RESEARCH HIERARCHY:

THE RELATIONSHIP AMONG UNIVERSITY CHARACTERISTICS AND

FEDERAL RESEARCH FUNDING

by

CHARLES FREDERICK MATHIES II

(Under the Direction of Sheila Slaughter)

ABSTRACT

This study examined the relationship among university characteristics and the amount of federal research funding expended. 375 universities were examined over a 35-year period ranging from 1972-2007. Using a principal component analysis, 21 variables relating to university characteristics and research, identified from the literature, were tested for inclusion in a principal component regression. Results found 11 variables were retained in the principal component analysis. The subsequent principal component regression found that the greater the number of faculty members (all ranks), average faculty salary (all ranks), number of graduate students, expenditures for research equipment, score on ARL index, and the presence of a medical school or a hospital increased the amount of federal research funding expended. All retained variables grew in their relative importance between 1992 and 2007 in the principal component regression. Two grouping methods were used to identify discrete groupings (clusters) of universities based on their relative amounts of federal R&D expenditures. Both methods found a consistent and stable hierarchy of universities that existed between 1972 and 2007 based on their amounts of federal research expenditures.

INDEX WORDS: Higher Education Research Funding, Federal Research Funding, Higher Education-Federal Government Relationship, Higher Education-Economic Development Connection

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CHARLES FREDERICK MATHIES II

B.B.A, The University of Toledo, 1995

M.Ed, The University of South Carolina, 1998

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CHARLES FREDERICK MATHIES II

Major Professor: Shelia Slaughter

Committee: Larry Leslie
Jim Hearn
Karen Webber

Electronic Version Approved:

Maureen Grasso
Dean of the Graduate School
The University of Georgia
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CHAPTER 1

INTRODUCTION

Recent, relative declines in state appropriations have encourage universities to increase their pursuit of external research funding. External funding, mainly coming from public (Federal and State governments) encourages universities to focus on research or knowledge creation.[1] With each passing year, universities, become more dependent on external revenue sources (Slaughter and Leslie, 1997).

Although historically universities have tried to achieve balance among the triumvirate activities of research, teaching, and service, the trend in recent years has been for universities to increasingly focus on research (Geiger, 2004). Accompanying this shift in priorities, universities sought to boost the amount of federal funding received for research activities. The primary purpose of this study was to examine the relationships among the amounts of federal research funding received and universities' characteristics. University characteristics consist of attributes that are unique to a particular university such as the number of faculty, average faculty salary, number of graduate students, and academic majors offered. A secondary purpose was to assess whether groups or clusters of universities can be identified, and institutional hierarchies established based upon their characteristics and the federal funding received.

What are some of the implications of the increased emphasis on research, or put another way, why is this study of important? Etzkowitz and Webster, (1996) argue that there exists a new

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[1] Universities create new revenue streams from knowledge created through external research contracts, grants, earmarks, patents, and licenses royalties.

“social contract” between academia and the public, a contract that requires large-scale government support of academic research. Etzkowitz (1998) refers to the environment of American higher education as one of an academic revolution where a majority of universities have evolved into entrepreneurial institutions incorporating economic development as part of their mission. That is, universities have created economic development through the translation of research findings into intellectual property (Etzkowitz and Webster, 1996).

Federal research funding has increasingly been viewed by universities, the communities they serve, and political leaders as a key element in technology-based economic development (Teich, 2000). In fact, several studies show that geographic concentrations of centers of knowledge creation in universities (and industry) facilitate the process of innovation and technology transfer (Feldman, 1994; Mita and Formica, 1997). Further research shows that the most successful innovation systems are sets of interrelated organizations that join together to bring new and better products to the market (HM Treasury, 2004).

Competition for research funding, especially in the form of federal dollars, is a central part of academic life (Feller, 1996; Teich, 2000), a competition that is not only fierce but also been shown to be steeply hierarchical in the past (Geiger, 1996). The fundamental competition involving universities is in the currency of ideas, the intellectual gain from teaching and research (Feller, 1996). Over the last century, the number of universities incorporating research into their missions has consistently grown (Cozzens, 1996; Geiger, 1996). The increased focus on research has resulted in many universities examining their research competiveness, the ability to compete for research inputs, outputs, and recognition (Feller, 2000). Research competiveness, however, is not a static quality. It depends on the interaction between universities and an evolving research environment (Geiger, 1996).

Teich (2000) stresses universities attracting the greatest amount of federal research funding are at the upper levels of an academic "pecking order." In fact, the bulk of academic research performed in the United States is undertaken by a small number of universities. Nevertheless, institutions across the country compete for federal research funding and seek to increase their ability to acquire more in the future. The prevailing perspective of many universities is that if they are not advancing, they are falling behind (Gumport, 1993). While some universities try to move up to become an elite research entities, those at the top of hierarchy strategize to protect their positions, thus intensifying this inter-university competition for federal research funding (Dill, 1996; Feller, 1996).

The purpose of this study was to examine the relationships among the amounts of federal research funding received and universities' characteristics. Also of interest was the amount of influence specific university characteristics have in obtaining federal research funding. Finally, how stable were these competitive relationships and what factors explain any movement within them, bearing in mind universities have considerable latitude in selecting and promoting the disciplines in which to conduct research and are free to focus internal resources however they want within some limits and constraints (Feller, 1996). In summary, this study identified characteristics that influence universities' ability to attract federal research funding and their similarities and differences.

Conceptual Framework

The resource-based theory of the firm (Barney 1991; Conner 1991; Penrose 1995; Conner and Prahalad, 1996) offered a conceptual framework, from the field of strategic management, which was adapted and used to understand how universities compete for federal research funding. This theory suggests that a firm's particular characteristics largely explain what is produced and how.

The theory posits that an organization's unique assets and capabilities, those that are difficult for others to imitate or copy, can position an organization to outperform its competition in the marketplace (Powers 2004). More specifically, a firm's competitive advantage is a reflection of how its "inputs, processes, and outputs" compare with those of its competitors. Firms can sustain their competitive advantages by implementing strategies that exploit their internal strengths through responding to environmental opportunities (Barney 1991; Penrose 1995).

Although the resource-based theory of the firm was originally developed to explain performance in the for-profit sector, it has been applied previously to research on universities (for example, Powers 2003, 2004). If the university is viewed conceptually as a firm and research is viewed as an "output" or "product" of interest, the analogy exists that there are a set of research university characteristics that "explain" or "predict" a university's relative success in attaining "inputs." Because the focus of this study, federal research funding, this theory was deemed "most appropriate," even though other theories related to university revenues clearly offered additional insights.[2] The conventional measure of research funding is the amount of federal research monies "expended". This was the measure utilized in this study.

[2] Probably the most insightful theory for understanding the ultimate purpose of revenues, from the research perspective, was offered by Howard Bowen (1980) in his "revenue theory of costs," which viewed resources as serving the ultimate goal of prestige maximization, i.e. universities maximize revenues to maximize prestige.

Research Questions

In the case of universities, and reflecting on the purpose of this study, the resource-based theory of the firm leads to several research questions:

1. What are the university characteristics that explain the amount of federal research funding received (measured by convention as research expenditures)**,** and how shall these characteristics be identified?[3]
2. What is the relative importance of these characteristics in explaining variations in federal research expenditures among a set of universities?
3. Based on relative amounts of federal research expenditures, can one identify discrete university groupings or "clusters" reflecting the "hierarchy" posited by Geiger and Feller (1995) Geiger (1996) and Teich (2000)?
    a. Does this hierarchy change or is it stable over time?
    b. For universities that move "up" or "down" in the hierarchy, are there specific factors that account for these movements?

Sample and Data

The sample for this study consists of the 375 universities reporting research expenditures for all years 1972 through 2007 on the Research and Development Expenditures portion of the College and University survey facilitated by the National Science Foundation (NSF). These universities also provided complete institutional characteristic data to the Integrated Postsecondary Education Data System (IPEDS) survey of the National Center for Educational

[3] The conventional approach to account for yearly federal research funding received is to use annual research expenditures because often research contracts, grants, and earmarks are expensed over multiple years. Accounting for yearly university research funding based on when awards were received and not expensed does not accurately represent the research conducted by a university on a yearly basis. Research expenditures capture the specific dollar amount spent on research projects within a fiscal year and thus provide a better measure of yearly research activity.

Statistics (NCES). IPEDS thus provides the potential "explanatory" variables. All fifty states are represented in the sample of both public and private universities. The universities differ in many ways, including student population size and Carnegie Classification. Of the 375 universities, 65% were public (35% private), 11% were religiously affiliated, and 17% were land grant institutions.

Methods

To answer research question one, a review of the literature of previous studies on university research funding was undertaken to identify university characteristics to be evaluated in a series of principal components analyses (PCA). Four PCAs were developed in 5-year intervals over a 15 year period 1992-2007. PCA is a method of data reduction that transforms a number of variables that may or may not be correlated into a smaller number of uncorrelated sets of variables called principal components. Unlike factor analysis, which analyzes the common variance, the original matrix in a PCA specifies the total variance explained by the components (variables) and assumes that each original measure is without measurement error. The principal components analyses determined which university characteristics to test further. This review was informed significantly by earlier parallel efforts (Ashton, 1984; Ashton and Leslie, 1986; Leslie and Brown, 1988; Groth, 1990; and Groth, Brown, and Leslie, 1992) that developed a Research Activity Index (RAI). Specific attention was given to studies that utilized the RAI and to those focused on competiveness in academic research.

To address research question two, a series of principal components regression models (PC regression) were developed for each of the four PCAs. The independent variables used in the PC regression models were derived from the PCAs completed for research question one. The PC regression models are similar in structure and form to an OLS regression model and can be interpreted in similar a manner (Montgomery, Peck, and Vining, 2001). The PC regression models were developed to establish whether the set of independent variables indentified under research question one explained a statistically significant proportion of the variance in federal research expenditures among universities and the relative predictive importance of the independent variables.

To answer research question three, the federal research expenditure values were examined for the sample universities for each year of the data to determine whether a "federal research funding hierarchy" exists among the universities. Two methods were used to group universities at 5-year intervals from 1972 to 2007. For the first method, a cluster analysis was used to "group objects of similar kind" into respective categories. Specifically, the cluster analysis identified sets of universities by both minimizing within-group variation and maximizing between-group variation. Due to large sample size ($n>250$), a two-step cluster analysis was utilized. A two-step cluster analysis was used due to the fact that the large data sets minimized scaling issues that may have arisen from other methods of cluster analysis. The cluster analysis empirically identified groupings of universities based on the amount of federal academic research funding received.

For the second method, universities were grouped together based on their percentage shares of the total federal research expenditures. Geiger and Feller (1995) suggested that the most succinct way to gauge a university's participation in the research economy and to measure its change over time was by its percentage share of total federal research expenditures. The percentage share of the total federal research expenditures was calculated for each university for each year of the sample. This approach obviates the issues of whether current or constant dollars should be used in an analysis over time (Geiger, 1996). Groupings included the following: all universities with at least a two percentage point share of the total federal research expenditures, all universities between a one and a half and one and ninety-nine hundredths share, all universities between a one and one and forty-nine hundredths percentage share, all universities between a half and ninety-nine hundredths share, and all universities below a half percentage share. Geiger and Feller (1995) and Geiger (1996) used this approach to establish that a hierarchy existed between universities based on their academic research funding and how universities' shares of research changed during the 1980s. The present study roughly doubled the number of universities in the sample compared with previous studies on hierarchies in academic research funding (Geiger and Feller, 1995; Geiger, 1996).

To answer research question 3a, an examination of the movement of universities between groups (using both methods of groupings from research question three**)** over the various 5-year intervals was completed. These approaches allowed a determination of whether the hierarchy was stable or changed over time and whether a given university changed its group peers (from research question three). To answer research question 3b, universities that moved up or down substantially (research question 3b) were further examined, specifically universities that moved from one group to another. Movements of universities between groups (using both methods of groupings from research question 3**)** over the various five year intervals were noted. Universities were identified as either "movers" or "non-movers" if (1) they had moved significantly up or down the hierarchy and (2) they had changed the group of universities in which they had been clustered or grouped with in either of the two methods. An examination of the characteristics of universities was employed to explain why some universities were "movers and others "non-movers".

Organization

The remainder of this dissertation is organized in the following way. Chapter two provides a review of literature on the importance of research funding to universities, the federal Government's role in allocating funding for academic research, and the conceptual framework for the study. Chapter three elaborates on the research design and details the methods used. The findings for the three research questions are provided in chapter four. Chapter five contains a discussion of the findings, including the implications, conclusions, summary of the conceptual and analytical framework, and suggestions for future research.

CHAPTER 2

REVIEW OF LITERATURE

This chapter examines previous research involving the importance of research funding to universities, the Federal Government's role in allocating funding for academic research, and the conceptual framework for the study, the resource based theory of the firm. Utilizing the purpose of the study, explaining the driving forces accounting for a university's research funding, this chapter provides details on the three component parts. First, what are the various perspectives on why research funding is important? Second, what does the literature say about the unique and important role the Federal Government serves as a source of research funding? And third, what is the basis for selecting the conceptual framework employed, the basic elements of this theory, the justification for using the theory in a higher education study, and reference to how others have used the theory in higher education. The chapter also reflects upon related studies, what they chose to consider and the approaches taken, and why R&D expenditures were selected for explaining research funding in contemporary U.S. universities.

Importance of Research Funding to Universities

While other studies have considered other bases for examining the topic of higher education research, R&D expenditures in American universities is the focus of this study. R&D expenditures were selected because it is money, *per se*, that is the major focus from a university and government perspective. Universities want and need money to advance their specific research agendas while governments, consider funding as its major instrument for implementing policy. In addition, R&D expenditures are a simple and straightforward measure, and most importantly, it is the most common measure used to assess a university's research activity. Put candidly, money is a direct measure that is easily understood and is the common metric available in pertinent data bases. Thus it is the measure for answering the question of which universities are getting more research funding than others, which universities are getting less, and why?

Financial resources are of great importance in providing the physical and human infrastructure needed for research; regardless of their scale of operations, research costs money (Teich and Gramp, 1996). The level of research investment will vary depending, in part, upon whether the university is concentrating on a few disciplines or across multiple areas of research. Regardless, the level of financial support for selected research programs by universities must be comprehensive (Teich and Gramp, 1996). Once a university commits to a particular research program it will need sufficient resources to protect its initial investment, which may include outbidding competitors to retain staff and faculty, upgrading facilities, and recruiting better graduate students (Teich and Gramp, 1996). Productive faculty members are the most likely to be lured away from other universities by the promise of better facilities, colleagues, salaries, and graduate students (Geiger, 1996). Many universities that have moved to the forefront of academic research follow the strategy of hiring faculty "stars" in order to establish department reputations and enhance the research programs of other faculty members (Geiger, 1996, 2004; Bok, 2003; Zucker and Darby, 1996, 1999, 2007). Unless financial resources are committed in full, it is difficult for a university to conduct outstanding research within any discipline (Teich and Gramp, 1996).

