to say, however, that the effect of research was unimportant. Like teaching productivity, research productivity exhibited a significant, positive effect upon departmental income production for all fields in both time periods. In the 1994 unpooled analysis the mean rate of return for research productivity across fields was 40.10%, and in 1996 it was nearly as high, 39.57%. In 1996 in no case was research productivity singularly at the top of the allocation function for these institutions; it was less 'productive" than teaching for the fields of Life Science and Physical Science, and was as productive as teaching for the fields of Engineering and Social Science.

The hypotheses generated from resource dependency theory and the theory of the firm both suggested that research productivity would have a significant positive effect upon the generation of departmental income. Furthermore, both theories suggested that there would be a significant positive change in the rate of return to research productivity. While research productivity exhibited strong positive effects in both the 1994 and 1996 analyses, no significant changes were observed between the two years. Some changes did occur, however, in the order of ranking of the fields and the percentage values on the rate of return estimates for research productivity in the unpooled analyses in both 1994 and 1996. In 1994 Life Science ranked first (79.04%), Engineering second (42.34%), and Social Science and Physical Science followed (26.39%) and (12.64%). (See Appendix 5.)

In 1996 Engineering had "caught up" with Life Science (67.71% and 67.49% respectively), while Social Science and Physical Science continued to lag behind (10.16% and 12.94% respectively; See Appendix 6). Overall, these results may be explained by federal research obligations; that is the "return" for research productivity in the Life Sciences may have been the greatest for both years because the federal obligations for basic and applied research was greatest for this field (NSF, 1993, pg. 355). Further, though substantially less than federal spending for research in the Life Sciences, the obligations for research in Engineering, specifically for applied research, have grown at the greatest rate among all fields (NSF, 1993, pg. 352-254). In short, because the federal government (along with industry) provided the majority of funds for sponsored research (NSF, 1993, pg. 333), the rate of return probably should have been greatest for departments in those fields that received the greatest share of funds, and this is what was found. Put another way, research was more "productive" for departments within Life Science and Engineering than for departments within the Physical Science and Social Science. Departments in *all* fields, however, could augment their current-fund revenues by securing external research grants and contracts. In essence, unlike teaching, externally-funded research yielded a double return: a return from the grant or contract revenue and a return from the institution.

Of course caution must be exercised when interpreting changes over such a short period of time as anomalous "shocks" to the system may skew the results. For example, increased state appropriations aimed at encouraging faculty to teach more, such as the

Teaching Incentive Program in Arizona, may bolster the return of state monies to teaching in any given year and mask the real, underlying rate of return. Likewise, the return to other endeavors, such as research, may be underestimated as a result of such single events. Furthermore, changes in the composition of the sample between both years may also impact the results. In 1994 eight institutions were represented in the sample; in 1996 six institutions were represented in the sample. The reduction in sample size may not only have an impact upon the power of the statistical analyses, but also upon the "representitiveness" of the sample, which changes between the years. Further, if the two states that were excluded in the 1996 analysis had some form of systematic bias that caused them not to report data to the AAU that year, then the real changes between time periods may not be estimated accurately. For example, if a state institution failed to report data because their research funding declined for a particular year, then the sample may be skewed, oversampling those institutions whose research funding is moderate to high.

Departmental Quality

The results showed that in 1994 there was a significant, negative relationship between departmental quality and departmental income production for three fields: Life Science, Engineering, and Physical Science (no significant effect existed for the field of Social Science). A one place lower ranking in 1994, resulted in a positive return of departmental income for these fields. In other words departments in Life Science, Engineering, and Physical Science somehow were being "penalized" for having relatively high national quality rankings. In 1996 this was still true for Life Science and Engineering, but not for the Physical Sciences. Allocations to both Engineering and Physical Science had changed significantly; institutions were marginally rewarding departments for higher quality rankings in the case of Physical Science and "penalizing" departments much less severely in the case of Engineering.

The negative relationship between departmental income production and quality in 1994 runs counter to the economic theory hypothesis, which suggests that departmental quality is part of the institution's utility function. And although 1994-1996 changes in the fields of Engineering and Physical Science were in a direction more consistent with this theory, the changes were small and, for Life Science and Engineering, they remained negative. In toto the effect of departmental quality upon the production of departmental income seemed to marginally negative.

Implications

The results of this study indicated that there is merit to both of the theoretical frameworks utilized: resource dependency theory and the theory of the firm. In keeping with resource dependency theory, the effect of teaching productivity upon the production of departmental income is strong and positive for all the fields in both years, and either increased or stayed constant between both years. Further, departmental quality does not contribute positively to the production of departmental income, except for the field of Physical Science in 1996; research productivity exhibits a strong and positive relationship with the production of departmental income, albeit a constant one. Hypotheses derived from the theory of the firm also were validated with respect to the diminishing rate or return to undergraduate teaching productivity, the trend towards an increasing rate of return for graduate instruction and departmental quality, and the strong positive rate of return for research productivity.

What were the implications of these results for major public research universities? If departments and faculty are rational economic actors they certainly *will* continue to give major attention to teaching, especially undergraduate teaching. However, as the results show, they should be alert to the possible declines in the rate of return associated with teaching undergraduates and to possible increases in the rate of return to graduate teaching and research productivity, and departmental quality, i.e., to cross-subsidization. While undergraduate instruction may cross-subsidize graduate instruction and departmental quality in some fields, no evidence is found that suggests undergraduate instruction directly cross-subsidizes research.

The implications for research productivity are mixed. While there is no evidence that research is being favored over teaching in the resource allocation process, it is true that departments are being rewarded for raising grant and contract revenues. Still, in no field does this rate of return exceed that of teaching productivity.

Improving quality is at best marginally rewarded, and may even be penalized. The clear message to faculty, department heads, students, and the public is that incentives are not targeted on quality improvement. How can this be reconciled with Bowen's (1987) and Clotfelter's (1996) view that institutions of higher education essentially spend the most to be the best, and Leslie's (1994) findings showing a connection between quality and financial resources. The answer may be that in times of economic scarcity university administrators must choose between rewarding quality and meeting minimal demands, that is providing only the resources to teach classes at a minimal level.

In the introduction of Chapter 1, it was argued that the basic problem of economic scarcity motivated this study of higher education finance. The problem, as manifested in public research universities, was the perception that universities and faculty may favor research over teaching in the allocation of scarce fiscal resources. This perception was expressed by many of the participant groups within higher education, and was explained, in theoretical terms, either as a rational response of faculty to maximizing their personal utility (James, 1990), or as rational response of faculty to the changing fiscal environment (Slaughter and Leslie, 1997). Although some *shifts* in resource allocation were observed to move in a direction that potentially favored research-related endeavors, i.e., graduate instruction and departmental quality, instruction, overall, was most greatly rewarded in the allocation process, and undergraduate instruction more so than graduate instruction. The major implication of this study, therefore, was that the problem of university attention to teaching (or the lack thereof), seemed to be more a perceptual one than a real one. This has great import for the many individuals and groups who subscribed to this view, especially for state officials who believed public research universities have lost sight of their teaching mission. Rather than relying on anecdotal evidence that does not *directly* reflect how resources are being allocated, these officials and the legislators whom they represent, need to know that these institutions have not lost sight of their essential mission --teaching of undergraduate students.