Universities have a number of incentives to obtain as much research funding as they can. First, the ability of a university to acquire external research funding means more money for research, which typically results in attracting even more research funding, and ultimately more prestige (Teich, 2000). Second, decreases in the share of total revenues emanating from government block grants over recent years has left universities more dependent on external revenue sources to sustain their operations (Slaughter and Leslie, 1997; Slaughter and Rhoades, 2004). Typically these external revenue sources come from quasi-market areas (Slaughter and Rhoades, 2004), one of the more important of which is funding for research. Research funding is particularly notable because it is a source of revenue not available to many other types of organizations because it requires the unique ability to create new knowledge, something for which universities are relatively well equipped. Third, research funding, particularly from federal sources, is increasingly viewed by universities, the communities they serve, and political leaders, as a key element in technology-based economic development (Teich, 2000; Bloch, 2007).

University prestige is most often not about how well the university teaches its students or how it provides service to the community, rather it is about how well it conducts research. Historically universities have tried to achieve balance among the triumvirate activities of research, teaching, and service (Geiger, 2004) although in recent years the trend has been for universities to increase their focus on research (Cozzens, 1996; Geiger, 1996, 2004). It is suggested that much of this increased focus is due to universities seeking "prestige maximization" (James, 1990). Universities seek to maximize their prestige through increasing the amount of revenue for research they receive and the quality of research they conduct. This notion is very similar to Howard Bowen's (1980) "revenue theory of costs" in that universities seek to maximize the amount of revenues they can raise as the cost of education for a university is based on the amount of revenues it can raise, i.e. universities spend as much as they can raise. In short, a university's prestige is based principally on the scholarship and research of its faculty members (Geiger, 2004). The most prestigious universities employ the strongest faculties and continuously seek to maintain their positions by hiring the best scholars and researchers away from other universities (Bok, 2003). A faculty member's personal prestige is usually a reflection of the general prestige of his or her work within the chosen field, specifically how important or fundamental their contributions are to the field (Geiger, 2004). Thus, the most renowned researchers are individuals who have contributed the most to their fields and in doing so have brought distinction to their universities.

Many universities directly or indirectly compare their relative positions in research productivity to peer institutions in order to determine whether they are gaining or losing prestige. Universities' drive for prestige is often defined relative to other universities and, as such, a university's goals often take on a positional aspect, one that can boarder on striving for prestige maximization and relative ranking compared to other universities (Winston, 1999). The prevailing perspective of many universities is if they are not advancing, they are falling behind (Gumport, 1993). But while there are many universities trying to move into "elite" status, others are seeking to protect their position in the top grouping (Dill, 1996; Feller, 1996).

American higher education, by its nature, is competitive and competition for research funding is a central fact of academic life (Feller, 1996; Teich, 2000). The fundamental competition is in the currency of ideas, which is the intellectual gain from research (Feller, 1996) and counting research expenditures is the most commonly used measure to rank and classify university research competiveness (Teich and Gramp, 1996; Geiger 2004). Feller (2000) defines research competiveness is the ability of a university to compete for research inputs, outputs, and recognition.

In the changing funding environment, many universities have been highly motivated to better understand the reasons for their relative competitiveness (Feller, 2000). But this is not a simple task. Most formal studies on university research competitiveness have used input measures (e.g., federal R&D expenditures) as a proxy for both inputs and outputs because the quantity and quality of outputs are not easily measured (Feller, 1996). Feller in reviewing the literature on university research competitiveness found that between 1940 and 1996 there were over ninety studies in this area, but that a number of the measures of research performance were often vague and poorly understood as "most of the studies lacked formal structural relationships with the control, intervening or confounding variables" (Feller, 1996, p.56).

Previous studies on university research competitiveness found numerous significant influential factors, including the quality of senior administrators and their level of support for research (Stahler and Tasch, 1992; Feller, 1996; Geiger, 1996; Savage, 1999), and the number of faculty employed and the quality of their research abilities (Feller, 1996; Teich and Gramp, 1996; Savage, 1999). Additional studies found universities having expectations for faculty to seek external research funding (Feller, 1996; Geiger, 1996), the ability to provide matching funds/cost-sharing of external awards (Vest, 1994), and the intensity of their focus on research at the disciplinary level (Stahler and Tasch, 1992; Savage, 1999) as significant factors. Several studies involving research capacity found influential factors, including the dollar amount of faculty and staff salaries (Savage, 1999), the quality and the number of equipment and staff (Feller, 1996; Savage, 1999), the quality and size of research facilities (Feller, 1996; Teich and Gramp, 1996; Savage, 1999), the quality and size of the campus library (Feller, 1996; Savage, 1999), and the number and quality of graduate assistants (Feller, 1996; Savage, 1999). Other studies focusing on institutional policies found that teaching loads of faculty (Feller, 1996) and having polices favorable toward research (Feller, 1996; Geiger 1996) as positive influences on a university's research competiveness. Several additional influences indentified, which are beyond the ability of a university to control, include geographic location, state higher education governance structure, and state financial resource base (Feller, 1996).

Another set of studies, which are complementary to the research competiveness studies, took a broader look and measured university research activity. Critics argue measuring research competitiveness by research expenditures may not assess a university's research activity in a broad sense as it misses other key indicators, such as the number of doctoral degrees awarded, research training provided to graduate students, the number of faculty publications, and the amount of library activity associated with research (Feller, 1996; Geiger, 2004). These broader studies on research activity are important because while studies on R&D expenditures accurately reflect a university's external research funding, they say much less about the overall scale of university research activity (Ashton and Leslie, 1986). One subset of these broader studies focused on research productivity and found wide variations in faculty publications, graduate student outputs and returns on investment (funding) of research across multiple disciplines (Wanner, Lewis, and Gregorio, 1981; Adams and Griliches, 1998; Crespi and Geuna, 2006). Specifically, the disciplines of life sciences, social sciences, natural sciences, and engineering had significantly different lag structures of faculty and graduate student publications after initial funding (Crepi and Geuna, 2006).

Another subset of the broader studies measuring university research activity developed and refined the Research Activity Index (RAI), (Ashton, 1984; Ashton and Leslie, 1986; Leslie and Brown, 1988; Groth 1990; Groth, Brown, and Leslie, 1992). The RAI index was designed to identify multiple factors that influence university research activity and to rank order university research activity on a multivariate basis (Ashton, 1984). These RAI studies are very important as they are used as guides in developing the methods and models used in answering the research questions for the present study. The RAI studies were chosen as guides because their methods and models produced results similar to the goals of this study. The specific measures of university research activity identified by the RAI studies as influential include yearly research expenditures, number of scientists and engineers employed, number of doctoral researchers employed, number of science and engineering graduate students, number of PhDs awarded, number of post-doctoral students employed, the Association of Research Libraries Index rank (ARLI), and total expenditures on capital and equipment (Ashton, 1984; Ashton and Leslie, 1986; Leslie and Brown, 1988; Groth 1990; Groth, Brown, and Leslie, 1992). Comparison of RAI scores and the R&D expenditures suggests that while there is considerable correlation between the two, there are important differences as some universities receive and spend various amounts of money for research (Ashton and Leslie, 1986; Leslie and Brown, 1988). Of particular interest to the present study, the RAI studies found that there were natural groupings of universities, that is, groups of universities with similar research characteristics clustering together on the RAI scale (Leslie and Brown, 1988).

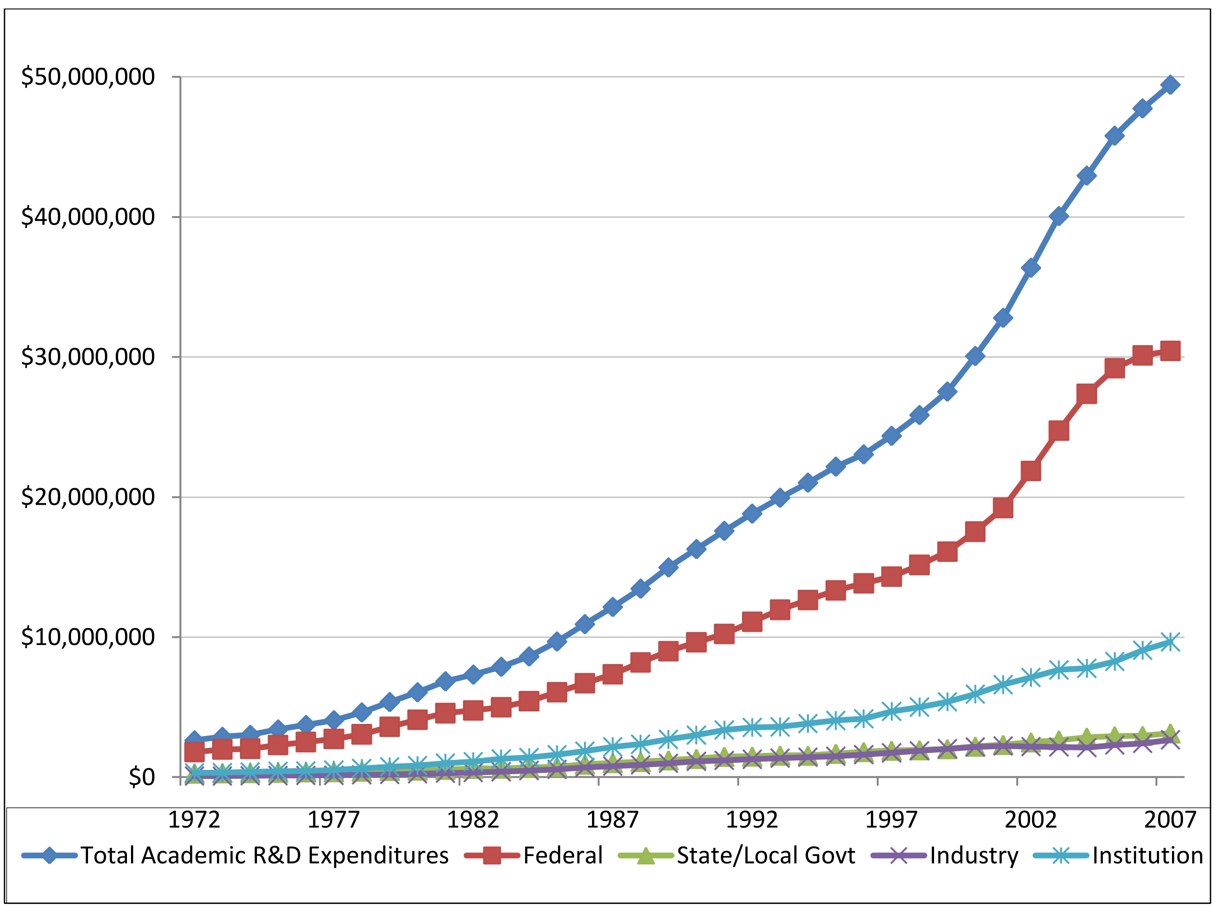
Over the last fifty years, the number of universities looking to maintain or enhance their ability to attract research funding and improve their research profile has greatly increased (Cozzens, 1996; Geiger, 1996; Feller, 2000). This has intensified an already highly competitive environment in which the amount of funding available for academic research, while increasing, has attracted new competitors for the available funding. This increased competition has in turn raised the cost for individual universities to support research activities (Dill, 1996). The increased costs have prompted many universities to focus more on applied research projects in hopes of generating commercial products (Dill, 1996; Slaughter and Leslie, 1997). But this can lead to other difficulties, particularly for public universities. On the one hand, federal research policy tends to emphasize research that is more basic whereas the goals of state and local governments tend to be more practical, that is more focused on specific local and state needs, such as economic development. This has often created conflicts between administrators and elected officials over the missions of public universities (Dill, 1996).

The second incentive for universities to maximize research revenues is acquiring new sources of external revenues has become more critical. The recent trend of public disinvestment in universities via relative decrease in state block grants and appropriations resulted in universities becoming more dependent on external revenue sources for general operations (Slaughter and Leslie, 1997; Slaughter and Rhoades, 2004). With drops in relative shares of state block grants and appropriations, universities scramble to secure funding from whatever sources they can. While recently the largest increases in funding have come from tuition revenue (Hasbrouck, 1999), revenue from research activities plays a prominent role. This behavior by universities using a unique asset to generate revenue is in-line with resource dependency theory, which suggests that a university's response to its environment can to some extent be predicted from its mix, or lack, of resources and attributes (Gornitzka, 1999).

Derek Bok (2003) warns though that there is never enough money to satisfy all university demands. By and large, universities have no strong incentive to cut costs in their quest for resources because unlike industry, they seek to maximize their prestige, not "profits" (Bowen, 1980). Within some limits and constraints, universities are free to focus internal resources however they want (Feller, 1996). This allows universities to decide how and in what manner revenues are expended. Universities desire to obtain more and more research funding in a never-ending cycle of raising all the money they can and spending all they raise. Generating new grant revenues is a major source of continued growth. Bowen (1980) conceptualizes this pattern as the "revenue theory of cost": University spending is based chiefly on how much revenue it can acquire.

Using Bok's and Bowen's assertions as a backdrop, it is not surprising to find that American universities are expending dollars on research at unprecedented levels. In fact, over the last thirty-five years, their expenditures for research grew immensely, from $2.6 billion in fiscal year 1972 to $49.4 billion in fiscal year 2007 (National Science Foundation 2009). Much of this growth has occurred in the last decade, having more than doubled, from $24.3 billion in fiscal year 1997 (National Science Foundation 2009). Chart 2.1 below illustrates the amount of academic research expenditures in America over 35 years (note dollars are in thousands).

Chart 2.1. *Academic Research Expenditures 1972-2007 (National Science Foundation, 2009)*



The third incentive for universities to maximize research revenues is that universities have become directly involved, formally or informally, in economic development (Yusuf, 2007). In general the government's role in academic research is to improve the nation's or state's ability to innovate (Olsen and Carlson, 2007; Wang, et. al, 2003). Public investment in research, mainly financed through universities, promotes economic development because it helps organizations and corporations, public or private, seize market opportunities through the technology transfer process (HM Treasury, 2004). As the United States shifts more into a knowledge economy, universities will increasingly play a critical role in economic development because they contain two key elements, talented individuals and advanced knowledge and technology (Nelson, 1986). Reagan-era policy shifts, including the 1980 Bayh-Doyle Act, which allowed university ownership of patents arising from government funded research, greatly influenced the behaviors of universities and changed perceptions of their usefulness in economic policy (Douglass, 2007).

Although a number of these policy shifts encouraged greater interaction between academia and industry, the cultures of industry and academia are fundamentally different and often at odds with one another. In general industry is focused on profit generation while higher education is traditionally more concerned with advancing and disseminating knowledge for its own sake. Put plainly, industry focuses primarily on development rather than research, which increases the burden on universities and government to fund and perform basic research (Bloch, 2007). Basic research is extremely important because technology transfer and economic development remain tethered to basic science: "At a certain point further advances become impossible without a deepening of scientific knowledge in specific areas or scientific breakthroughs that loosen or eliminate particular constraints" (Yusuf, 2007 p.5).

Policymakers at national and sub-national levels see opportunities to promote economic development through increasing academic research funding, which they believe will stimulate local economies through technology transfer and licensing, spin-off companies, and high-tech employment (Teich, 2000). New marketable products are outputs of a technology transfer processes that begin with research and invention, proceeds with product development, and results in products ready for market introduction (Feldman, 1994). In a number of cases, many of these new products would have been developed and commercialized without academic research, but it would have been more time consuming and expensive to do so. Mansfield (1990) provides evidence showing that without academic research, one-tenth of the new products would not have been developed and the development and market introduction of new products likely would have been delayed by as many as eight or nine years.

Some of the most successful technology transfer systems in the United States have distinct clusters of universities and industry in close geographic proximity. On the whole these clusters are sets of interrelated organizations joined together through opportunities and incentives ultimately bringing new products to the market (HM Treasury, 2004). The geographical clustering creates a technological, knowledge, and human resource infrastructure that supports and promotes knowledge transfer and ultimately brings new products to the market (Feldman, 1994; Mita and Formica, 1997; Yusuf, 2007). While these clusters are not new creations, what is new is that universities are increasingly being found at the center of the clusters and are being highly proactive in forming new clusters (Bloch, 2007).

Within the knowledge economy, knowledge transferred into commercialized products is vital for economic development as governments cannot rely on regional or national networks due to how assimilated research “spills over” and generates economic opportunities (HM Treasury, 2004).[4] Academic research, while unlikely to have immediate application, has the greatest potential for spillover and long-term benefits economically as well as socially (Leyden and Link 1992; Feldman, 1994; Mansfield and Lee 1996; Feldman, Link, and Siegel, 2002; HM Treasury, 2004). Within the United States, states in particular face problems of ensuring that the economic benefits, or “spillovers” from research, are captured within the economy of the state itself (Geiger and Sá, 2005). In short, national and sub-national governments need to have vibrant knowledge creation and technology transfer systems within their borders for sustained economic growth (HM Treasury, 2004).

Universities are no longer seen as discreet organizations, but rather as needed partners in a larger economic development strategy (Geiger, 2005). If technology transfer continues to be the principle driver of economic growth, universities are likely to emerge as the most dynamic organization government policy can impact (Yusuf, 2007). Governments, acting as partners with universities, can encourage research and promote economic development opportunities by providing universities access to resources, capital and non-taxable debt (Wyman, 1997). This makes funding for academic research, for policymakers at all levels, an important policy tool in promoting economic growth for the foreseeable future.

The Unique and Important Role of the Federal Government as a Source of Research Funding

While universities have had a long and distinguished track record of conducting research, it was not until the conclusion of World War II that universities had a permanent role in American research and science policy. The definitive justification for this role was stated in a report entitled *Science: The Endless Frontier*, which was composed by President Truman’s science

[4] Assimilated research refers to research that has gone through the technology transfer process; from undertaking the actual research, the research findings being incorporated by industry, and finally transformed into a commercial product.

advisor, Vannevar Bush, (Geiger, 1993). The report proposed that the Federal Government form a partnership with American universities and industries because scientific progress was "essential for fighting diseases, national security and increasing public welfare" (Bush, 1945). Two key pieces of Bush's report for moving science forward were to establish peer review panels to choose the most meritorious projects to fund and to allow public dissemination of research findings. The intent was to allow industry to freely apply newly created knowledge and develop new products while encouraging universities to expand the existing scientific knowledge base (Bush, 1945). The report strongly asserted that it was important that the government fund public centers of knowledge creation because fundamental research was noncommercial in nature and would not receive the attention and support it needed if left solely to industry.

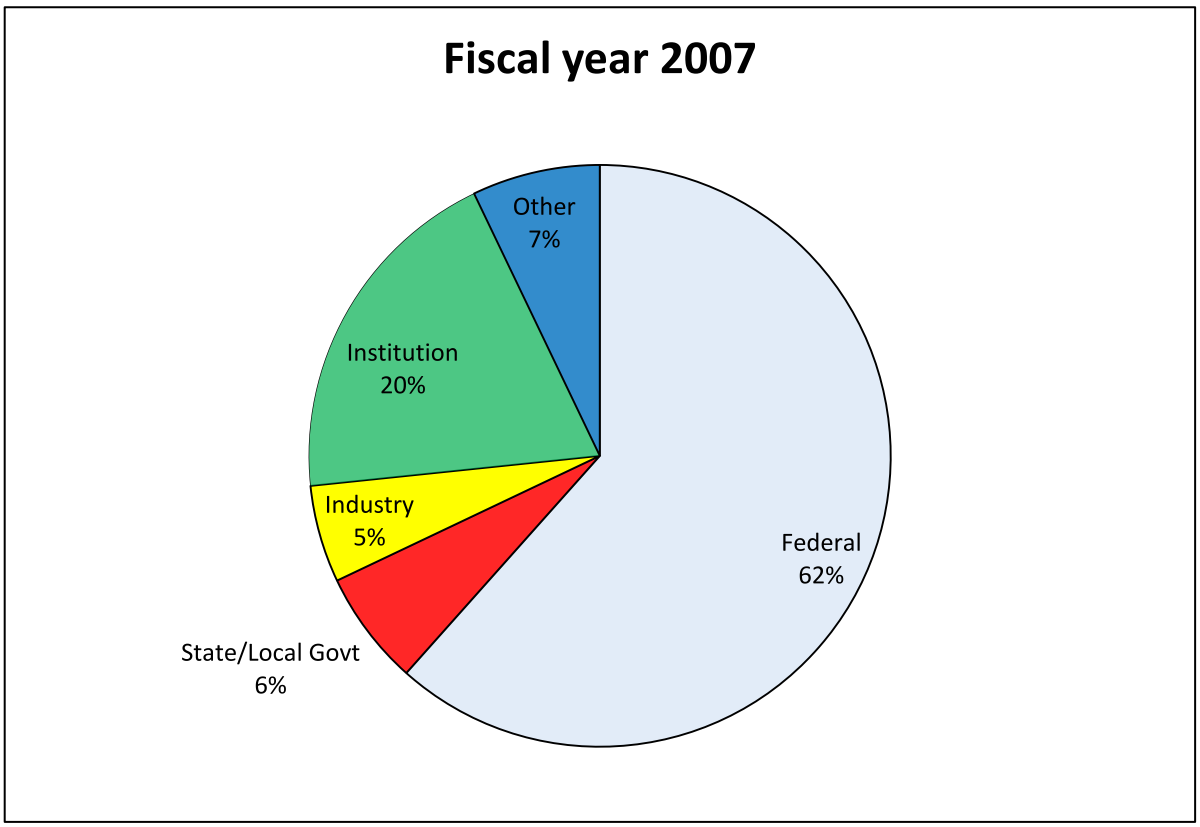
By the 1950s, there were fourteen different federal agencies directly funding research in American universities (Price, 1968). In the mid-1960s, the impact of the Cold War and the Russian launch of Sputnik resulted in more research funding being directed from federal agencies into American universities (Geiger, 1993). During this Cold War/post-Sputnik era, American universities saw a great expansion of their faculties, facilities, graduate enrollments, and in the volume of research performed (Geiger, 1993). Many recall this period as the "golden age" of research during which money flowed freely from the Federal Government to universities, and the peer review system became the entrenched method for allocating funds (Graham and Diamond, 1997).

Starting in the 1980s, the Federal Government began to expand research, systematically funding universities, a trend that continues to today (Geiger, 1993). This was driven in large part by two major initiatives. First, in December 1980, Congress passed the Bayh-Dole Act, giving universities patent ownership for inventions and discoveries arising from federally-funded research, thereby encouraging greater interaction between universities and industry (Geiger, 2004). Prior to Bayh-Dole, any inventions produced as a result of federally-funded academic research were publicly available (Langenberg, 2007). The Act enabled universities to profit directly from academic research through their ability to license or hold equity in companies built around intellectual property (Slaughter and Rhoades, 1996). This pushed applied research which had been solely the domain of corporations, front and center and into the mainstream of academic research (Geiger, 2004). With multiple Congressional initiatives like the Bayh-Dole Act, coupled with the rise in the biogenetics industry, applied research surged within universities (Bok, 2003).

The second major initiative, in large part a reaction to a threat of decreased federal funding in the 1970s, originated in the universities themselves. Prior to the 1980s, universities and colleges had relied on various higher education associations to represent their interests in Washington D.C. (Savage, 1999). However, sensing the threat, universities began employing full-time federal relations staff to lobby Congress and federal agencies directly for research funding (Best, 2004). One of the results was that special "earmarked" funds were captured by universities (Savage, 1999, 2007), and since the mid 1980s, universities have steadily increased their solicitation of Congress for earmarks (Cook, 1998; Savage, 2007).

Universities support research in a variety of ways, but the majority of academic research funding comes from public sources. In fact, the four main sources of academic research funds are the Federal Government, State governments, industry, and universities themselves, funds they generate through non-research activities (Powers, 2004; National Science Foundation, 2009). Since World War II, the Federal Government has been the largest sponsor of academic research (Smith and Karlesky, 1977). Most of this funding comes from discretionary funds within various agencies and, though substantial, it is small by comparison to the overall federal budget (roughly 2 to 5 percent) (Olsen and Carlson, 2007). Chart 2.2 below shows the sources of academic research funding for fiscal year 2007, and illustrates that the Federal Government is clearly the largest sponsor of academic research. Currently the federal funding comes from over twenty different agencies, but by far the largest shares come from just two, the NIH and NSF (Teich, 2000). The "Other" category includes funds from non-profit foundations and individual private gifts restricted by donors for academic research (National Science Foundation, 2009).

Chart 2.2. *Sources of Academic Research Funding (National Science Foundation, 2009)*



The three main methods the Federal Government uses to fund academic research are contracts, grants and direct funds (earmarks) (Savage, 1999, 2007), with grants being the dominant mode, although the recent trend has been an increase in earmarks (Feller, 2000;

Greenough, Mconnaughay, and Kesan, 2007). Federal contracts are “purchases” of information, engineering, and “hardware” from universities and involve the hiring of individuals perceived as most likely to do the best job (Arnold, 1968). Contracts typically are long-term arrangements and in most cases subject to a review process (Arnold, 1968).

Grants are defined, individual, short-term “one-shot” projects (Arnold, 1968) and are typically distributed through an open competition based on peer review of the quality of proposals with an emphasis on scientific merit as a proposal selection criterion (Feller, 2000; Payne 2003). These characteristics are in-line with the values Vannevar Bush formally proposed in 1945. It is important to note that significant federal funding decisions regarding academic research are public policy as well as political decisions that reflect changes over time in the relative budgets of the various, pertinent federal agencies (Payne, 2003; Olsen and Carlson, 2007).

A major concern with federal grants, in the minds of some, lies in the tendency of grants to be concentrated in a relatively small number of universities (Arnold, 1968; Savage, 1999, 2007; Feller, 2000). In other words, the rich get richer. The ability to compete successfully for grants increases as the universities receiving funding accumulate additional scientists and graduate students, better facilities, improved fiscal and supporting services, and the like (Arnold, 1968). The “arms race” for faculty over the last few years has escalated this concern and has created an environment where the best scholars and scientists migrate to institutions that already have the strongest faculties (Bok, 2003). Because federal grant proposals are judged on the singular basis of merit, it is understandable that peer-reviewed awards to be concentrated in a relatively small number of universities (Arnold, 1968).

An academic earmark is a legislative provision dictating that an agency of the Federal Government will provide funding for a distinct research project at a specific university (Cook, 1998; Savage, 1999, 2007). Earmarking is a method for universities, especially those not in the elite group, to acquire federal funding without going through a peer review process. In general federal agencies do not have a favorable view of earmarks, largely because the money comes out of the agencies' allocated budget for peer reviewed research projects, unless Congress allocates additional funds to support the directed projects (Olsen and Carlson, 2007). The result of which is a pattern of reduction in the amount of funds for peer-reviewed proposals.

Over the last twenty years, the growth of universities bypassing the peer review system and seeking earmarks has been tremendous (Feller, 2004; Savage, 2007). The amount of academic earmarks a university receives is largely determined by the intensity of its lobbying efforts, the presence of a medical school, having highly ranked graduate programs, and being located in a district with an elected representative on the House or Senate Appropriations Committees (Figueiredo and Silverman, 2002). The average return on lobbying for earmarks, controlling for other factors, is from 11 to 36 times the amount a university expends on lobbying (Figueiredo and Silverman, 2002).

Critics argue that by earmarking funds members of Congress are providing a special benefit for their constituents and friends, a benefit that is based on who one knows rather than the merit of the science proposed (Savage, 1999). Despite official pronouncements against earmarking by academic associations and scientific societies, no university, university administrator, or faculty member has ever been sanctioned in any form for participating in earmarking (Savage, 2007). This absence of sanctions has encouraged more and more universities to seek earmarked funding.

Detractors assert that earmarks undermine the peer review system and the basic scientific method, both of which are deep-seated traditions of higher education (Savage, 2007). They also argue that by funding research through earmarks, the best science and scientists do not necessarily receive the funds their merit deserves. Defenders of earmarks however claim that the peer review system is a flawed and biased system that leaves many institutions with no other remedy for obtain federal funds (Savage, 1999; Savage 2007). The defenders argue that peer review panels are inherently biased because they are comprised of faculty and researchers from a handful of elite institutions and in turn reward their colleagues with grants of federal research funds (Savage, 1999, 2007; Payne, 2003).

While the peer review system assures excellence, it can also lead to risk adverse, non-innovating science (Olsen and Carlson, 2007). Earmarks spread money beyond the top one hundred research universities to which the peer review process allocates more than 80 percent of federal research and development funding (Cook, 1998 p.39). Defenders maintain that this is a more equitable system and allows for the creation of new centers of scientific excellence that would not have a chance of receiving federal funds under a strict peer review system (Savage, 2007). Earmarks for facilities and equipment are highly valued by universities because there are no other federal funds available to support the maintenance and upgrading of academic research infrastructure (Cook, 1998). Since the 1960s, with the exception of federal earmarks and a few programs in the NSF and NIH, institutions have relied heavily on state governments and internal sources to fund new research facilities and equipment critical to developing world class research programs (Cook, 1998, Savage 2007).

For universities to compete for federal funding, they are required to make strategic and tactical choices such as finding niche strengths, building and maintaining specific research units, and organizing financial resources in an orderly manner (Feller, 1996; Teich and Gramp, 1996, Feller 2000). Having a systematic approach to the planning and management of research initiatives facilitates a university's ability to conduct research (Dill, 1996) as no one university can excel or lead in every field (Feller, 1996). To compete for federal funds within any discipline, universities must have the capacity to conduct the research, from having the physical space and necessary policies to employing the requisite researchers (Dill, 1996). This means that there is either a critical minimum number of faculty members within a specific discipline or a number of faculty members across disciplines from which to form coalitions of overlapping research interests in order to pool together necessary internal funds, equipment, and facilities (Feller, 1996). Often universities will establish centers and institutes specifically designed to bring faculty together into an interdisciplinary unit for specific research purposes.

The Resource-Based Theory of the Firm

The resource-based theory of the firm offers a conceptual framework for understanding how universities compete and organize themselves to obtain federal funding for research. This theory was developed as management theory, specifically, from understanding the sources of sustained competitive advantage through the strategic management of resources. The resource-based theory of the firm posits an organization's unique assets and capabilities, those that are difficult for others to imitate or copy and can position an organization to outperform its competition in the marketplace (Powers, 2004). Organizations, or rather firms, sustain their competitive advantages by implementing strategies that exploit their internal strengths through responding to environmental opportunities (Barney, 1991; Conner, 1991; Penrose, 1995).

Two fundamental assumptions of the resource-based theory of the firm are that organizations within an industry (or group) "may be heterogeneous with respect to the strategic resources they control and that resources may not be perfectly mobile across firms allowing for the heterogeneity to be long lasting" (Penrose, 1991, p.101). Organizations are intrinsically historical and social entities and their ability to acquire and exploit resources depends on their place in space and time (Barney, 1991).[5] Strictly speaking, it is never resources themselves that are the "inputs" in the production process, but only the services they can render, which are a function of the way they are used (Penrose, 1995). In short organizations within a particular industry vary in regard to the resources they control and their ability to use them. These differences provide organizations with competitive advantages or disadvantages in pursuing opportunities available within their industry.