Recommendations for Future Research

The scope of work to be done in fully specifying the production function for higher education is immense. This study adds to the existing literature dealing with instruction and research by considering data from using academic departments in four fields within public research universities.

Repeating this analysis for departments from other fields within these institutions would provide a more comprehensive analysis. Analysis of data for departments from the Humanities, for example, would permit an interesting comparison of departments that represent traditionally low cost technologies. Data for professional schools, such as Law and Medicine, would also help to develop a broader depiction of the production function for these institutions. The effects of the interactions between these fields also would be instructive: Does the addition or deletion of certain types of departments significantly impact the overall, university production function? Or is there such a thing as an overall function? Do complementarities exist, for example between some Physical Science departments and Engineering departments, between Life Science departments and Medical departments?

While there are many important effects that can be observed among the interactions of these different fields, there is also a lot of rich information to be exploited within each field group. By limiting analyses to individual fields, it would be possible to collect data that would more adequately define the quality and quantity of inputs and outputs. Also, the interactions between the teaching and research, joint production, could be specified in the model.

With reference to Pfeffer and Salancik's resource dependency theory, the need exists to construct an index of criticality that not only reflects the importance of inputs to university functioning, *per se*, but that also reflects the level of vulnerability that exists when and if the inputs are withdrawn. For example, while tuition and fees represent a growing and critical resource to public universities, students appear to lack the ability to influence internal activities in important ways, at least in comparison with the influences of governors and state legislators.

The challenge to adequately define the production function for higher education is one that will be carried into the 21^{st} Century, as it is at the core of understanding the complex organization that is the modern-day university. At the heart of the matter is the need to define and understand the complex technologies of instruction and research, and the instruction-research nexus. As our understanding of these technologies develops, all stakeholders in the university community, students, faculty, administrators, legislators, and the public, will be more able to make informed decisions about the allocation of the scarce fiscal resources among the varied and competing needs of the institution.

APPENDIX 1

Consumer Price Index (CPI) factors: Fiscal years 1985 through 1994

Fiscal Year	Consumer Price Index	CPI Adjustment Factor
1984-85	105.679	1.396
1985-86	108.817	1.356
1986-87	111.233	1.326
1987-88	115.842	1.273
1988-89	121.192	1.217
1989-90	126.975	1.162
1990-91	133.917	1.102
1991-92	138.208	1.067
1992-93	142.525	1.035
1993-94	147.517	1.000

APPENDIX 2

Mean Values of 1994 Untransformed Data

	Mean	Standard Deviation	Range	Minimum	Maximum
NRE1	147189.8	158071.7	780354.7	9527.6	789882.3
UGCH1	681.9	1067.9	4474.0	8.7	4482.7
GCH1	155.3	138.0	692.3	0.0	692.3
RE1	188020.3	236045.3	1299383.1	2132.8	1301515.9
STANDING1	59.1	22.7	81.0	20.0	101.0
FTE1	13.0	12.5	56.9	0.5	57.4
NRE2	249891.9	229892.7	1040875.0	4337.8	1045212.9
UGCH2	755.0	653.6	2428.0	14.0	2442.0
GCH2	331.7	426.2	2076.8	0.0	2076.8
RE2	237259.2	263200.4	1047749.8	0.0	1047749.8
STANDING2	32.8	25.2	99.0	3.0	102.0
FTE2	22.2	20.2	97.5	0.0	97.5
NRE3	395729.9	305652.6	1472108.3	1281.9	1473390.3
UGCH3	2380.7	2059.1	9573.0	158.1	9731.1
GCH3	335.6	345.3	1850.6	25.6	1876.3
RE3	355363.2	405011.5	1707507.3	238.9	1707746.2
STANDING3	42.1	28.5	96.0	7.5	103.5
FTE3	41.0	30.9	116.6	0.2	116.7
NRE4	250052.6	191202.2	1081455.0	41089.8	1122544.8
UGCH4	2067.7	1247.7	5110.7	106.5	5217.2
GCH4	277.6	348.2	2241.3	48.2	2289.5
RE4	101856.8	132043.1	677242.9	2854.1	680097.0
STANDING4	40.1	22.3	95.0	1.0	96.0
FTE4	30.6	22.2	120.4	3.2	123.6

Where,

NRE = Non Restricted Current-Fund Expenditures.
UGCH = Undergraduate Credit Hours.
GCH = Graduate Credit Hours.
RE = Sponsored Research Expenditures.
STANDING = Quality Ranking.
FTE = Full Time Faculty Equivalent.

1 = Life Science.
2. = Engineering.
3. = Physical Science.
4. = Social Science.

APPENDIX 2 (CONT.)

Mean Values of 1994 FTE Transformed Data

	Mean	Standard Error	Range	Minimum	Maximum
NRE1	11864.8	869.6	42970.1	8445.0	51415.1
UGCH1	49.7	9.8	474.7	0.7	475.4
GCH1	17.9	3.0	126.3	0.0	126.3
RE1	20020.3	3708.6	152279.2	479.7	152758.9
STANDING1	59.1	3.2	81.0	20.0	101.0
NRE2	98154.9	86525.0	4328343.6	9475.8	4337819.4
UGCH2	474.8	438.8	21974.9	2.3	21977.2
GCH2	18.6	5.0	241.7	0.0	241.7
RE2	12487.6	3047.3	148065.6	1.0	148066.6
STANDING2	32.8	3.6	99.0	3.0	102.0
NRE3	10274.4	728.8	36906.4	7039.7	43946.0
UGCH3	92.2	22.2	847.0	21.0	868.0
GCH3	24.5	15.0	752.8	1.9	754.6
RE3	23488.9	12530.7	616141.1	5.6	616146.7
STANDING3	42.1	4.0	96.0	7.5	103.5
NRE4	8250.5	170.0	8187.7	6734.0	14921.7
UGCH4	82.2	9.7	510.1	4.7	514.8
GCH4	10.4	2.1	108.4	3.9	112.3
RE4	4079.8	778.1	31228.3	80.8	31309.1
STANDING4	40.1	3.2	95.0	1.0	96.0

Where,

NRE = Non Restricted Current-Fund Expenditures.
UGCH = Undergraduate Credit Hours.
GCH = Graduate Credit Hours.
RE = Sponsored Research Expenditures.
STANDING = Quality Ranking.
FTE = Full Time Faculty Equivalent.

1 = Life Science.
2. = Engineering.
3. = Physical Science.
4. = Social Science.

APPENDIX 2 (CONT.)

Mean Values of 1996 Untransformed Data

	Mean	Standard Deviation	Range	Minimum	Maximum
NRE1	1550344	1744910	7293193	77155	7370348
UGCH1	6515	8996.582	35053	94	35147
GCH1	1247.5	1908.072	10837	47	10884
RE1	1657051	1393442	6922968	22398.94	6945367
STANDING1	61.66912	21.09248	74.75	26.25	101
FTE1	17.52943	17.86295	68.86984	1.110138	69.97998
NRE2	2160209	2046191	9590575	338401	9928976
UGCH2	5973.412	5768.097	23847	61	23908
GCH2	2273.618	3371.744	16401	5	16406
RE2	1984028	2185333	8266093	2412	8268505
STANDING2	34.55882	25.77239	81.5	3	84.5
FTE2	24.22021	22.70542	105.7002	4.430137	110.1303
NRE3	3331260	2954908	13897602	61128	13958730
UGCH3	16776.62	16773.53	57985	41	58026
GCH3	2282.676	3182.595	15940	9	15949
RE3	2995629	3605129	15966595	44281	16010876
STANDING3	42.76471	30.41823	96	7.5	103.5
FTE3	44.07567	36.46493	140.106	1.045551	141.1516
NRE4	2068779	1877822	10379428	270217	10649645
UGCH4	13469.44	10643.06	43706	982	44688
GCH4	2501.706	3121.489	18284	395	18679
RE4	1026105	1399510	5710458	1896.85	5712355
STANDING4	41.55882	20.38828	73.5	8.5	82
FTE4	31.46495	26.22982	143.3872	3.712893	147.1001

Where,

NRE = Non Restricted Current-Fund Expenditures.
UGCH = Undergraduate Credit Hours.
GCH = Graduate Credit Hours.
RE = Sponsored Research Expenditures.
STANDING = Quality Ranking.
FTE = Full Time Faculty Equivalent.

1 = Life Science.
2. = Engineering.
3. = Physical Science.
4. = Social Science.

APPENDIX 2 (CONT.)

Mean Values of 1996 FTE Transformed Data

	Mean	Standard Deviation	Range	Minimum	Maximum
NRE1	83296.07	10562.18	52749.61	68657.84	121407.4
UGCH1	342.2686	225.9022	881.581	1.418964	883
GCH1	88.25505	65.60789	244.979	2.665044	247.6441
RE1	174143.4	214744.2	1103519	4908.611	1108427
STANDING1	61.66912	21.09248	74.75	26.25	101
NRE2	88458.95	9119.814	34863.03	75679.88	110542.9
UGCH2	257.2772	165.9886	879.6423	9.225399	888.8677
GCH2	72.32532	35.09204	148.2667	0.702235	148.9689
RE2	85995.85	68035.31	260383.8	338.7581	260722.6
STANDING2	34.55882	25.77239	81.5	3	84.5
NRE3	74729.12	12130.04	51260.73	58464.85	109725.6
UGCH3	420.7922	353.1177	2042.214	7.422773	2049.636
GCH3	54.13855	45.55737	213.0719	0.197045	213.2689
RE3	138709.8	390270	2292255	4469.623	2296724
STANDING3	42.76471	30.41823	96	7.5	103.5
NRE4	64945.65	6506.683	28130.05	53308.01	81438.06
UGCH4	446.2389	207.2569	927.1545	100.367	1027.521
GCH4	102.132	99.36456	443.1344	25.7723	468.9066
RE4	36614.13	44950.41	186167.3	163.9694	186331.3
STANDING4	41.55882	20.38828	73.5	8.5	82

Where,

NRE = Non Restricted Current-Fund Expenditures.
UGCH = Undergraduate Credit Hours.
GCH = Graduate Credit Hours.
RE = Sponsored Research Expenditures.
STANDING = Quality Ranking.
FTE = Full Time Faculty Equivalent.

1 = Life Science.
2. = Engineering.
3. = Physical Science.
4. = Social Science.

APPENDIX 3

Credit Hour Definition

A credit-hour is a unit of academic achievement used in the United States and Canada. When students satisfy the requirements of a course (a specified set of content), which is typically an exam, then they get accredited to their record of academic achievement a specified number of units referred to as "credit-hours" or simply "credits". When they accumulate a specified number of credit-hours, they then get a degree or other academic award.

Typically, the credit-hour of a course is equal to the hours that the course meets for a lecture every week. Thus a lecture course meeting three times a week is worth 3 credit-hours. Some courses, however, have instruction other than lectures, such as laboratories, seminars, etc. Typically, these courses meet more often than a lecture course to pursue an activity that is more time consuming. For example, a laboratory in chemistry may meet for four hours a week but have the intellectual content equivalent to a three hour lecture per week. It then has a three credit-hour accreditation even though it meets for four hours a week.

The credit-hour by itself is not an output or consumed resource unless it is achieved or consumed by a student. It then becomes a Student Credit-Hour. (Hussain, 1976)

APPENDIX 4

White's Test for Heteroscedasticity

This test is based on Halbert White's, "A Heteroscedasticity-Consistent Covariance Estimator and a Direct Test for Heteroscedasticity", 1980. It is applicable only to the residuals from a least squares regression. If the regression is, say

$$y_t = \beta_1 + \beta_2 x_t + \beta_3 z_1$$

the test is based on the augmented regression,

$$u_t^2 = \beta_1 + \beta_2 x_t + \beta_3 z_t + \beta_4 x_t^2 + \beta_5 z_t^2 + \beta_6 x_t z_t$$

With large numbers of right-hand variables, it is not practical to include all the terms that are products of the original variables, so cross-products are eliminated and only the variable and its square included.

The output from the test is an *F*-statistic which will have an asymptotic χ^2 distribution with degrees of freedom equal to the number of regressors in the test regression. The statistic provided a test of the hypothesis that the coefficients of the variables in the augmented regression are all zero. White offers this as a general test for model misspecification, since the null hypothesis underlying the test assumes that the errors are both homoscedastic and independent of the regressors and that the linear specification of the model is correct. Failure of any one or more of these conditions could lead to a significant test statistic. Conversely, a non-significant test statistic would be very reassuring since it implies that none of the three conditions is violated.

APPENDIX 4 (CONT.)

Results from the Transformed Regressions
($\chi^2_{15} = 30.5779$; p=0.01)

Field	**1994** (TR^2)	**1996** (TR^2)
Life Science	12.392	18.015
Engineering	27.799	13.757
Physical Science	15.835	20.027
Social Science	28.313	32.072

APPENDIX 5

1994 Uncorrected and Heteroscedasticity Corrected Results for the SUR Estimation

Variables	1994 Uncorrected Results	1994 Heteroscedasticity Corrected Results
$\beta_{94(1,1)}$	0.853395 (1.303)	0.07412 (0.519)
$\beta_{94(1,2)}$	0.151422* (1.942)	0.185755*** (6.792)
$\beta_{94(1,3)}$	0.128022*** (3.279)	0.119059*** (5.915)
$\beta_{94(1,4)}$	0.784039*** (28.513)	0.790358*** (100.927)
$\beta_{94(1,5)}$	0.006883 (0.648)	0.008551** (2.314)
$\beta_{94(2,1)}$	0.099762 (0.356)	-0.19495** (-2.128)
$\beta_{94(2,2)}$	1.338206*** (8.283)	1.271175*** (12.318)
$\beta_{94(2,3)}$	-0.31026* (-1.79)	-0.07529 (-0.600)
$\beta_{94(2,4)}$	0.455058*** (3.987)	0.42341*** (5.939)
$\beta_{94(2,5)}$	0.009858 (1.509)	0.007846* (1.726)
$\beta_{94(3,1)}$	0.309307*** (2.787)	0.174439*** (3.771)
$\beta_{94(3,2)}$	1.769762*** (18.718)	1.954455*** (22.528)
$\beta_{94(3,3)}$	-0.82451*** (-5.598)	-0.85622*** (-9.963)
$\beta_{94(3,4)}$	0.191979*** (2.638)	0.126452** (2.388)
$\beta_{94(3,5)}$	0.004359** (2.026)	0.003695** (2.254)
$\beta_{94(4,1)}$	0.389454*** (3.340)	0.146296 (1.594)
$\beta_{94(4,2)}$	0.938847*** (6.512)	1.117036*** (7.892)
$\beta_{94(4,3)}$	-0.52682*** (-3.536)	0.155347 (0.841)
$\beta_{94(4,4)}$	0.607033*** (5.886)	0.263902*** (2.616)
$\beta_{94(4,5)}$	0.002624 (1.060)	-0.00096 (-0.464)