Three key concepts of this theory are firm resources, competitive advantage, and sustained competitive advantage. Firm resources are grouped into 4 categories: physical capital resources (Barney, 1991; Grant, 1991; Penrose, 1995); human capital resources, specifically the skills of the employees of an organization in producing, creating, or offering a product to the market (Grant, 1991); financial resources (Barney, 1991), and organizational resources (Barney, 1991; Penrose, 1995), which are resources controlled by an organization enabling it to improve its efficiency and effectiveness in the marketplace. All resources within any category can be classified into one of two groups, assets or capabilities (Wade and Hulland, 2004). Assets are anything tangible or intangible that can serve as an input or output of a process (Srivastava et. al., 1998; Teece et. al., 1997; Wade and Hulland, 2004) while capabilities are the transformation of

[5]An organization's ability to acquire and use resources changes over space and time. An organization located at a specific place might experience a competitive advantage due to resources available at this location (ex: coal available in the ground near an organization). But over time, this competitive advantage might be lost as resources are used up or better, more efficient resources are being used by competitors (ex: limited supply of coal in the ground, once mined … it is gone and the organization's competitive advantage is lost; a competitive advantage experienced at one point in time doesn't necessary provide a competitive advantage at another point in time).

inputs into outputs of greater worth. These can include skills of employees, managerial ability of executives, or the processes of an organization in producing or creating a product (Amit and Schoemaker, 1993; Capron and Hulland, 1999; Christensen and Overdorf, 2000; Wade and Hulland, 2004).

The theory is about the competitive advantage of the firm and the connection of this advantage to resources. An organization is able to achieve a competitive advantage when implementing a strategy or process not simultaneously implemented by any current or potential competitors due to the resources controlled by the organization (Barney, 1991). The organization can sustain their competitive advantage so long as others are unable to duplicate the benefits of the operational strategy or process (Barney, 1991; Wade and Hulland, 2004). The sustained competitive advantage, however, does not imply that it will “last forever”; rather it suggests that it will not necessarily be lost through duplication efforts of other organizations (Barney, 1991). For an organization’s resource to be able to provide a competitive advantage it must possess four attributes: It must be valuable, rare, imperfectly imitable, and have no equivalent substitute (Barney, 1991; Conner, 1991).

Resources are considered valuable when they enable an organization to conceive of or implement strategies that improve efficiency or effectiveness in the marketplace (Barney, 1991). The rareness of an organization’s resource is defined when it can provide a unique set of capabilities or opportunities thus generating a potentially competitive advantage (Barney, 1991). A resource is considered imperfectly imitable when other organizations, which do not possess the resource(s), cannot obtain or duplicate them (Barney, 1991). Lastly, for an organization’s resource to be a source of competitive advantage there must be no strategically equivalent resource available as a substitute for it (Barney, 1991). These are the foundations of the theory of the resource-based theory of the firm.

Although the theory was originally developed to explain for-profit firm performance, its application to universities (as firms) is appropriate due to the highly competitive environment of federal research funding (Powers, 2004). Of particular interest to this study is how universities have competed for federal funding over time and have indentified important characteristics that influence the reasons for their success. The resource-based theory of the firm provides a useful lens through which to understand how universities develop a competitive advantage in obtaining federal funding and how it can be sustained over time.

The theory has direct application to organizational planning. Grant (1991), using a five-stage process, demonstrated how for-profit firms incorporate resource-based theories into a framework for strategic planning. The five stages include analyzing the organization's resource base; appraising the organization's ability to use resources (capabilities); analyzing the revenue generation of the organization's resources and capabilities; selecting a strategy (or strategies) to utilize the organization's resources, and upgrading and expanding the pool of resources and capabilities of the organization to show how a purposeful and well thought-out strategic plan can increase organizational performance (profit).

This is analogous to how universities try to obtain federal research funding. Often universities will identify specific research domains or projects for which they would like funding (Gieger, 1993; Payne, 2003). In most cases these research domains, or projects, are developed within departments or disciplines in which the university has previously built the necessary infrastructure to be competitive in the peer review process (Geiger, 1993). In some cases though, universities attempt to expand their research profiles within a discipline or a new field. In either case, universities purposely design their research proposals to take advantage of their environment, for example, their position or reputation within a discipline, relationship with national or sub-national government officials, national or sub-national government's focus or priorities. An example of this is how federal funding for academic research has shifted from the predominately defense department sponsored research projects that began in the 1940s to one of technological and health/medical related sponsored research projects starting in the 1980s (Geiger, 1993). In large part this has involved focusing research efforts in areas where funding is available, i.e., to meet the changing demands and needs of federal and state governments.

A significant aspect of the theory is that an organization's products must either be distinctive in the eyes of the buyers (for example, the organization's product must offer consumers a dissimilar and attractive attribute in comparison to substitutes) or it must offer an identical product at a lower cost (Conner, 1991). This is analogous to one of the criteria of the peer review process of the Federal Government: "How well qualified is the proposer (individual or team) to conduct the project?" (National Science Foundation, 2007a). In other words, the expertise and skills of the faculty member(s) proposing the research are criteria of the peer review process. Simply put, proposals by faculty members with a good research track record and high level expertise are much more likely to be funded than proposals by less experienced and distinguished faculty members.

Using the resource-based theory of the firm, university structural characteristics, location, and the investments in faculty and facilities would be considered as resources. Each is not readily mobile or easily transferred to another university[6], in-line with the theory's requirements. Once

[6] Though faculty can and do move from one university to another, most tenured faculty (or on tenure track) tend to stay at a university over multiple years and not move on a yearly basis. As such, faculty members can be considered as a not readily mobile resource under the resource-based theory of the firm.

acquired, these resources allow a university to conceive and implement a unique research agenda that other institutions cannot duplicate. Competing universities can undertake similar research projects within the same disciplines, but a university's particular faculty members and facilities uniquely position it to create or exploit research opportunities that cannot be duplicated or substituted. Thus, it would be expected that differences among universities in amounts of federal research funding obtained would be a function of their overall "resources" and their abilities to convert these resources into research products, both tangible and theoretical.

There have been a number of previous studies within higher education that have used the resource-based theory of the firm as a theoretical framework. Most of these have focused on science policy, innovation, start-up formations, and technology transfer. The use of the theory in science policy and innovation studies, of which universities are a critical element is viewed as a "crucial conceptual development" over the last twenty years (Martin, 2008 p.27). Rothaermal, Agung, and Jiang (2007), in a detailed analysis of the literature on university entrepreneurship, identified nine distinct studies using the resource-based theory of the firm as a theoretical lens. In fact, this theory was the second most used theoretical framework after network theory (Rothaermal, Agung, & Jiang, 2007). Most of the studies indentified were recent, having been published within the last ten years. Two of the studies bear special mention in relation to this study.

Powers and McDougall (2005) used the resource-based theory of the firm to test whether specific resource sets are predictive of the number of start-up companies formed, as well as the number of initial public offerings (IPOs) to which a university had previously licensed a technology. The authors used the resource-based theory of the firm as a theoretical lens because they hypothesized that certain resources provided advantages in the technology transfer process.

Specifically, the level of R&D revenues, the quality of faculty members, the age of the technology transfer office, and the level of venture capital invested within a university's local area were all important predictors of start-up formation and the number of IPOs to which a university had previously licensed a technology. In the second study, Druilhe and Garnsey (2004) used the resource-based theory of the firm to develop a typology for categorizing spin-outs derived from university entrepreneurial activities.

In regard to the other studies described by Rothaermal, Agung, and Jiang (2007), Markman et al. (2005) found that the resources and competency of a university's technology transfer office impact the speed of the commercialization of academic research. Wright, Vohora, and Lockett's (2004) findings suggest that spinouts resulting from joint ventures with industrial partners provide a faster and more cost-effective way of commercializing university intellectual property than did university-only backed start-ups. O'Shea et al. (2005) found that previous success with technology transfers, faculty quality, science and engineering funding, and a strong commercial resource base are positively related to university spin-out developments. Lockett and Wright (2005) found the number of spin-out companies created is significantly associated with a university's expenditures on intellectual property protection, the skills of the technology transfer office staff, and the university's royalty structure. In sum, studies using the resource-based theory of the firm found that the quality of university resources, physical and human, impacts the university's entrepreneurial ability.

Josh Powers (2003, 2004) published two higher education studies, not identified by Rothaermal, Agung, and Jiang (2007), which used the resource-based theory of the firm. In the first study, Powers (2003) examined the effects of resources, both internal and external, on the university technology transfer process. His findings suggested that the most important resource for achieving high levels of technology transfer was the quality of the science and engineering faculty. He also found that both federal and industry R&D funding were important contributors to a university's patenting ability, but having a medical or engineering school were not significant predictors of technology performance. The second Powers study (2004) investigated the effects of various sources of R&D funding on university licensing activities. Employing four different sources in his models, (federal, state, industry, and internal), he found that only federal funding had a significant influence on university licensing activity, for both large and small companies. Internal funding had a significant influence only on licensing activity for small companies; State funding had a significant influence on licensing activity for large companies, while industry funding was not a significant influence on licensing activity for either large or small companies (Powers, 2004).

Summary

The three sections of this chapter examine previous research pertinent to this study. First, literature involving the importance of research funding to universities was indentified. Second, literature on the Federal Government's role in allocating funding for academic research was described. Finally the conceptual framework for the study, the resource based theory of the firm, was discussed along with the justification for applying it in this study.

CHAPTER 3

DATA SOURCES AND RESEARCH DESIGN

This chapter is divided into five sections. The first section reviews the research questions to be tested; the second section examines the analytical framework; the third section presents the data sources; the fourth section outlines the statistical methods; and the final section describes the limitations of the study.

Research Questions

As mentioned in chapter 1, this study was designed with three research questions in mind. First, what are the university characteristics that explain the amount of federal research funding received (measured by convention as research expenditures)**,** and how shall these characteristics be identified? Second, what is the relative importance of these characteristics in explaining variations in federal research expenditures among a set of universities? Third, based on relative amounts of federal research expenditures, can one identify discrete university groupings or "clusters" reflecting the "hierarchy" posited by Geiger and Feller (1995), Geiger (1996) and Teich (2000)? Additionally, does this hierarchy change or is it stable over time, and for universities who moved "up" or "down" are there specific factors that account for these movements within the hierarchy?

Analytical Framework

The analytical framework for evaluating university characteristics that explain the amount of federal research funding received and ranking them accordingly was provided by a series of studies using the Research Activity Index (RAI). The two primary studies used in developing the methods for this study are a pair of dissertations completed at the University of Arizona. Each of these dissertations contained comprehensive sections detailing steps and methods used in developing the RAI. The first dissertation entitled “A research activity index of major research universities” by Arthur Ashton (1984) described the formation of an overall RAI and subsequently used to rank universities. The second dissertation entitled “Research activity in major universities and fields of science” by Randall Groth (1990) expanded the RAI to rank universities within fields of science and engineering (FSERAI). Both of the dissertations utilized similar theoretical frameworks and methodologies in the development of their respective indexes. Three additional studies using the RAI also helped shaped this study. The first study entitled “Research activity in American universities” by Arthur Ashton and Larry Leslie (1986), further detailed the RAI and ranked 68 universities in 1980. The second study entitled “Beyond R&D expenditure ranking: The scale of research activity in American universities” by Larry Leslie and Kenneth Brown (1988), expanded the number of variables and universities included in the RAI. The final study entitled “Research activity in major research universities: An alternative ranking system” by Randall Groth, Kenneth Brown, and Larry Leslie (1992) ranked the top 100 research universities for the years 1980, 1985, and 1987.

While these RAI studies differed from this study in that the former evaluated university research activity and this study evaluated university research expenditures, the RAI studies were important because they provided a method to identify and test university characteristics that determined the amount of federal research funding received. The RAI was developed through a four-step process involving, 1) creating a data base of “potential” research related variables for each university, 2) through the application of principal component analysis (PCA), reducing the collected data into a subset of primary component variables, 3) again through the application of

PCA, generating a weight or loading factor for each primary component variable, 4) creating an index score for each university by multiplying each primary component variable's loading factor scores by the individual university's data values. This four-step process produced the RAI which empirically indentified influences (variables) on university research activity and is used to rank universities accordingly. For the present study though, the PCA was used solely to indentify university characteristics that influenced a university's ability to attract federal research funding.

Data Sources

In this section the population of universities is presented as well as the criteria for selecting the variables and the primary data sources.

Population

An initial population of 510 universities was selected for this study. This initial population consisted of all universities and colleges that reported research expenditures for every year from 1972 through 2007 on the Survey of Research and Development Expenditures at Universities and Colleges facilitated by the National Science Foundation (academic R&D expenditures survey, NSF). The initial population of 510 universities was reduced to a final 375 universities (see Table 3.1 for complete list of the 375 universities included in the study). A number of these universities were excluded because they either were U.S territories (ex: Puerto Rico), had incomplete data from other sources, or were not structured as a traditional American university (ex: Woods Hole Oceanographic Institution). The basis for excluding these universities was to focus the study on American universities with similar missions (teaching, research, and service).