* Significant at the 0.10 confidence level
** Significant at the 0.05 confidence level
*** Significant at the 0.01 confidence level

APPENDIX 6

1996 Uncorrected and Heteroscedasticity Corrected Results for the SUR Estimation

Variables	1996 Uncorrected Results	1996 Heteroscedasticity Corrected Results
$\beta_{96(1,1)}$	-0.2206** (-2.427)	0.012417 (0.333)
$\beta_{96(1,2)}$	1.058127*** (9.567)	0.410855*** (3.914)
$\beta_{96(1,3)}$	0.574135** (2.337)	0.014357 (0.103)
$\beta_{96(1,4)}$	0.203087* (1.739)	0.674893*** (14.467)
$\beta_{96(1,5)}$	0.002051 (1.559)	0.001246** (2.116)
$\beta_{96(2,1)}$	-0.01177 (-0.333)	-0.00679 (-0.552)
$\beta_{96(2,2)}$	0.603802*** (4.750)	0.326625*** (3.479)
$\beta_{96(2,3)}$	-0.5608* (-1.782)	0.281842 (1.212)
$\beta_{96(2,4)}$	0.948541*** (5.486)	0.677151*** (6.656)
$\beta_{96(2,5)}$	0.000899 (1.276)	0.00063** (2.396)
$\beta_{96(3,1)}$	0.010094 (0.451)	-0.01351 (-1.414)
$\beta_{96(3,2)}$	0.555276*** (8.124)	0.660964*** (5.371)
$\beta_{96(3,3)}$	1.076029*** (17.721)	1.205234*** (14.875)
$\beta_{96(3,4)}$	0.212496*** (5.750)	0.129424** (2.357)
$\beta_{96(3,5)}$	-0.0006 (-0.496)	-0.00058*** (-4.965)
$\beta_{96(4,1)}$	-0.00512 (-0.496)	-0.00594 (-0.622)
$\beta_{96(4,2)}$	0.905259*** (17.591)	0.927867*** (17.541)
$\beta_{96(4,3)}$	0.634073*** (8.787)	0.632964*** (8.396)
$\beta_{96(4,4)}$	0.111951*** (2.740)	0.101633** (2.342)
$\beta_{96(4,5)}$	1.24E-05 (0.051)	-3.17E-05 (-0.132)

* Significant at the 0.10 confidence level
** Significant at the 0.05 confidence level
*** Significant at the 0.01 confidence level

APPENDIX 7

1994 & 1996 Heteroscedasticity Corrected Results for the Pooled SUR Estimation

Variable 94 and 96 Pooled Results	Coefficient
$\beta_{94\&96(1,1)}$	0.080775 (0.7272)
$\beta_{94\&96(1,DV1)}$	-0.08904 (-0.21599)
$\beta_{94\&96(1,2)}$	0.184006*** (8.622)
$\beta_{94\&96(1,DV2)}$	0.080665 (0.0721)
$\beta_{94\&96(1,3)}$	0.117476*** (7.478)
$\beta_{94\&96(1,DV3)}$	-0.12751 (-0.0859)
$\beta_{94\&96(1,4)}$	0.791306*** (129.476)
$\beta_{94\&96(1,DV4)}$	-0.04355 (-0.0876)
$\beta_{94\&96(1,5)}$	0.008471*** (2.939)
$\beta_{94\&96(1,DV5)}$	-0.00645 (-0.934)
$\beta_{94\&96(2,1)}$	-0.20227** (-2.470)
$\beta_{94\&96(2,DV1)}$	0.195558** (2.338)
$\beta_{94\&96(2,2)}$	1.263625*** (13.667)
$\beta_{94\&96(2,DV2)}$	-0.90019*** (-5.68407)
$\beta_{94\&96(2,3)}$	-0.09649 (-0.859)
$\beta_{94\&96(2,DV3)}$	0.419405 (1.231)
$\beta_{94\&96(2,4)}$	0.436345*** (6.833)
$\beta_{94\&96(2,DV4)}$	0.20015 (1.292)
$\beta_{94\&96(2,5)}$	0.008224** (2.021)
$\beta_{94\&96(2,DV5)}$	-0.00757* (-1.854)
$\beta_{94\&96(3,1)}$	0.173497*** (3.069)

APPENDIX 7 (CONT.)

1994 & 1996 Heteroscedasticity Corrected Results for the Pooled SUR Estimation

Variable 94 and 96 Pooled Results	Coefficient
$\beta_{94\&96(3,DV1)}$	-0.18424*** (-3.226)
$\beta_{94\&96(3,2)}$	1.952472*** (18.399)
$\beta_{94\&96(3,DV2)}$	-1.28539*** (-8.630)
$\beta_{94\&96(3,3)}$	-0.86688*** (-8.24908)
$\beta_{94\&96(3,DV3)}$	2.045962*** (16.286)
$\beta_{94\&96(3,4)}$	0.131834** (2.036)
$\beta_{94\&96(3,DV4)}$	-0.00067 (-0.008)
$\beta_{94\&96(3,5)}$	0.00367* (1.832)
$\beta_{94\&96(3,DV5)}$	-0.00425** (-2.119)
$\beta_{94\&96(4,1)}$	0.145858** (2.059)
$\beta_{94\&96(4,DV1)}$	-0.16564 (-0.487)
$\beta_{94\&96(4,2)}$	1.117712*** (10.232)
$\beta_{94\&96(4,DV2)}$	-0.21334 (-0.114)
$\beta_{94\&96(4,3)}$	0.156524 (1.098)
$\beta_{94\&96(4,DV3)}$	0.487455 (0.184)
$\beta_{94\&96(4,4)}$	0.263048*** (3.378)
$\beta_{94\&96(4,DV4)}$	-0.15471 (0.101)
$\beta_{94\&96(4,5)}$	-0.00096 (-0.604)
$\beta_{94\&96(4,DV5)}$	0.001346 (0.158)

* Significant at the 0.10 confidence level
** Significant at the 0.05 confidence level
*** Significant at the 0.01 confidence level

APPENDIX 8

Heteroscedasticity Corrected Results for 1994, 1996, and the Δ 1994 and 1996

Coefficients	Unpooled 1994 Results	Unpooled 1996 Results	Δ 1994 and 1996 Unpooled Results	Δ 1994 and 1996 Pooled Results
$\beta_{(1,1)}$	7.41% (0.519)	1.24% (0.333)	-6.17%	-8.90% (-0.215)
$\beta_{(1,2)}$	18.58%** (6.792)	41.08%*** (3.914)	22.5%	8.07% (0.072)
$\beta_{(1,3)}$	11.91%*** (5.915)	1.43% (0.103)	-10.48%	-12.75% (-0.085)
$\beta_{(1,4)}$	79.04%*** (100.927)	67.49%*** (14.467)	-11.55%	-4.35% (-0.087)
$\beta_{(1,5)}$	0.86%** (2.314)	0.12%** (2.116)	-0.74%	-0.64% (-0.934)
$\beta_{(2,1)}$	-19.49%** (-2.128)	-0.68% (-0.552)	18.81%	19.56%** (2.338)
$\beta_{(2,2)}$	127.12%*** (12.318)	32.66%*** (3.479)	-94.46%	-90.02%*** (-5.684)
$\beta_{(2,3)}$	-7.53% (-0.600)	28.18% (1.212)	35.71%	41.94% (1.230)
$\beta_{(2,4)}$	42.34%*** (5.939)	67.71%*** (6.656)	25.37%	20.01% (1.292)
$\beta_{(2,5)}$	0.78%* (1.726)	0.06%** (2.396)	-0.72%	-0.76%* (-1.853)
$\beta_{(3,1)}$	17.44%*** (3.771)	-1.35% (-1.414)	-18.79%	-18.42%*** (-3.225)
$\beta_{(3,2)}$	195.45%*** (22.528)	66.09%*** (5.371)	-129.36%	-128.54%*** (-8.630)
$\beta_{(3,3)}$	-85.62%*** (-9.963)	120.52*** (14.875)	206.14%	204.59%*** (16.286)
$\beta_{(3,4)}$	12.64%** (2.388)	12.94%** (2.357)	0.30%	-0.07% (-0.008)
$\beta_{(3,5)}$	0.37%** (2.254)	-0.06%*** (-4.965)	-0.43%	-0.42%** (-2.119)
$\beta_{(4,1)}$	14.63% (1.594)	-0.59% (-0.622)	-15.22%	-16.56% (-0.487)
$\beta_{(4,2)}$	111.70%*** (7.892)	92.78%*** (17.541)	-18.92%	-21.33% (-0.114)
$\beta_{(4,3)}$	15.53% (0.841)	63.29%*** (8.396)	47.76%	48.74% (0.183)
$\beta_{(4,4)}$	26.39%*** (2.616)	10.16%** (2.342)	-16.23%	-15.47% (-0.101)
$\beta_{(4,5)}$	-0.09% (-0.464)	0.00% (-0.132)	0.09%	0.13% (0.158)

* Significant at the 0.10 confidence level
** Significant at the 0.05 confidence level
*** Significant at the 0.01 confidence level

APPENDIX 9

SUR Estimation on 1994 Semi-Log Transformed Variables

	Coefficient	Std. Error	t-Statistic	Prob.
$\beta_{94(1,1)}$	9.233714	0.440305	20.97119	0
$\beta_{94(1,2)}$	0.144743	0.037634	3.846108	0.0002
$\beta_{94(1,3)}$	0.090038	0.027403	3.285733	0.0012
$\beta_{94(1,4)}$	0.05264	0.03626	1.451722	0.1484
$\beta_{94(1,5)}$	-0.00279	0.00205	-1.35859	0.176
$\beta_{94(1,6)}$	0.047686	0.004745	10.04901	0
$\beta_{94(2,1)}$	8.577848	0.274952	31.19757	0
$\beta_{94(2,2)}$	0.332181	0.047513	6.991373	0
$\beta_{94(2,3)}$	-0.01335	0.01957	-0.6821	0.4961
$\beta_{94(2,4)}$	0.104788	0.016251	6.44816	0
$\beta_{94(2,5)}$	-0.00208	0.001791	-1.16094	0.2472
$\beta_{94(2,6)}$	0.018591	0.003087	6.022615	0
$\beta_{94(3,1)}$	7.5027	1.214344	6.178396	0
$\beta_{94(3,2)}$	0.510097	0.156934	3.250383	0.0014
$\beta_{94(3,3)}$	-0.02514	0.13501	-0.18618	0.8525
$\beta_{94(3,4)}$	0.058618	0.06208	0.944239	0.3463
$\beta_{94(3,5)}$	0.002111	0.003469	0.60852	0.5436
$\beta_{94(3,6)}$	0.014392	0.004699	3.062465	0.0025
$\beta_{94(4,1)}$	10.07547	0.711121	14.16842	0
$\beta_{94(4,2)}$	0.142725	0.066364	2.15064	0.0329
$\beta_{94(4,3)}$	0.10708	0.094453	1.133678	0.2585
$\beta_{94(4,4)}$	-0.00549	0.03202	-0.17128	0.8642
$\beta_{94(4,5)}$	-0.00246	0.001853	-1.32504	0.1869
$\beta_{94(4,6)}$	0.021516	0.003797	5.666382	0

$$\ln(NRE)_{94(1)} = \beta_{94(1,1)} + \beta_{94(1,2)}[UGCH] + \beta_{94(1,3)}[GCH] + \beta_{94(1,4)}[RE] + \beta_{94(1,5)}[STANDING] + \beta_{94(1,6)}[FTE]$$

Observations: 50

R-squared	0.868711	Mean dependent var	11.49272
Adjusted R-squared	0.853792	S.D. dependent var	0.914378
S.E. of regression	0.349633	Sum squared resid	5.378687

APPENDIX 9 (CONT.)

$\ln(NRE)_{94(2)} = \beta_{94(2,1)} + \beta_{94(2,2)}[UGCH] + \beta_{94(2,3)}[GCH] + \beta_{94(2,4)}[RE] + \beta_{94(2,5)}[STANDING] + \beta_{94(2,6)}[FTE]$			
Observations: 50			
R-squared	0.914896	Mean dependent var	12.05103
Adjusted R-squared	0.905226	S.D. dependent var	0.954612
S.E. of regression	0.293881	Sum squared resid	3.800119

$\ln(NRE)_{94(3)} = \beta_{94(3,1)} + \beta_{94(3,2)}[UGCH] + \beta_{94(3,3)}[GCH] + \beta_{94(3,4)}[RE] + \beta_{94(3,5)}[STANDING] + \beta_{94(3,6)}[FTE]$			
Observations: 50			
R-squared	0.677357	Mean dependent var	12.53455
Adjusted R-squared	0.640693	S.D. dependent var	1.068042
S.E. of regression	0.640208	Sum squared resid	18.03411

$\ln(NRE)_{94(4)} = \beta_{94(4,1)} + \beta_{94(4,2)}[UGCH] + \beta_{94(4,3)}[GCH] + \beta_{94(4,4)}[RE] + \beta_{94(4,5)}[STANDING] + \beta_{94(4,6)}[FTE]$			
Observations: 50			
R-squared	0.83081	Mean dependent var	12.19853
Adjusted R-squared	0.811584	S.D. dependent var	0.691377
S.E. of regression	0.300106	Sum squared resid	3.962788

APPENDIX 9 (CONT.)