Table 3.1. *Universities in Sample – Listed Alphabetically*[7]

University Name	*IPEDS Unit ID*
Abilene Christian University	222178
Alabama Agricultural and Mechanical University	100654
Albany State University	138716
Alcorn State University	175342
Alfred University	188641
American University	131159
Amherst College	164465
Andrews University	168740
Arizona State University	104151
Auburn University *	100858
Augsburg College	173045
Augustana College (Rock Island, IL)	143084
Augustana College (Sioux Falls, SD)	219000
Ball State University	150136
Barnard College	189097
Baylor University	223232
Boston College	164924
Boston University	164988
Bowdoin College	161004
Bowling Green State University *	201441
Bradley University	143358
Brandeis University	165015
Brigham Young University *	230038
Brown University	217156
Bryn Mawr College	211273
Bucknell University	211291
California Institute of Technology	110404
California State Polytechnic University Pomona	110529
California State University-Chico	110538
California State University-Fresno	110556
California State University-Fullerton	110565
California State University-Long Beach	110583
California State University-Los Angeles	110592
California State University-San Bernardino	110510
Carleton College	173258
Carnegie Mellon University	211440
Case Western Reserve University	201645

[7] *= university had data in 1 or more data bases combined with branch campuses

Table 3.1. *Universities in Sample – continued*

University Name	*IPEDS Unit ID*
Catholic University of America	131283
Central Washington University	234827
Chicago State University	144005
Claremont Graduate School	112251
Clark Atlanta University	138947
Clark University	165334
Clarkson University	190044
Clemson University	217882
Cleveland State University	202134
College of the Holy Cross	166124
College of William and Mary	231624
College of Wooster	206589
Colorado School of Mines	126775
Colorado State University	126818
Columbia University in the City of New York	190150
Connecticut College	128902
Cornell University	190415
Creighton University	181002
CUNY Brooklyn College	190549
CUNY City College	190567
CUNY Graduate School and University Center	190576
CUNY Hunter College	190594
CUNY Queens College	190664
CUNY York College	190691
Dartmouth College	182670
De Paul University	144740
Denison University	202523
Drake University	153269
Drexel University	212054
Duke University	198419
Duquesne University	212106
East Carolina University	198464
East Tennessee State University	220075
Eastern Michigan University	169798
Eastern Washington University	235097
Emory University	139658
Fairfield University	129242
Fisk University	220181
Florida Agricultural and Mechanical University	133650
Florida Atlantic University	133669

Table 3.1. *Universities in Sample – continued*

University Name	*IPEDS Unit ID*
Florida Institute of Technology	133881
Florida State University	134097
Fordham University	191241
Franklin and Marshall College	212577
Furman University	218070
Gallaudet University	131450
George Mason University	232186
George Washington University	131469
Georgetown University	131496
Georgia Institute of Technology	139755
Georgia Southern University	139931
Georgia State University	139940
Grambling State University	159009
Grand Valley State University	170082
Grinnell College	153384
Harvard University	166027
Harvey Mudd College	115409
Haverford College	212911
Hofstra University	191649
Howard University	131520
Idaho State University	142276
Illinois Institute of Technology	145725
Illinois State University	145813
Indiana State University	151324
Indiana University, Bloomington *	151351
Iowa State University	153603
Ithaca College	191968
Jackson State University	175856
James Madison University	232423
John Carroll University	203368
Johns Hopkins University	162928
Kansas State University	155399
Kent State University *	203517
Kentucky State University	157058
Lamar University-Beaumont	226091
Lehigh University	213543
Loma Linda University	117636
Long Island University *	192448
Louisiana State University *	159391
Louisiana Tech University	159647

Table 3.1. *Universities in Sample – continued*

University Name	*IPEDS Unit ID*
Loyola University of Chicago	146719
Manhattan College	192703
Mankato State University	173920
Marquette University	239105
Marshall University	237525
Massachusetts College of Phar & Allied Hlth Sci	166656
Massachusetts Institute of Technology	166683
Medical College of Georgia	140401
Medical University of South Carolina	218335
Miami University *	204024
Michigan State University	171100
Michigan Technological University	171128
Middlebury College	230959
Milwaukee School of Engineering	239318
Mississippi State University	176080
Missouri State University	179566
Montana State University - Bozeman	180461
Montana Tech of the University of Montana	180416
Montclair State University	185590
Morehead State University	157386
Mount Holyoke College	166939
New Jersey Institute Technology	185828
New Mexico Highlands University	187897
New Mexico Institute of Mining and Technology	187967
New Mexico State University *	188030
New School for Social Research	193654
New York Institute of Technology *	194091
New York University	193900
Norfolk State University	232937
North Carolina Agricultural & Tech State University	199102
North Carolina Central University	199157
North Carolina State University at Raleigh	199193
North Dakota State University	200332
Northeastern Illinois University	147776
Northeastern University	167358
Northern Arizona University	105330
Northern Illinois University	147703
Northwestern University	147767
Nova Southeastern University	136215
Oakland University	171571

Table 3.1. *Universities in Sample – continued*

University Name	*IPEDS Unit ID*
Occidental College	120254
Ohio University *	204857
Ohio State University *	204796
Oklahoma State University *	207388
Old Dominion University	232982
Oregon Health Sciences University	209490
Oregon State University	209542
Pennsylvania State University *	214777
Philadelphia College of Pharmacy and Science	215132
Pittsburg State University	155681
Polytechnic University	194541
Pomona College	121345
Portland State University	209807
Prairie View A&M University	227526
Princeton University	186131
Providence College	217402
Purdue University *	243780
Reed College	209922
Rensselaer Polytechnic Institute	194824
Rice University	227757
Rochester Institute of Technology	195003
Rutgers the State University of NJ*	186380
Sam Houston State University	227881
San Diego State University	122409
San Francisco State University	122597
San Jose State University	122755
Seton Hall University	186584
Simmons College	167783
Smith College	167835
South Carolina State University	218733
South Dakota School of Mines & Technology	219347
South Dakota State University	219356
Southern Illinois University-Carbondale	149222
Southern Illinois University at Edwardsville	149231
Southern Methodist University	228246
Southern University A&M College	160621
St Cloud State University	174783
St John's University (Jamaica, NY)	195809
St Joseph's University	215770
St Louis University	179159

Table 3.1. *Universities in Sample – continued*

University Name	*IPEDS Unit ID*
St Olaf College	174844
Stanford University	243744
State University of West Georgia	141334
Stephen F Austin State University	228431
Stevens Institute of Technology	186867
Sul Ross State University	228501
SUNY at Albany	196060
SUNY at Binghamton	196079
SUNY at Buffalo	196088
SUNY at Stony Brook	196097
SUNY College at Brockport	196121
SUNY College at Buffalo	196130
SUNY College at Cortland	196149
SUNY College at Fredonia	196158
SUNY College at Geneseo	196167
SUNY College at Oswego	196194
SUNY College of Environmental Sci & Forestry	196103
SUNY Health Science Center at Brooklyn	196255
SUNY Health Science Center at Syracuse	196307
Swarthmore College	216287
Syracuse University	196413
Tarleton State University	228529
Teachers College, Columbia University	196468
Temple University	216339
Tennessee State University	221838
Tennessee Technological University	221847
Texas A&M University, Commerce	224554
Texas A&M University, Kingsville	228705
Texas A&M University *	228723
Texas Christian University	228875
Texas Southern University	229063
Texas Tech University	229115
Texas Woman's University	229179
Thomas Jefferson University	216366
Trinity College (Hartford, CT)	130590
Trinity University	229267
Truman State University	178615
Tufts University	168148
Tulane University	160755
Tuskegee University	102377

Table 3.1. *Universities in Sample – continued*

University Name	*IPEDS Unit ID*
Union College (Schenectady, NY)	196866
United States Coast Guard Academy	130624
United States Naval Academy	164155
University of AK Fairbanks	102614
University of Akron *	200800
University of Alabama	100751
University of Alabama at Birmingham	100663
University of Alabama in Huntsville	100706
University of Arizona	104179
University of Arkansas at Pine Bluff	106412
University of Arkansas for Medical Sciences	106263
University of Arkansas	106397
University of California-Berkeley	110635
University of California-Davis	110644
University of California-Irvine	110653
University of California-Los Angeles	110662
University of California-Riverside	110671
University of California-San Diego	110680
University of California-San Francisco	110699
University of California-Santa Barbara	110705
University of California-Santa Cruz	110714
University of Central Florida	132903
University of Chicago	144050
University of Cincinnati *	201885
University of Colorado *	126614
University of Connecticut	129020
University of Dayton	202480
University of Delaware	130943
University of Denver	127060
University of Detroit Mercy	169716
University of Florida	134130
University of Georgia	139959
University of Hawaii at Manoa	141574
University of Houston	225511
University of Idaho	142285
University of Illinois at Chicago	145600
University of Illinois at Urbana-Champaign	145637
University of Iowa	153658
University of Kansas *	155317
University of Kentucky	157085

Table 3.1. *Universities in Sample – continued*

University Name	*IPEDS Unit ID*
University of Louisiana at Monroe	159993
University of Louisville	157289
University of Maine	161253
University of Maryland at Baltimore	163259
University of Maryland at College Park	163286
University of Maryland Baltimore County	163268
University of Maryland Eastern Shore	163338
University of Massachusetts Lowell	166513
University of Medicine and Dentistry of New Jersey	187222
University of Memphis	220862
University of Miami	135726
University of Michigan, Ann Arbor *	170976
University of Minnesota, Twin Cities *	174066
University of Mississippi *	176017
University of Missouri, Columbia	178396
University of Missouri, Kansas City	178402
University of Missouri, Rolla	178411
University of Missouri, St Louis	178420
University of Montana	180489
University of Nebraska *	181464
University of Nevada-Las Vegas	182281
University of Nevada-Reno	182290
University of New Hampshire	183044
University of New Mexico *	187985
University of North Carolina at Chapel Hill	199120
University of North Carolina at Charlotte	199139
University of North Carolina at Greensboro	199148
University of North Dakota	200280
University of North Texas	227216
University of Northern Iowa	154095
University of Notre Dame	152080
University of Oklahoma *	207500
University of Oregon	209551
University of Pennsylvania	215062
University of Pittsburgh *	215293
University of Rhode Island	217484
University of Rochester	195030
University of San Francisco	122612
University of South Alabama	102094
University of South Carolina, Columbia *	218663

Table 3.1. *Universities in Sample – continued*

University Name	*IPEDS Unit ID*
University of South Dakota	219471
University of South Florida	137351
University of Southern California	123961
University of Southern Mississippi	176372
University of Tennessee	221759
University of Texas - Pan American	227368
University of Texas at Arlington	228769
University of Texas at Austin	228778
University of Texas at El Paso	228796
University of Texas Hlth Sci Ctr Houston	229300
University of Texas Hlth Sci Ctr San Antonio	228644
University of Texas Medical Branch at Galveston	228653
University of Texas Southwestern Med Ctr Dallas	228635
University of the Pacific	120883
University of Toledo *	206084
University of Tulsa	207971
University of Utah	230764
University of Vermont	231174
University of Virginia	234076
University of Washington - Seattle	236948
University of West Florida	138354
University of Wisconsin-Eau Claire	240268
University of Wisconsin-Green Bay	240277
University of Wisconsin-La Crosse	240329
University of Wisconsin-Madison	240444
University of Wisconsin-Milwaukee	240453
University of Wisconsin-Oshkosh	240365
University of Wisconsin-Parkside	240374
University of Wisconsin-Superior	240426
University of Wisconsin-Whitewater	240189
University of Wyoming	240727
Utah State University	230728
Vanderbilt University	221999
Vassar College	197133
Villanova University	216597
Virginia Commonwealth University	234030
Virginia Military Institute	234085
Virginia Polytechnic Institute and State University	233921
Virginia State University	234155
Wake Forest University	199847

Table 3.1. *Universities in Sample – continued*

University Name	*IPEDS Unit ID*
Washington State University	236939
Washington University	179867
Wayne State University	172644
Wellesley College	168218
Wesleyan University	130697
West Texas A&M University	229814
West Virginia University	238032
Western Illinois University	149772
Western Kentucky University	157951
Western Michigan University	172699
Western Washington University	237011
Wichita State University	156125
Williams College	168342
Worcester Polytechnic Institute	168421
Wright State University *	206604
Yale University	130794
Yeshiva University	197708
Youngstown State University	206695

Criteria

In 1980, Victor Wenk (p.22-23), of the National Center of Educational Statistics (NCES), proposed that for federal policy studies the following characteristics of indicators were needed:

1) A conceptual basis readily understandable by all potential audiences
2) Clear delineation of the proper uses and limitations of the method used in building the indicator, its results, and its possible misuses
3) Ease of gathering and updating reliable and timely data.

Ashton (1984, p.38-39) expanded Wenk's suggestions and proposed that the criteria for the selection of variables should be augmented in two ways. First, variables possess face validity; that is, they should be reliable and stable over time, and they should be readily available. Second, formative development of criteria needs to be undertaken through statistical analyses that allow for the elimination of unimportant variables. Specifically, the list of independent variables should be reduced by eliminating variables with low multiple correlations from a correlation analysis. Ashton concluded by proposing that the surviving variables must also make a substantive contribution to the RAI (through their component loadings in a PCA or similar factor analysis). Groth (1990), following Wenk's and Ashton's processes, developed the FSERAI and showed that their approach could be adapted to investigate parallel inquiries on university research activity. The process for selecting the variables used in this study followed the approaches established by Wenk (1980), Ashton (1984), and Groth (1990).

Primary Data Sources

The main data source for this study was the academic R&D expenditures survey administered by the NSF. This survey provided research expenditure data for each university in the sample from the years 1972 through 2007. Date for a number of university characteristics data were obtained from the Integrated Postsecondary Education Data System (IPEDS) database of the National Center of Educational Statistics (NCES). Data collected via IPEDS included student enrollment, number of faculty members (by rank), and faculty salaries. Additional university characteristic data came from individual higher education organizations. Examples included membership in organizations, such as the Association of American Universities (AAU) or a score or ranking, such as the Association of Research Libraries' Library Investment Index (ARL index). The number of graduate students, new graduate students, post-doctorates, and non-faculty research staff came from the Survey of Graduate Students and Post-doctorates (post docs) in Science and Engineering (graduate student survey) conducted by NSF and the National Institutes of Health (NIH).

Variables

The dependent variables, in each of the PC regressions, were the federal R&D expenditures from the R&D expenditures survey administered by the NSF. A large number of independent variables were selected and screened for inclusion in this study, but many failed to meet the criteria for acceptance. The independent variables for the initial screening were selected by reviewing the relevant literature and examining national data bases. Specific attention was paid to the studies that developed and used the Research Activity Index (RAI) (Ashton, 1984; Ashton and Leslie, 1986; Groth, 1990; and Groth, Brown, and Leslie, 1992; Leslie and Brown, 1988). As stated previously, the RAI studies evaluated university research activity, a much broader measure than this study which only evaluated university research expenditures. The RAI studies were important for this study because they provided a method to identify and test university characteristics that determined the amount of federal research funding universities received.

The RAI studies ranked and ordered universities based on a broad range of research variables including the amount of research expenditures by source (federal, state, industry, etc.), the number of scientists employed, number of doctoral students employed, number of post-docs employed, and the number of graduate students enrolled, as well as a university's rank on the Association of Research Libraries Index (ARL). A couple of variables that had been originally included in the RAI studies needed to be excluded from this study due to the fact they were no longer collected: specifically, the number of full-time and part-time scientists as well as total capital expenditures. Additionally, the amount ($) of research expenditures by all sources was excluded because this variable was the focus of this study, and the dependent variable for research question two. In total, eight of the twelve variables used in the RAI studies were included into the PCA for this study.

Next, additional variables were considered and added for evaluation after reviewing previous studies on university research expenditures (Feller, 1996, 2000; Geiger, 1996; Geiger and Feller, 1995; Teich, 2000; Teich and Gramp, 1996) and university involvement in technology transfer and economic development (Bloch, 2007; Douglas, 2007; Feldman, 1994; Leyden and Link, 1992; Mansfield and Lee, 1996; Yusuf, 2007). In part as a replacement for the number of scientists employed variable used in the RAI studies, the number of faculty members by rank was included in the analysis. Other variables added at this time included additional university demographic variables, such as Land-Grant institution, Carnegie Classification, or an AAU member, and whether the university was affiliated with a hospital or a medical school. The Carnegie Classification variable was broken into five distinct variables, one for each Carnegie Classification, and was coded as binary (yes/no).

The inclusion of the number of faculty members by rank and salary, university demographics, and whether a university was affiliated with a medical school or hospital is supported by the conceptual framework of this analysis. The conceptual framework of the study, the resource-based theory of the firm (see chapter 2 for further discussion), suggests that a firm's (in this study a university's) characteristics, which include assets and capabilities, can give it a competitive advantage over other firms. An argument can be made that high salaried faculty represent the "highest functioning" members across the academy (not withstanding cost of living adjustments based on location). It stands to reason that the "highest functioning" faculty members are producing research at or near the top levels within their field and, in turn, would likely be awarded funding in a competitive review process. Following that train of thought, universities that employ the "highest functioning" faculty members are then conceivably at a competitive advantage in obtaining federal research funding. Thus the inclusion of not only how many faculty members are employed, but also who (based on average salary) is employed, is reasonable. Inclusion of indentified university demographic variables from previous studies allows for the examination of additional university characteristics. Lastly, the inclusion of which universities are affiliated with a hospital or a medical school is practical. Universities with hospitals and medical schools are likely to have an advantage over other universities in obtaining federal research funding as more than half (55% in fiscal year 2007) of all federal R&D expenditures comes from the biological sciences and medical sciences disciplines.

Table 3.2 lists the variables that were selected from the literature, passed through the first cut of screening and subsequently were tested in the PCAs.

Table 3.2. *Variables Selected for Testing in the PCAs*

Name	Source	Description
Religious Institution	IPEDS	(Y/N) university affiliated with a religious denomination
Land Grant University	IPEDS	(Y/N) university is charted as a Land Grant University
AAU Member	AAU	(Y/N) university is a member of the AAU
Control of University	IPEDS	Public or private control of university
Hospital Affiliated	IPEDS	(Y/N) university affiliated with hospital
Medical Degree	IPEDS	(Y/N) university grants medical degree
Carnegie Classification	IPEDS	Type of institution by Carnegie Classification (5 binary)
ARL Index Score	ARL	Score on the ARL Index
% Change in Federal R&D	NSF	% yearly change federal R&D–average 4 previous years
Equipment Expenditures	NSF	$, total research equipment expenditures (in thousands)
Average Salary Assistant	IPEDS	$, average salary assistant professors
Average Salary Associate	IPEDS	$, average salary associate professors
Average Salary Professor	IPEDS	$, average salary professors
Total Assistant Professors	IPEDS	# of assistant professors
Total Associate Professors	IPEDS	# of associate professors
Total Professors	IPEDS	# of professors
Graduate Students	NSF/NIH	# of graduate students
Post Docs	NSF/NIH	# of post-doctorate positions
Non-Faculty Researchers	NSF/NIH	# of non-faculty research staff
Doctoral Degrees	NSF/NIH	# of doctoral degrees awarded

Statistical Methods

Research Question One

To answer the first research question, a two stage process was undertaken. First, a review of the literature of previous studies on university research activity and research funding was undertaken to identify university characteristics to be evaluated in a principal components analysis (PCA). PCA is a method of data reduction that transforms a number of variables that may or may not be correlated into a smaller number of uncorrelated sets, which are called "principal components". PCA seeks to find the smallest number of linearly weighted combinations of observed variables that maximize the proportion of the total variation (Jolliffe, 2002). Unlike (common) factor analysis, which analyzes the common variance, the original matrix in a PCA specifies the total variance explained by the components (variables) and assumes that each original measure is without measurement error. "Common" factor analysis yields maximally independent factors, i.e., clusters of variables yielded when one shoots rotated (90 degrees) vectors through the data in a three-dimensional space. The object of PCA is to maximize the variance of a single "factor" when one has in mind examining a single concept, in this case research funding.

The selection of PCA to address the first research question was informed significantly by earlier parallel efforts (see Ashton, 1984, and Groth, 1990, in particular) that developed the RAI studies.[8] The primary objective of developing the PCA in this study was to derive a set of explanatory variables that explained the amount of federal research funding a university receives. For this study, the RAI studies were used as a guide and as such, a PCA was completed to derive

[8] As it was noted previously, the RAI studies differed from this study in that they evaluated university research activity, while this study evaluated university research expenditures. The RAI studies used PCA to reduce a large set of variables and empirically identify influential variables on university research activity.

a set of explanatory variables to be used in a regression analysis answering research question two.

The first step in developing the PCA was to include the same variables used in the RAI studies by Ashton (1984), Ashton and Leslie (1986), Groth (1990), and Groth, Brown, Leslie (1992), and Leslie and Brown (1988) except that the amount ($) of research expenditures (the "dependent variable in this study) was excluded. Next, six variables specifying the number of faculty members, average faculty salary by rank, university demographics and the medical school/hospital variable were added. This resulted in twenty-two variables to be tested. Data were collected for the selected variables for each university in the population for the years 1972 through 2007 (where available) and were loaded into a single longitudinal data base.

Second, following Ashton's (1984) suggestion to reduce the number of variables to the most efficient number, a multiple step data reduction process was applied to all initially selected variables. The first step in testing the variables within a PCA is an examination of the correlation matrix. Any variables with consistently weak correlations with others were removed. Second, an analysis of the anti-image correlations was conducted as a check for a measure of sample adequacy (MSA) with variables below .50 being removed. Third, a check of the Kaiser-Meyer-Olkin (KMO) measure of sample adequacy (overall model MSA) and Bartlett's Test of Sphericity were completed. If KMO was under .500 or the significance level of Bartlett's Test above 0.001, variables were removed to correct for model fit (Jolliffe, 2002). Fourth, an evaluation of the communalities was undertaken. Communalities represent the proportion of variance in the original variables that is accounted for by the factor solution and the factor solution should explain at minimum half (≥0.50) of the original variables' variance (Jolliffe, 2002). Variables under 0.50 were removed from the analysis. Lastly, a check of a variable's complex structure was completed. Complex structure occurs when one variable has high loadings (>0.40) on more than one component (Jolliffe, 2002). If a variable had a complex structure it was removed from the analysis. If a variable was removed at any step in testing the PCA was recalculated and testing started over at step one.

PCA was selected as a data reduction technique over factor analysis because PCA has a straightforward principal component method while factor analysis uses inferential assumptions. A PCA can be developed by indentifying *n* explanatory variables in a functional relationship. Each principal component is a linear combination of the original variables, with coefficients equal to the Eigenvectors of the correlation or covariance matrix (Jolliffe, 2002). Consider the following linear functions of these variables:

$$c_1 = a_1x_1 + a_2x_2 + \cdots + a_nx_n$$

$$c_2 = b_1x_1 + b_2x_2 + \cdots + b_nx_n$$

$$\vdots$$

$$c_n = n_1x_1 + k_2x_2 + \cdots + n_nx_n$$

If we choose values of a from the 1st equation such that the variances are maximized subject to the requirement that

$$a_1^2 + a_2^2 + \ldots + a_n^2 = 1$$

This restriction, referred to as the normalization condition, is necessary to ensure that the value of c_1 is not indefinitely increased and guarantees that the Eigenvectors have unit length (Jolliffe, 2002). c_1 is called the first principal component and it is a linear function of the explanatory variables (x_i) that has the greatest variance. The sum of the variances of the principal component is equal to the sum of the variances of the original independent variables, that is

$$var\,(c_1) + var(c_2) + \ldots + var(c_n) = var(x_1) + var(x_2) + \ldots + var(x_n)$$

The variability of the principal components is no different than the variability of the original independent variables. The first principal component should be able to explain variations in the value of the dependent variable better than any other linear combination of explanatory variables subject to the normalization rule. We then can consider other linear functions, such as c_2 which is uncorrelated with c_1, subject to the condition that

$$b_1^2 + b_2^2 + \ldots + b_n^2 = 1$$

c_2 is said to be the second principal component and this procedure is repeated we have k linear functions c_1, c_2, …, c_k, which are called the principal components of the x_i.

The principal components are then sorted in descending order by Eigenvalue, which are equal to the variances of the components. Following Jolliffe's (2002) recommendation, multiple steps were taken in indentifying which principal components to retain in the study. First, in examining the cumulative percentage of total variation to which the principal components contribute, the number of principal components that fell in a range between seventy to ninety percent were indentified and retained. This range indentified the smallest number of principal components accounting for the largest amount of variance. Second, following "Kaiser's rule" (Jolliffe, 2002), the number of principal components with an Eigenvalue over 1.0 were identified and retained. Finally, an examination of the Scree plot graph was undertaken. Looking at where the Scree plot graph defines a straight, horizontal line, the first point on that straight line is chosen to be the last principal component. All variables to the right of this chosen last principal component were excluded from the study.

Research Question Two

To address the second research question, a series of principal components regression models (PC regression) were developed for each data year. The independent variables used in the PC regression models were derived from the PCA completed for research question one. The PC regression models were similar in structure and form to an OLS regression model (Montgomery, Peck, and Vining, 2001). These regression models were constructed to establish whether the set of principal components indentified in research question one explain a statistically significant proportion of the variance in federal research expenditures among the sample of universities. The dependent variable for the PC regression models was lagged two years (ex: federal R&D expenditures fiscal year 2007 used independent variables from fiscal year 2005). This was to account for time needed for changes to a university's characteristics (ex: hiring of faculty members) that could impact the amount of federal research funding a university receives

The use of PC regression was chosen for this analysis because of its desirable properties compared to an OLS regression. First, a PCA reduces the number of independent variables within an analysis and indentifies the most influential ones. Using a PC regression does not substantially degrade the model fit to the original data and results in a more plausible relationship model (i.e. by using less explanatory variables) than can be obtained via an ordinary OLS model (Montgomery, Peck, and Vining, 2001). Second, unlike the original explanatory variables, the principal components, are mutually orthogonal (i.e. they are uncorrelated). In other words, there is zero multicollinearity among the principal components (Jolliffe, 2002). This was a concern for this study because an OLS model was initially developed for the twenty-two independent variables and it showed numerous collinearity issues.

Following the guidelines of Jolliffe (2002) and Liu et al. (2002), the first step in a PC regression is to compute the standardized dependent variable and the *n* standardized independent variables to set-up *p* standardized principal component regression equations.

$$Y' = (Y - \bar{Y}) / S_Y \qquad (1)$$

$X_i' = (X_i - \bar{X}_i)/S_{Xi}$ (*i* = 1, …, *n*) (2)

$C_i = a_{i1}X_1' + a_{i2}X_2' + \ldots + a_{ip}X_n'$ (*i* = 1, …, *p*) (3)

where Y' stands for the standardized dependent variable, Y the dependent variable, S_Y the standard deviation of dependent variable, $\bar{Y}$ the mean of dependent variable, X_i' the *i*th standardized independent variable, X_i the *i*th independent variable, $\bar{X}_i$ the mean of the *i*th independent variable, S_{Xi} the standard deviation of the *i*th independent variable, C_i the *i*th principal component, a_{ij} the coefficient of principal component matrix (consisting of C_i and X_i').

Next, a determination of the best standardized principal component regression equation, based on adjusted R^2 and standard error of estimates is completed.

$\hat{y}_j' = \sum B_i' C_i$ (*j* = 1, …, $m \leq p$; *i* = 1, …, $K \leq n$) (4)

where $\hat{y}_j'$ is the estimate of the *j*th standardized principal component regression equation, B_i' the *i*th standardized partial regression coefficient.

Applying the computation of the principal components based on the standardized independent variables (equation 3) to the best standardized principal component regression (equation 4) yields the standardized linear regression equation.

$\hat{y}' = \sum b_i' X_i'$ (*i* =1, ..., $K \leq n$) (5)

where $\hat{y}'$ is the estimate of the standardized linear regression equation, b_i' is the *i*th standardized partial regression co-efficient of the standardized linear regression equation.

After a computation of the partial regression coefficients (equation 6) and constant (equation 7), a final transformation of the standardized linear regression equation into the general linear regression equation is completed (equation 8).

$b_i = b_i' (\frac{Lyy}{Lx_i x_i})^{1/2}$ (*i* = 1, …, $K \leq n$) (6)

$$b_0 = \hat{Y} - \sum b_i \hat{X}_i \qquad (i = 1, \ldots, K \leq n) \qquad (7)$$

$$\hat{y} = b_0 + \sum b_i X_i \qquad (i = 1, \ldots, K \leq n) \qquad (8)$$

where b_i is the *i*th partial regression coefficient of the general linear regression equation, *Lyy* the sum of squares of dependent variable Y, Lx_ix_i the sum of squares of the *i*th independent variable X_i, b_o the constant of the general linear regression equation.

To answer the sub-questions of research question two, the sample was divided into smaller groups. For examining differences between public and private universities, the sample was divided into two sub-groups. For each of these two data sub-sets, a series of PC regressions were developed using the same process and initial variables used for research question two. For examining differences between types of universities, the sample was divided into smaller groups based on the Carnegie Classification system. For each of these data sub-sets, a series of PC regressions was developed using the same process and initial variables used for research question two.

Research Question Three

Here, each university's federal research expenditures were examined for each year to determine whether a "federal research funding hierarchy" existed. Two methods were used to group universities at five year intervals. First, a cluster analysis was performed to "group objects of similar kind" into respective units. The cluster analysis indentified homogenous subgroups of cases within the population by defining a measure of similarity between observations and then applying a set of rules to classify observations into groups based on their inter-observation similarities (Montgomery, Peck, and Vining, 2001). Specifically, the cluster analysis identified and grouped sets of universities that were similar in regard to federal expenditures. The cluster analysis minimized both within-group variation and maximized between-group variation. In short, it was aimed at sorting universities into groups so that the degree of association was maximal if they belonged to the same group and minimal otherwise. Due to the large number of universities in the population (n>250), a two-step cluster analysis was utilized. A two-step cluster analysis was utilized to minimize scaling issues that may have arisen from the one-step process. The two-step process first created pre-clusters and then it "clustered the pre-clusters" using hierarchical methods.

For the second method, universities were grouped based on their percentage shares of the sum of all federal research expenditures. Geiger and Feller (1995) suggested that the most succinct way to gauge a university's participation in the research economy and to measure its change over time was by a university's percentage share of total federal research expenditures. This approach also obviated the issues of whether current or constant dollars should be used in an analysis over time (Geiger, 1996). This method was used by Geiger and Feller (1995) and Geiger (1996) to establish that a hierarchy existed between universities based on their academic research funding and to explain how universities' shares of research funding changed during the 1980s. The groupings included the following: all universities with at least a two percentage point share of the total federal R&D expenditures, all universities between a one and a half and one and ninety-nine hundredths share, all universities between a one and one and forty-nine hundredths percentage share, all universities between a half and ninety-nine hundredths share, and all universities below a half percentage share. The present study roughly doubles the number of universities in the sample compared with previous studies that addressed hierarchies in academic research funding (Geiger and Feller, 1995; Geiger, 1996).

To answer the sub-questions of research question three, the sample was examined at various points in time to determine whether the hierarchies changed over time. Universities earning the largest percentage of the total federal research expenditures were ranked at the top and the universities awarded the smallest percentage at the bottom. Movements of universities between groups (using both methods of groupings from research question three**)** over the various five-year intervals were noted. Universities were identified as either "movers" or "non-movers" if (1) they had moved significantly up or down the hierarchy and (2) had changed the group of universities in which they had been clustered in either of the two methods. To determine what accounted for movement, a series of PC regressions (same models as used in research question two) were employed to explain why universities were "movers or "non-movers".

Limitations

There are several limitations of this study. First, thirty-one of the universities in the sample (8.3%) reported their R&D expenditure data on a system-wide, multiple campuses basis whereas their university characteristics were reported on an individual campus basis.[9] For these cases, the choice was made to go forward and use data that contained both combined and individual campus data due in many cases, to the fact that branch campuses do not conduct much, if any, of the research undertaken within a particular university.

Second, there were very few data elements missing for some universities or particular year. The most specific issue concerned the use of the ARL index score, as many universities were not ARL members. The lowest ARL index score for a given year was assigned to all universities that did not have an ARL index score. In spite of this problem with the ARL index, it was included because previous research, specifically the RAI studies, showed that the index was a potent

[9] See appendix A for specific details on which universities had combined campuses that created data issues; most common issue was research expenditures on the Research and Development Expenditures at Universities and Colleges survey were reported for all campuses of a university while for IPEDS, the ARL Index, and graduate student survey data were reported as individual campuses of a university.

variable for understanding the research process. The inclusion was aimed to positively impact the validity of findings, while not adversely affecting the reliability of models or findings.