SUR Estimation on 1996 Semi-Log Transformed Variables

	Coefficient	Std. Error	t-Statistic	Prob.
$\beta_{96(1,1)}$	10.52617	0.943901	11.15178	0
$\beta_{96(1,2)}$	0.237316	0.04752	4.994037	0
$\beta_{96(1,3)}$	0.15005	0.101944	1.471887	0.1439
$\beta_{96(1,4)}$	-0.02741	0.079651	-0.34407	0.7314
$\beta_{96(1,5)}$	-0.0007	0.003672	-0.19094	0.8489
$\beta_{96(1,6)}$	0.043664	0.004675	9.340014	0
$\beta_{96(2,1)}$	10.43721	0.451898	23.09642	0
$\beta_{96(2,2)}$	0.282458	0.037811	7.470328	0
$\beta_{96(2,3)}$	0.170651	0.051553	3.31021	0.0013
$\beta_{96(2,4)}$	0.007834	0.034547	0.226757	0.821
$\beta_{96(2,5)}$	-0.00318	0.001757	-1.80715	0.0734
$\beta_{96(2,6)}$	0.012585	0.003136	4.012455	0.0001
$\beta_{96(3,1)}$	9.345249	1.436185	6.506997	0
$\beta_{96(3,2)}$	0.150164	0.087888	1.708581	0.0903
$\beta_{96(3,3)}$	0.08701	0.079334	1.096755	0.2751
$\beta_{96(3,4)}$	0.176936	0.083077	2.129776	0.0354
$\beta_{96(3,5)}$	0.000796	0.003623	0.219818	0.8264
$\beta_{96(3,6)}$	0.016352	0.004321	3.784567	0.0002
$\beta_{96(4,1)}$	8.283787	0.863704	9.591008	0
$\beta_{96(4,2)}$	0.445493	0.062421	7.136901	0
$\beta_{96(4,3)}$	0.252889	0.066598	3.797227	0.0002
$\beta_{96(4,4)}$	-0.01077	0.02447	-0.44019	0.6606
$\beta_{(4,5)}$	-0.00383	0.002295	-1.67023	0.0977
$\beta_{96(4,6)}$	0.009469	0.002758	3.432993	0.0008

$$\ln(NRE)_{96(1)} = \beta_{96(1,1)} + \beta_{96(1,2)}[UGCH] + \beta_{96(1,3)}[GCH] + \beta_{96(1,4)}[RE] + \beta_{96(1,5)}[STANDING] + \beta_{96(1,6)}[FTE]$$

Observations: 50			
R-squared	0.870722	Mean dependent var	13.70436
Adjusted R-squared	0.847637	S.D. dependent var	1.110818
S.E. of regression	0.433593	Sum squared resid	5.264093

APPENDIX 9 (CONT.)

$\ln(NRE)_{96(2)} = \beta_{96(2,1)} + \beta_{96(2,2)}[UGCH] + \beta_{96(2,3)}[GCH] + \beta_{96(2,4)}[RE] + \beta_{96(2,5)}[STANDING] + \beta_{96(2,6)}[FTE]$			
Observations: 50			
R-squared	0.922103	Mean dependent var	14.2175
Adjusted R-squared	0.908193	S.D. dependent var	0.873762
S.E. of regression	0.264748	Sum squared resid	1.962555

$\ln(NRE)_{96(3)} = \beta_{96(3,1)} + \beta_{96(3,2)}[UGCH] + \beta_{96(3,3)}[GCH] + \beta_{96(3,4)}[RE] + \beta_{96(3,5)}[STANDING] + \beta_{96(3,6)}[FTE]$			
Observations: 50			
R-squared	0.762069	Mean dependent var	14.55382
Adjusted R-squared	0.719581	S.D. dependent var	1.147147
S.E. of regression	0.607467	Sum squared resid	10.33245

$\ln(NRE)_{96(4)} = \beta_{96(4,1)} + \beta_{96(4,2)}[UGCH] + \beta_{96(4,3)}[GCH] + \beta_{96(4,4)}[RE] + \beta_{96(5,5)}[STANDING] + \beta_{96(6,6)}[FTE]$			
Observations: 50			
R-squared	0.895208	Mean dependent var	14.25544
Adjusted R-squared	0.876495	S.D. dependent var	0.771437
S.E. of regression	0.271108	Sum squared resid	2.057993

APPENDIX 10

Wald Test on the Equality of Coefficients across Fields for 1994.

Wald Test (χ^2_8)	**Life Science**	**Engineering**	**Physical Science**	**Social Science**
Life Science				
Engineering	2.30576			
Physical Science	2.019493	0.072404		
Social Science	8.078148***	3.640633*	4.997324**	

* Significant at the 0.10 confidence level
** Significant at the 0.05 confidence level
*** Significant at the 0.01 confidence level

Wald Test on the Equality of Coefficients across Fields for 1996.

Wald Test (χ^2_8)	**Life Science**	**Engineering**	**Physical Science**	**Social Science**
Life Science				
Engineering	1.387809			
Physical Science	128.9771***	27.5922***		
Social Science	57.49092***	8.239244***	26.09426***	

* Significant at the 0.10 confidence level
** Significant at the 0.05 confidence level
*** Significant at the 0.01 confidence level

REFERENCES

Allen, H. (1996) Faculty Workload and Productivity in the 1990's: Preliminary Findings in *Almanac of Higher Education*, National Education Association, Washington DC.

Alpert, D. (1985) Performance and Paralysis: The Organizational Context of the American Research University Journal of Higher Education Vol.(56), pp. 241-281.

American Association of Universities Data Exchange (AAUDE) (1994-1996) *Cost and Enrollment Data Files* Minneapolis, MN.

Ashar, H., and Shapiro, J. (1988) Measuring Centrality: A Note on Hackman's Resource-Allocation Theory *Administrative Science Quarterly*, Vol.(33), pp. 275-283.

Astin, A. (1968) Undergraduate Achievement and Institutional Excellence *Science* Vol.(161), No.(3842), pp. 661-668.

Baldridge, J. (1971) *Power and Conflict in the University* New York: Wiley.

Becker, W. (1975) The University Professor as a Utility Maximizer and Producer of Learning, Research, and Income *The Journal of Human Resources* pp. 107-115.

Becker, W. (1983) Economics Education Research: Part II, New Directions in Theoretical Model Building *Journal of Economic Education* Vol.(14), No.(2), pp. 4-11.

Berg, D., and Hoenack, S. (1987) The Concept of Cost Related-Tuition and its Implementation at the University of Minnesota *Journal of Higher Education* Vol.(58), No(3), pp.276-305.

Blau, P. (1963) *The Dynamics of Bureaucracy: A Study of Interpersonal Relations in Two Government Agencies* 2nd. Ed., Chicago, University of Chicago Press.

Bolman, L., and Deal, T. (1986) *Modern Approaches to Understanding and Managing Organizations* San Francisco: Josey Bass.

Boyer, E. (1987) College: The Undergraduate Experience in America *A Nation at Risk* Princeton, Carnegie Foundation for the Advancement of Teaching.

Bowen, H. (1980) *The Costs of Higher Education: How Much Do Colleges and Universities Spend Per Student and How Much Should They Spend* Jossey-Bass.

Breneman, D. (1970) *An Economic Theory of Ph.D. Production: The Case at Berkeley* Berkeley: Ford Foundation Program for Research in University Administration, University of California.

Breneman, D. (1976) The Ph.D. Production Process *Education as and Industry* (Edited by J. Froomkin, D. Jamison, and R. Radner), Cambridge: Ballinger.

Brinkman, P. (1981) Factors Affecting Instructional Costs at Major Research Universities *Journal of Higher Education* Vol.(52), No.(3), pp. 265-278.

Brinkman, P. (1990) College and University Adjustments to a Changing Financial Environment in *The Economics of American Universities: Management, Operations, and Fiscal Environment*, SUNY press, NY.

Brinkman, P., and Leslie, L. (1986) Economies of Scale in Higher Education: Sixty Years of Research Review of Higher Education Vol.(10), No.(1), pp. 1-28.

Brown, Jr., G. (1992) Report of the Task Force on the Health of Research: Chairman's Report *Report to the Committee on Science, Space, and Technology* U.S. House of Representatives, Washington DC, Government Printing Office.

Carnegie Commission on Higher Education (1971) *New Students and New Places* NY:McGraw-Hill.

Clotfelter, C. (1996) *Buying the Best: Cost Escalation in Elite Higher Education* Princeton University Press.

Cohen, A. M., and March, J. G. (1974) *Leadership and Ambiguity: The American College President* New York: McGraw Hill.

Cohn, E., Rhine, S., and Santos, M. (1989) Institutions of Higher Education as Mult-Product Firms: Economies of Scale and Scope *The Review of Economics and Statistics* Vol.(71), pp. 284-290.

Dawes, R. (1971) A Case Study of Graduate Admissions: Applications of Three Principles on Human Decision Making. *American Psychologist,* Vol.(26), pp. 180 - 188.

David, P. (1997) A Survey of Universities: The Knowledge Factory *The Economist* Oct. 4th, pp. 160-161.

Dornbusch, S. (1979) Perspectives from Sociology: Organizational Evaluation of Faculty Performances *Academic Rewards in Higher Education* (Edited by Lewis, D. and Becker, W.), Cambridge: Ballinger.

Dundar, H. and Lewis, D. (1995) Departmental Productivity in American Universities: Economies of Scale and Scope, *Economics of Education* Review Vol.(14), No.(2), pp. 119-144.

Etzioni, A. (1964) *Modern Organizations* Englewood Cliffs, NJ, Prentice Hall

Fairweather, J. (1996) *Faculty Work and Public Trust: Restoring the Value of Teaching and Public Service in American Academic Life* Allyn and Bacon.

Fisher, F. (1970) Tests on Equality between Sets of Coefficients in Two Linear Regressions: An Expository Note *Econometrica* March, pp. 361-366.

Garvin, D. (1980) *The Economics of University Behavior* New York, NY: Academic Press

Galbraith, J. (1967) *The New Industrial State* Boston: Houghton Mifflin.

Gander, J. (1995) Academic Research and Teaching Productivities: A Case Study *Technological Forecasting and Social Change* Vol.(49), pp. 311-319.

Froomkin, J. (1978) *The Financial Prospects of the Postsecondary Sector, 1975-1990* Washington, DC: Joseph Froomkin Inc.

Froomkin, J. (1990) The Impact of Changing Levels of Financial Resources on the Structure of Colleges and Universities *The Economic of American Universities: Management, Operations, and Fiscal Environment* (Edited by Hoenack, S., and Collins, E.) State University of New York Press.

Goldberger, M., Maher, B., and Flattau, P. (1995) *Research-Doctorate Programs in the United States: Continuity and Change* National Academy Press.

Hackman, J. (1985) Power and Centrality in the Allocation of Resources in Colleges and Universities *Administrative Science Quarterly* Vol.(30), pp. 61-77.

Hansen, W. and Stampen, J. (1994) Economics and Financing of Higher Education: The Tension Between Quality an Equity, in Altback, P., Berdahl, R. and Gumport, P *Higher Education in American Society*, Prometheus Books, NY.

Hanushek, E. (1979) Conceptual and Empirical Issues in the Estimation of Education Production Functions *Journal of Human Resources* Vol.(13), No.(3), pp. 351-388.

Hasbrouk (1997) Implications of the Changing Funding Base of Public Universities Unpublished Dissertation, Center for the Study of Higher Education, University of Arizona.

Herber, B. (1996) *Public Sector Economics* Unpublished Class Notes, University of Arizona.

Hickson (1971) *Writers on Organizations* Harmonsworth, Penguin.

Hoenack, S., Weiler, W., Goodman, R., and Pierro, D. (1986) Marginal Costs of Instruction *Research in Higher Education* Vol.(24), No.(4), pp. 335-417.

Hopkins, D. (1990) The Higher Education Production Function: Theoretical Foundations and Empirical Findings *The Economics of American Universities* (Edited by Hoenack, S., and Collins, E.) Albany, NY: State University of New York Press.

Hopkins, D., and Massy, W. (1981) *Planning Models for Colleges and Universities* Stanford: Stanford University Press.

Hussain, K. M. (1976) *Institutional Resource Allocation Models in Higher Education* Center for Educational Research and Innovation; OECD.

James, E. (1978) Product Mix and Cost Disaggregation: A Reinterpretation of the Economics of Higher Education Economics *Journal of Human Resources* Vol.(13), No.(2), pp. 157-185.

James, E. (1983) How Nonprofits Grow: A Model *Journal of Policy Analysis and Management* Vol.2., Spring, pp. 350-365

James, E. (1986) The Private Nonprofit of Education: A Theoretical Model and Application to Japan *Journal of Comparative Economics* Vol.(10), pp. 255-276.

James, E. (1990) Decision Processes and Priorities in Higher Education *The Economics of American Universities: Management, Operations, and Fiscal Environment* State University of New York Press

James, E. and Neuberger, E. (1981) The University Department as a Nonprofit Labor Cooperative Public Choice Vol.(36), pp. 585-612.

Jencks, C. and Reisman, D. (1968) *The Academic Revolution* NY: Doubleday.

Johnes, G. (1996) Evaluating Universities' Preferences for Teaching and Research *Journal of Education Finance* Vol.(22), pp. 214-219.

Joint Legislative Budget Committee (1997) Unpublished *Teaching Incentive Grant Proposal*, Arizona State Legislature.

Jones, L., Lindzey, G., and Coggeshall, P. (1982) *An Assessment of Research Doctorate Programs in the United States* Washington DC, National Academy Press

Kerr, D. (1994) *Troubled Times for American Higher Education: The 1990's and Beyond*, State University of New York Press, New York.

Lau, L. (1979) Educational Production Functions *Economic Dimensions of Education* (Edited by Widham. D.), National Academy of Education.

Leslie, L. (1995) What Drives Higher Education Financial Management in the 1990's and Beyond? The New Era in Financial Support *Journal for Higher Education Management*.