Third, the sample of universities was limited to 375 institutions, a limitations based on the requirement that R&D expenditure data was provided for all years from 1972-2007 in the Research and Development Expenditures at Universities and Colleges survey. While these universities are the main players in the academic research, accounting for over 90% of all federal R&D expenditures in any given year, some universities receiving significant federal research funding are not included.

Summary

The five sections on date sources and research design were specified in detail. A supporting analytical framework was presented; the criteria for selection of the research variables were identified; and the selection of the sample of research universities was described. The statistical methods for reducing and indentifying the principal variables (components) and their influence on the amount of federal R&D expenditures were presented. The two methods for grouping universities to determine R&D hierarchies were detailed. Finally, the limitations of the study were discussed.

CHAPTER 4

FINDINGS

This chapter is divided into three sections. The first section discusses the university characteristics that explain the amount of federal research funding a university receives (measured by convention as research expenditures) and how the characteristics change over time. The second section evaluates the relative importance of the identified characteristics in explaining variations in federal research expenditures and how they change over time. The third section evaluates and identifies discrete university groupings or “clusters” and determines whether they reflect the “hierarchy” posited by Geiger and Feller (1995), Geiger (1996) and Teich (2000). Additionally, these groups and “clusters” are examined to identify how they change over time.

Identified University Characteristics

A two-stage process was undertaken to identify university characteristics (variables) that explain the amount of federal research funding a university receives. The first step in the process was a review of relevant literature of previous studies on university research activity and research funding and an examination of national data bases. Specific attention was paid to the studies that developed and used the Research Activity Index (RAI; Ashton, 1984; Ashton and Leslie, 1986; Groth, 1990; Groth, Brown, and Leslie, 1992; and Leslie and Brown, 1988), studies on university research expenditures (Feller, 1996; 2000; Geiger, 1996; Geiger and Feller, 1995; Teich, 2000; Teich and Gramp, 1996) and studies on university involvement in technology transfer and economic development (Bloch, 2007; Douglas, 2007; Feldman, 1994; Leyden and

Link, 1992; Mansfield and Lee, 1996; Yusuf, 2007). Table 3.2 (chapter 3) lists the variables selected from the literature, then passed through screening for acceptance (as detailed in chapter 3) and subsequently tested for inclusion in the analysis.

Several issues surrounded the selection of variables for this study. First, as detailed previously in chapter 3, the RAI studies were used as a guide in developing this study as they provided a method to identify and test university characteristics that determined the amount of federal research funding universities receive. Some of the variables in the RAI studies were excluded due to the fact they are no longer collected by the federal government: Specifically the number of full-time and part-time scientists and total capital expenditures. The variables for the number of scientists were replaced in this study by the number of faculty members by academic rank. The total capital expenditures variable was replaced by the amount of R&D equipment expenditures. Second, two of the variables used in the RAI studies were excluded and replaced for this study due to data issues. The RAI studies used the number of full-time and part-time graduate students. In examining the data provided by the Survey of Graduate Students and Postdoctorates in Science and Engineering (graduate student survey conducted by the NSF and NIH), a number of universities (6% -7% within a given year) did not provide the number of full-time or part-time graduate students. All of these universities did, however, provide the total number of graduate students (regardless of enrollment status), so the choice was made to use this variable as a replacement. Third, a university's score on the ARL index was used in the RAI studies as well as this study. However, not all the universities in the sample are members of the ARL. Following the same decision rules as the RAI studies, universities that were not members of the ARL in a given year were assigned the lowest ARL value, since these universities did not qualify for ARL membership.

The second step in the process of identifying university characteristics (variables), that explain the amount of federal research funding received, was to apply a Principal Components Analysis (PCA) to all variables selected for screening, as a way to reduce the number variables for this study. PCA is a method of data reduction that transforms a number of variables that may or may not be correlated into a smaller number of uncorrelated sets that are called “principal components.” A key objective of this analysis was to identify specific university characteristics that explain the amount of federal research funding and to identify, whether, over time, there was a change in the identified university characteristics. The choice of examining the change over time required multiple years of data analysis, however, there were again data issues that limited the study. First, the earliest available faculty data (number and salary) by faculty rank was 1988. Second, the federal government (IPEDS) did not collect or release data on faculty data by rank for fiscal years 1989 and 2001.

When building the PCAs in 5-year increments, only 4 PCAs over a 15 year time period (1992, 1997, 2002, and 2007) could be developed due to data availability for all variables to be screened. Additionally, the original plan in the analysis was to test the multiple PCAs on a 1-year, 2-year, and 3-year lags to determine which lag produced the best models. The idea behind using the 1, 2, and 3-year lags in the PCAs is that the investment by a university in faculty and facilities does not result in an immediate “pay-off” in federal R&D funding. Typically there is a short time period, one to three years, from when a university invests money in faculty and facilities, and when the university can expect to receive federal R&D funding. An example of using lags in building the lagged PCAs is as follows: for the 1-year lagged 2007 PCA, the 2006 independent variables would be used, for the 2-year lagged 2007 PCA, 2005 independent variables would be used, and for the 3-year lagged 2007 PCA, 2004 independent variables would be used. However, due to missing faculty data in fiscal years 1989 and 2001, the 1-year and 3-year lag PCAs could not be built for all 4 models (years). This resulted in only the 2-year lag PCAs being developed and used in this analysis (0-year lag or same year data models were developed and are included in Appendix B for comparison).

Table 4.1. *$ Values for Weighting to 1992 Model*

	Dependent Variable weighting value in 1992$s	Independent Variables weighting value in 1990$s
$1 in 1992 model =	$1.00	$1.00
$1 in 1997 model =	$0.87	$0.84
$1 in 2002 model =	$0.78	$0.75
$1 in 2007 model =	$0.68	$0.66

To measure accurately the value of a dollar over time, all dollar values in the 1997, 2002, and 2007 models were transformed from their nominal dollar values to the real dollar values of the 1992 model (dependent variables were transformed to 1992 values while independent variables were transformed to 1990 values to account for the 2-year lag in the models). To determine the real value of a dollar in 1990 and 1992 for these three PCAs, the Consumer Price Index (CPI) was used (comparing rates from December to December between the indentified years). An example applying this transformation can be seen with the 2007 model where the dependent variable (federal R&D expenditures) was multiplied by 0.68 and the independent variables of equipment expenditures and mean faculty salaries (all ranks) variables were multiplied by 0.66. Table 4.1 above has the transformation values for each model (year) based on the CPI index.

The CPI and the Producer Price Index (PPI) are two common measures of price change over time produced by the U.S. Bureau of Labor Statistics. The choice to use the CPI over the Producer Price Index (PPI) was made because the CPI captures the dollar value for goods that are the out-of-pocket expenditures by American consumers, regardless of where the goods are produced. The PPI targets the dollar value of goods produced by American producers, regardless of where they are consumed. The CPI was deemed to be more appropriate to address the change over time of the value of the dollar in these variables since the both the dependent and independent variables in this study were either expenditure variables (what a university expended dollars for, i.e. spent on goods and services) or faculty salary (expenditures on service provided to the university by faculty members).

The 2-year lag 2007 PCA was the first PCA developed. The initial examination of the correlation matrix showed that there were a sufficient number of correlations between variables in the PCA to continue the analysis. The first variables removed from the 2-year lag 2007 PCA were during the analysis of the anti-image correlations. All five of the Carnegie Classification variables (Doctoral, Masters, Baccalaureate, Medical, and Engineering) were removed at this stage. The variables for Land-Grant status and the percentage change in federal R&D were removed in the next stage of the analysis, the evaluation of communalities. As stated in chapter 3, communalities represent the proportion of variance in the original variables that is accounted for by the factor solution and the factor solution should explain at minimum half (≥ 0.50) of the original variables' variance (Jolliffe, 2002). The last variables removed from the 2-year lag 2007 PCA were due to their complex structure. As discussed previously in chapter 3, complex structure occurs when one variable has high loadings (>0.40) on more than one principal component (Jolliffe, 2002). The variables for religious institution, the number of non-faculty researchers, the number of post-docs, and AAU membership status were removed in this step.

The 2-year lag 2002 PCA was then developed. The initial examination of the correlation matrix showed that there were a sufficient number of correlations between variables in the 2-year lag 2002 PCA to continue the analysis. Like the 2-year lag 2007 PCA, the first variables removed from the 2-year lag 2002 PCA were all five of the Carnegie Classification variables during the analysis of the anti-image correlations. In the next step, the analysis of the communalities, the variables for Land-Grant status and the percentage change in federal R&D were removed. Finally, in the final step of checking for complex structure, the variables for religious institution, the number of non-faculty researchers, the number of post-docs, and AAU membership status were removed.

The 2-year lag 1997 PCA was developed next. The initial examination of the correlation matrix showed that there were a sufficient number of correlations between variables in the PCA to continue the analysis. Like the 2-year lag 2007 PCA and the 2-year lag 2002 PCA, all five of the Carnegie Classification variables were removed after the analysis of the anti-image correlations. However, the 2-year lag 1997 PCA was different from the two previously developed PCAs because the variable for the percentage change in federal R&D was also removed during this stage. In the analysis of communalities, the variable for Land-Grant status was removed. Next, in the check for complex structure, the variables for religious institution, the number of post-docs, and the number of non-faculty researchers and were removed. Lastly, in a final re-check of the communalities, the variable for control was removed.

The 2-year lag 1992 PCA was the last PCA developed. The initial examination of the correlation matrix showed that there were a sufficient number of correlations between variables in the PCA to continue the analysis. Like the 2-year lag 2007 PCA and the 2-year lag 2002 PCA, during the analysis of the anti-image correlations all five of the Carnegie Classification variables were identified to be removed. Next, during the check for communalities, the variables for Land-Grant status and the percentage change in federal R&D variable were removed. The analysis for complex structure revealed that the variables for religious institution, the number of post-docs, the number of non-faculty researchers, and AAU membership were to be removed. In a re-check of the commonalities the control variable was removed. Finally, during a re-check of the complex structure the number of doctoral degrees awarded variable was removed. Table 4.2 below presents the complete list of variables that were retained for the four 2-year lag PCAs. The variables that are retained in each PCA are the characteristics identified that explain the amount of federal research funding received for a given year.

Table 4.2. *Variables Kept in 2-Year Lag PCAs*

1992	1997	2002	2007
Hospital Affiliated	Hospital Affiliated	Hospital Affiliated	Hospital Affiliated
Medical Degree	Medical Degree	Medical Degree	Medical Degree
ARL Index Score	ARL Index Score	ARL Index Score	ARL Index Score
Equipment Expend	Equipment Expend	Equipment Expend	Equipment Expend
Avg. Salary Assistant	Avg. Salary Assistant	Avg. Salary Assistant	Avg. Salary Assistant
Avg. Salary Associate	Avg. Salary Associate	Avg. Salary Associate	Avg. Salary Associate
Avg. Salary Professor	Avg. Salary Professor	Avg. Salary Professor	Avg. Salary Professor
# Assistant Professors	# Assistant Professors	# Assistant Professors	# Assistant Professors
# Associate Professors	# Associate Professors	# Associate Professors	# Associate Professors
# Professors	# Professors	# Professors	# Professors
# Graduate Students	# Graduate Students	# Graduate Students	# Graduate Students
	# Doctoral Degrees	# Doctoral Degrees	# Doctoral Degrees
	AAU Status	Control	Control

As table 4.2 shows, the variables retained in each of the four 2-year lag PCAs were not the same. Since research question two required the development of PC regression models for each of the four years, there was a desire for modeling and analysis purposes to have the same variables for each yearly model. Since the 1992 2-year lag PCA had the smallest number of variables (eleven) retained in a PCA, and all of its retained variables were retained in the other three PCAs, the decision was made to re-run the other three PCAs with the same variables as the 1992 2-year lag PCA. All three of the re-developed yearly PCAs (1992, 2002, 2007) based on the 1992 PCA tested positively for model fit and passed the multiple stages of data reduction (examination of correlation, analysis of anti-image correlations, check of KMO and Bartlett's Test of Sphericity, evaluation of communalities, and check for complex structure). The re-developed 1997, 2002, and 2007 2-year lag PCAs were then kept as the PCAs for these years for the remainder of this study. The original 2-year lag PCAs for 1997, 2002, and 2007 are presented in Appendix C.

Table 4.3. *Eigenvalues for 2-Year Lag PCAs*

Principal Component	1992	1997	2002	2007
Prin_1	5.877	5.704	6.027	5.984
Prin_2	1.910	2.236	2.030	1.987
Prin_3	1.261	1.218	1.143	1.186
Prin_4	0.619	0.613	0.577	0.566
Prin_5	0.348	0.354	0.350	0.344
Prin_6	0.287	0.301	0.314	0.323
Prin_7	0.213	0.219	0.213	0.234
Prin_8	0.198	0.121	0.109	0.145
Prin_9	0.138	0.098	0.090	0.098
Prin_10	0.084	0.078	0.083	0.069
Prin_11	0.065	0.058	0.065	0.064

For each of four PCAs, the first three principal components were retained based on the evaluation of their Eigenvalues and Scree plot graphs. As stated previously in chapter 3, principal components with an Eigenvalue over 1.0 and principal components to the left of where the Scree plot graph defines a straight, horizontal line are to be retained (Jolliffe, 2002). Table 4.3 contains the Eigenvalues for the 2-year lag PCAs, specifically showing that the first three principal components are to be retained in the analysis (appendix D displays the Scree plot graphs for each PCA).

For all four of the 2-year lag PCAs, the first principal component seemed to reflect the ARL index score, the amount of research expenditures, the number of assistant professors, the number of associate professors, the number of professors, and the number of graduate students and was labeled “resources” accordingly. In all four of the 2-year lag PCAs, the second principal component appeared to capture the amount of dollars spent on faculty salaries for all ranks and was labeled “salary” accordingly. In all four of the 2-year lag PCAs, the third principal component appeared to suggest whether a university was affiliated with a hospital and granted medical degrees and was labeled “medical” accordingly. The first three principal components (PCs) and their original variable loading matrixes for each of the four 2-year lag PCAs are summarized in tables 4.4.a, 4.4.b, 4.4.c, and 4.4.d below.

Table 4.4.a. *Component and Variable Loading Matrixes for the 3 PCs – 2007 2-Year Lag PCA*

Variable	Resources	Salary	Medical
Hospital Affiliated	0.110	0.120	0.911
Medical Degree	0.357	0.134	0.809
ARL Index Score	0.744	0.355	0.248
Equipment Expenditures ($)	0.621	0.300	0.308
# of Assistant Professors	0.918	0.014	0.120
# of Associate Professors	0.913	0.034	0.123
# of Professors	0.912	0.267	0.136
Average Salary Assistant Professors	0.224	0.915	0.101
Average Salary Associate Professors	0.122	0.953	0.075
Average Salary Professors	0.223	0.924	0.176
# of Graduate Students	0.828	0.287	0.182

Rotation Method: Varimax with Kaiser Normalization.