Leslie, L. and Rhoades, G. (1995) Rising Administrative Costs: On Seeking Explanations, *Journal of Higher Education*, Vol.(66), No.(2), pp. 187 - 212.

Leslie, L., Oaxaca, R. and Rhoades, G. (Work in Progress) *NSF Sponsored Study on the Quality of Undergraduate Education*

Levin, H. 91976) Concepts of Economic Efficiency and Educational Production *Education as and Industry* (Edited by Froomkin, J., and Radner, R.), Cambridge: Ballinger.

Lewis, D., and Becker, W. (1979) *Academic Rewards in Higher Education* Cambridge: Ballinger.

Lewis, D., Dalgaard, B., and Boyer, C. (1985) Cost-Effectiveness of Computer Aided Economics Instruction American Economic Review Vol.(75), No.(2), pp. 91-96.

Manahan, J. (1983) An Educational Production Function for Principles of Economics Journal of Economic Education Vol.(14), No.(2), pp.11-16.

Massy, W. (1996) *Resource Allocation in Higher Education* The University of Michigan Press, Ann Arbor

Massy, William F., & Wilger, Andrea K. (1992). Productivity in postsecondary education: A new approach. *Educational Evaluation and Policy Analysis* Vol.(14), No.(4), pp. 361-376.

Mayhew, L. (1970) *Graduate and Professional Education, 1980: A Survey of Institutional Plans* NY: McGraw-Hill.

Mayhew, L., Ford, P., and Hubbard, D. (1990) *The Quest for Quality* Jossey-Bass Publishers, San Francisco.

McPherson, M. and Shapiro, M. (1993) The Effect of Government Financing on the Behavior of Colleges and Universities In *Paying the Piper* The University of Michigan Press, Ann-Arbor.

Morgan, A. W. (1984) The New Strategies: Root, Context and Overviews *Responding to New Realities and Funding* (September), pp. 5-19

Murphy, J.L. (1973) *Introductory Econometrics* Richard D Irwan Inc. Georgetown, Ontario.

National Center for Education Statistics (1993) *Digest of Education Statistics*, Washington: U.S. Department of Education

National Center for Education Statistics (1996) *Digest of Education Statistics*, Washington: U.S. Department of Education

National Science Board (1993) *Science and Engineering Indicators*, U.S. Government Printing Office, Washington DC.

Nelson, R., and Heverth, K. (1992) Effect of Class Size on Economies of Scale and Marginal Costs in Higher Education *Applied Economics* Vol.(24), pp. 473-482.

Nerlove, M. (1972) On Tuition and the Costs of Higher Education: Prolegomena to a Conceptual Framework *Journal of Political Economy* Vol.(80), No.(3), pp. S178-S218

Oliver, R., and Hopkins, D. (1976) Instructional Costs of University Outputs *Education as an Industry* (Edited by Froomkin, J., and Jamison, D., and Radner, R.), Cambridge: Ballinger.

Pfeffer, J, and Moore, W. (1980) Proven University Budgeting: A Replication and Extension Administrative Science Quarterly Vol.(25), pp. 637-653.

Pfeffer, J. and Salancik, G. (1974) Organizational Decision-Making as a Political Process: The Case of a University Budget *Administrative Science Quarterly* Vol.(19), (December), pp. 135-150.

Pfeffer, J. and Salancik, G. (1978) *The External Control of Organizations: A Resource Dependence Perspective*, New York: Harper & Row.

Polachek, S., Thomas, J, and Henrick, J. (1978) Educational Production Functions Journal of Educational Statistics Vol.(3), No.(3), pp.209-301.

Radner, R., and Leonard, S. (1975) *Demand and Supply in U.S. Higher Education* NY: McGraw Hill.

Ramanathan, R. (1995) *Introductory Econometrics with Applications* Harcourt Brace College Publishers San Diego

Sengell, Jr., L., Lillydahl, J., and Sengell, Sr., L. (1996) Will Changing Times Change the Allocation of Faculty in *The Journal of Human Resources* Vol. 31, No. 2, Spring 1996, pg. 429-449.

Sengupta, J. (1975) Cost and Production Functions in the University Education System: An Econometric Analysis *Analytical Models in Educational Planning and Analysis* (Edited by Correa, H.), NY: David MacKay.

Slaughter, S. (1998) Federal and Suppy Side Institutional Resource Allocation at Public Research Universities *The Review of Higher Education* Spring 1998 Vol. 21, No.3, pg. 209-244.

Slaughter, S., and Leslie, L. (1997) *Academic Capitalism: Politics, Policies, and the Entrepreneurial University* The Johns Hopkins University Press, Baltimore.

Sigma Xi (1989) *An Exploration of the Nature and Quality of Undergraduate Education, in Science Mathematics and Engineering* New Haven

Southwick, L. (1969) Cost Trends in Land Grant Colleges and Universities Applied Economics Vol.(1), (August), pp. 167-182.

Thompson, J. (1967) *Organizations in Action: Social Science Bases of Administrative Theory* NY: McGraw Hill.

Thurrow, L. (1990) Planning for the New World Economy *Planning in Higher Education* Vol.(4), pp. 17-32.

Tierney, M. (1980) An Estimate of Departmental Cost Functions *Higher Education* Vol.(9), pp. 453-468.

Tuckman, H. (1979) The Academic Reward Structure in American Higher Education Academic Reward in Higher Education Vol.(4), pp. 90-99.

Tuckman, H. and Chang, C. (1990) Participant Goals, Institutional Goals, and University Resource Allocation Decisions in *The Economics of American Universities: Management, Operations, and Fiscal Environment*, State University of New York Press, New York

Verry, D., and Davies, B. (1976) *University Costs and Output* Amsterdam: Elsevier

Vladeck, B. (1976) Why Nonprofits Go Broke The Public Interest Vol.(42), pp. 86-101.

Volk, C. (1995) *Assessing Competing Models of Resource Allocation at a Public Research 1 University Through Multivariate Analysis of State Financing* Unpublished Doctoral Dissertation, Center for the Study of Higher Education, University of Arizona.

Wallhaus, R. (1975) The Many Dimensions of Productivity Measuring and Increasing *Academic Productivity* San Francisco: Jossey Bass.

Ward, G. (1997) *The Effects of Separately Budgeted Research Expenditures on Faculty Instructional Productivity in Undergraduate Education* Unpublished Dissertation, Center for the Study of Higher Education, University of Arizona.

White, H. (1980) A Heteroscedasticity-Consistent Covariance Estimator and a Direct Test for Heteroscedasticity Econometrica, Vol.48, pp. 817-838.

Wildavsky, A. (1968) *The New Politics of the Budgetary Process* Glenview, Illinois: Scott, Foresman and Co.

Zemsky, R., Massy, W. and Oedel, P. (1995) On Reversing the Ratchet in *Change* Vol.(25) pg. 56-62.

IMAGE EVALUATION TEST TARGET (QA-3)

150mm

6"

APPLIED IMAGE, Inc
1653 East Main Street
Rochester, NY 14609 USA
Phone: 716/482-0300
Fax: 716/288-5989