Table 4.4.b. *Component and Variable Loading Matrixes for the 3 PCs – 2002 2-Year Lag PCA*

Variable	Resources	Salary	Medical
Institution has Hospital	0.133	0.148	0.903
Institution grants medical degree	0.354	0.141	0.814
ARL Index Score	0.714	0.390	0.208
$ Research Equipment Expenditures	0.664	0.370	0.237
# of Assistant Professors	0.898	0.003	0.179
# of Associate Professors	0.902	0.005	0.169
# of Professors	0.919	0.243	0.115
Average Salary Assistant Professors	0.201	0.937	0.103
Average Salary Associate Professors	0.133	0.948	0.095
Average Salary Professors	0.214	0.924	0.177
# of Graduate Students	0.837	0.306	0.157

Rotation Method: Varimax with Kaiser Normalization.

Table 4.4.c. *Component and Variable Loading Matrixes for the 3 PCs – 1997 2-Year Lag PCA*

Variable	Resources	Salary	Medical
Institution has Hospital	0.116	0.112	0.908
Institution grants medical degree	0.355	0.080	0.822
ARL Index Score	0.754	0.292	0.239
$ Research Equipment Expenditures	0.684	0.281	0.244
# of Assistant Professors	0.886	-0.035	0.119
# of Associate Professors	0.905	0.024	0.119
# of Professors	0.937	0.172	0.091
Average Salary Assistant Professors	0.175	0.946	0.053
Average Salary Associate Professors	0.081	0.965	0.050
Average Salary Professors	0.221	0.922	0.170
# of Graduate Students	0.848	0.265	0.219

Rotation Method: Varimax with Kaiser Normalization.

Table 4.4.d. *Component and Variable Loading Matrixes for the 3 PCs – 1992 2-Year Lag PCA*

Variable	Resources	Salary	Medical
Institution has Hospital	0.100	0.089	0.902
Institution grants medical degree	0.334	0.052	0.827
ARL Index Score	0.731	0.266	0.296
$ Research Equipment Expenditures	0.685	0.260	0.362
# of Assistant Professors	0.913	0.077	0.113
# of Associate Professors	0.901	0.105	0.076
# of Professors	0.910	0.208	0.095
Average Salary Assistant Professors	0.218	0.891	0.023
Average Salary Associate Professors	0.149	0.946	0.072
Average Salary Professors	0.236	0.911	0.137
# of Graduate Students	0.829	0.296	0.230

Rotation Method: Varimax with Kaiser Normalization.

Evaluation of Relative Importance of University Characteristics

Four principal components regression models (PC regression) were developed for each of the 2-year lag PCAs to evaluate the relative importance of the identified characteristics in explaining variations in federal research expenditures. As discussed previously in chapter 3, PC regression models are similar in structure, form, and interpretation to an ordinary OLS regression model (Montgomery, Peck, and Vining, 2001). For the PC regression models in this study, the dependent variable is the amount of federal R&D expenditures in a given fiscal year (in thousands $). The initial steps in developing the PC regression models required the construction of the standardized dependent and independent variables for all four PC regressions (equations 1 and 2 from chapter 3). Taking the coefficients a_{ij} from the corresponding (year) table 4.4, a computation of the principal components based on the standardized independent variables was then calculated (equation 3). The next step required a determination of the best standardized principal component regression equation, based on adjusted R^2 and standard error of estimates (equation 4). Three standardized principal component regression equations were completed for each yearly model since there were three principal components retained for each of the four PCAs. Tables 4.5.a, 4.5.b, 4.5.c, and 4.5.d present the standardized partial regression coefficients of the standardized principal component regression equations and their collinearity statistics. The collinearity statistics, VIF and tolerance, for each of the standardized principal component regressions for all four PC regressions fell within acceptable ranges. Tolerance levels lower than .25 and VIFs greater than 4 are arbitrary but common cut-off criteria for deciding when a given independent variable displays "too much" multicollinearity: Values below .25 or above 4 suggest a multicollinearity problem.

Table 4.5.a. *Standardized Partial Regression Coefficients and Collinearity Statistics – 2007*

Model	B_i^'	Std. Error	*T*	*P*	Tolerance	VIF
1 C1	0.151	0.007	20.645	0.000	1.00	1.00
2 C1	0.108	0.011	10.157	0.000	0.44	2.28
2 C2	0.079	0.015	5.349	0.000	0.44	2.28
3 C1	0.063	0.013	4.780	0.000	0.27	3.74
3 C2	0.055	0.015	3.718	0.000	0.40	2.49
3 C3	0.144	0.026	5.541	0.000	0.29	3.50

Table 4.5.b. *Standardized Partial Regression Coefficients and Collinearity Statistics – 2002*

Model	B_i^'	Std. Error	*T*	*P*	Tolerance	VIF
1 C1	0.151	0.007	20.670	0.000	1.00	1.00
2 C1	0.104	0.011	9.810	0.000	0.44	2.28
2 C2	0.085	0.014	5.999	0.000	0.44	2.28
3 C1	0.071	0.013	5.254	0.000	0.26	3.85
3 C2	0.068	0.015	4.653	0.000	0.40	2.52
3 C3	0.105	0.027	3.831	0.000	0.27	3.70

Table 4.5.c. *Standardized Partial Regression Coefficients and Collinearity Statistics – 1997*

model	B_i^'	Std. Error	*T*	*P*	Tolerance	VIF
1 C1	0.148	0.008	19.602	0.000	1.00	1.00
2 C1	0.119	0.010	12.282	0.000	0.58	1.73
2 C2	0.065	0.014	4.619	0.000	0.58	1.73
3 C1	0.080	0.013	6.216	0.000	0.31	3.20
3 C2	0.051	0.014	3.626	0.000	0.55	1.81
3 C3	0.121	0.027	4.522	0.000	0.33	3.02

Table 4.5.d. *Standardized Partial Regression Coefficients and Collinearity Statistics – 1992*

Model	B_i^'	Std. Error	*T*	*P*	Tolerance	VIF
1 C1	0.137	0.008	17.202	0.000	1.00	1.00
2 C1	0.113	0.012	9.355	0.000	0.43	2.33
2 C2	0.048	0.018	2.663	0.008	0.43	2.33
3 C1	0.052	0.015	3.431	0.001	0.25	4.05
3 C2	0.040	0.017	2.332	0.020	0.43	2.34
3 C3	0.165	0.027	6.134	0.000	0.34	2.96

The check of the adjusted R^2 and the standard error of estimates, measuring the goodness of fit of the linear models, showed the third model in all four PC regressions, with all three standardized principal components included (C1 + C2 + C3), was the best standardized principal component regression equation. Tables 4.6.a, 4.6.b, 4.6.c, and 4.6.d display the adjusted R^2 and the standard error of estimates results and show that the third model had the highest adjusted R^2 and lowest standard errors of estimates for each year.

Table 4.6.a. *Std. Equations, Adjusted R^2, Std. Error of Estimate, F Value and P Value - 2007*

Standardized PC Regression Equation	Adjusted R^2	Std. Error of Estimates	*F*	*P*
$0.151C_1$	0.532	0.684	426.230	<0.001
$0.108C_1 + 0.079C_2$	0.564	0.660	243.197	<0.001
$0.063C_1 + 0.055C_2 + 0.144C_3$	0.597	0.635	185.307	<0.001

Table 4.6.b. *Std. Equations, Adjusted R^2, Std. Error of Estimate, F Value and P Value - 2002*

Standardized PC Regression Equation	Adjusted R^2	Std. Error of Estimates	*F*	*P*
$0.151C_1$	0.533	0.684	427.237	<0.001
$0.104C_1 + 0.085C_2$	0.573	0.654	251.653	<0.001
$0.071C_1 + 0.068C_2 + 0.105C_3$	0.588	0.642	178.826	<0.001

Table 4.6.c. *Std. Equations, Adjusted R^2, Std. Error of Estimate, F Value and P Value - 1997*

Standardized PC Regression Equation	Adjusted R^2	Std. Error of Estimates	*F*	*P*
$0.148C_1$	0.506	0.703	384.220	<0.001
$0.119C_1 + 0.065C_2$	0.532	0.684	213.247	<0.001
$0.080C_1 + 0.051C_2 + 0.121C_3$	0.555	0.667	156.413	<0.001

Table 4.6.d. *Std. Equations, Adjusted R^2, Std. Error of Estimate, F Value and P Value - 1992*

Standardized PC Regression Equation	Adjusted R^2	Std. Error of Estimates	*F*	*P*
$0.137C_1$	0.441	0.748	295.908	<0.001
$0.113C_1 + 0.048C_2$	0.450	0.742	153.915	<0.001
$0.052C_1 + 0.040C_2 + 0.165C_3$	0.499	0.708	125.252	<0.001

The next step necessitated the application of the best standardized principal component regression equation to the principal components for each of the four PC regressions (equation 5). This resulted in the development of the standardized linear equation for each year. Table 4.7 presents the coefficients of the standardized linear equation for each year.

Table 4.7. *Coefficients for Standardized Linear Equations*

	1992	1997	2002	2007
Hospital Affiliated	0.158	0.125	0.114	0.145
Medical Degree	0.156	0.132	0.120	0.146
ARL Index Score	0.098	0.104	0.099	0.102
Equipment Expenditures	0.106	0.098	0.097	0.100
# of Assistant Professors	0.069	0.083	0.083	0.076
# of Associate Professors	0.064	0.088	0.082	0.077
# of Professors	0.071	0.095	0.094	0.092
Avg. Salary Assistant	0.051	0.069	0.089	0.079
Avg. Salary Associate	0.057	0.062	0.084	0.071
Avg. Salary Professor	0.071	0.085	0.097	0.090
# of Graduate Students	0.093	0.108	0.097	0.094

Next, the computation of the partial regression coefficients (equation 6) and the constant (equation 7) were required and carried out for each PC regression. The final transformation of each of the four standardized linear regression equations into the general linear regression equation was then completed (equation 8). Table 4.8 below displays the general linear regression constant and coefficients for each of the four models.

Table 4.8. *Constant and Coefficients for General Linear Equations*

	1992	1997	2002	2007
Constant	-58047.85	-82103.51	-131080.48	-115504.69
Variables				
Hospital Affiliated	23812.90	19658.11	23773.30	35097.17
Medical Degree	18920.59	16668.25	20072.40	28501.79
ARL Index Score	6934.96	7987.58	10657.31	10465.29
Equipment Expenditures[1]	1.42	1.24	1.69	1.82
# of Assistant Professors	37.96	49.12	66.62	62.50
# of Associate Professors	28.60	41.96	53.74	57.28
# of Professors	20.13	28.13	36.46	40.36
Avg. Salary Assistant[2]	0.61	1.02	1.50	1.30
Avg. Salary Associate[2]	0.59	0.67	1.15	0.96
Avg. Salary Professor[2]	0.40	0.51	0.68	0.65
# of Graduate Students	4.41	5.15	6.16	5.92

note:1= dollar values in units of thousands

note:2= dollar values in single unit (ones)

The coefficients of the general linear equations provide the relative importance of identified university characteristics in explaining the variations in federal research expenditures and how they change over the years. To illustrate the values, in 2007, having a hospital contributed on average, and ceteris paribus[10](c.p.), $35,097,170 (in 1992 dollars) in federal research funding. In 1992, for every $1,000 in research equipment expenditures it contributed on average, and c.p., $1,420 in federal research funding while for every $1 in average salary for assistant professors it contributed on average, and c.p., $610 in federal research funding. As table 4.8 demonstrates, all the characteristics grew in their relative importance between 1992 and 2007. However, some of the variables grew more than others. The variables for the number of associate professors, the number of professors, and the average salary for assistant professors all more than doubled their relative importance. The smallest growth in relative importance was for the variable for the amount of expenditures for research equipment.

It is worth noting that although results herein largely are implied to be "casual" in regard to federal R&D funding, in reality separating cause from effect is very difficult (the "identification problem"). For example, do changed staffing patterns result in more R&D revenues? Or is it the other way around? In all likelihood, effects operate in both directions.

Identified Groups or "Clusters"

Two different methods were used to group universities to determine whether a "federal research funding hierarchy" existed as posited by Geiger and Feller (1995), Geiger (1996), and Teich (2000) and which universities moved "up" or "down" the hierarchy during the 35 years between 1972 and 2007. Universities were grouped and examined by each method at five year intervals for a total of eight groupings (1972, 1977, 1982, 1987, 1992, 1997, 2002, and 2007).

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[10] All other things being equal or held constant

The first method used a cluster analysis with the federal research expenditures as the basis for constructing the clustering variable. For the cluster analysis, a two-step cluster analysis was used due to the large size of the sample (n>250). The earliest four time points (1972-1987) each had just two clusters, a high group and low group with the vast majority of universities belonging to the low cluster. Although, starting in 1992, the clustering of universities started to change and additional clusters began appearing. Table 4.9 details the number of universities within the clusters at the eight 5-year time points.

Table 4.9. *Number of Universities in Clusters – Cluster Analysis*

Year	1st cluster	2nd cluster	3rd cluster	4th cluster	5th cluster
1972	331	44			
1977	325	50			
1982	329	46			
1987	347	28			
1992	291	64	19	1	
1997	312	63			
2002	276	77	22		
2007	262	64	33	15	1

The additional clusters (3^{rd} – 5^{th}) in the later years appeared mostly to partition universities in the higher cluster from the earlier years into smaller clusters. If a university was in the lowest cluster in 1972, in most cases, it remained in the lowest cluster over the years. Of the 331 universities that were in the lowest cluster in 1972, 262 (79.2%) of the universities were in the lowest cluster in 2007. While some of the universities in the lowest cluster in 1972 did move "up" out of the lowest cluster, they were not able to move into the highest cluster(s). Of the 69 universities that were in the lowest cluster in 1972 and were not in the lowest cluster in 2007, 55 were in the next cluster up (2^{nd} cluster) and 14 universities were in the middle (3^{rd}) cluster. None were in the top two clusters. These patterns in 2007 were similar to those in 2002. Of the 331 universities that were in the lowest cluster in 1972, 276 (83.4%) were in the lowest cluster in 2002. The remaining 55 universities that were in the lowest cluster in 1972 were in the middle (2^{nd}) cluster in 2002. Like 2007, none were in the highest cluster in 2002. Table 4.10 lists the 14 universities that were in the lowest cluster in 1972 and were in the middle (3^{rd}) cluster in 2007. All 14 of these universities were among the 55 universities that placed into the middle (2^{nd}) cluster in 2002.

Table 4.10. *Universities in Lowest Cluster in 1972 and Middle Cluster in 2007*

University Name	State
Boston University	MA
Emory University	GA
Georgia Institute of Technology	GA
Northwestern University	IL
Oregon Health Sciences University	OR
University of Alabama at Birmingham	AL
University of Arizona	AZ
University of Cincinnati	OH
University of Florida	FL
University of Illinois at Chicago	IL
University of Iowa	IA
University of Maryland at College Park	MD
University of Virginia	VA
Vanderbilt University	TN

In examining these 14 universities more closely, four were private universities (Boston, Emory, Northwestern, and Vanderbilt), 13 had medical schools (Georgia Tech did not), eight had hospitals affiliated with them, 12 were members of the Association of Research Libraries (Alabama-Birmingham and Oregon Health Sciences did not), and eight were members of the AAU. These 14 universities are located in 12 states spread across the country (Alabama, Arizona, Florida, Georgia, Illinois, Iowa, Maryland, Massachusetts, Ohio, Oregon, Tennessee, and Virginia).

Of the 44 universities[11] that were in the highest cluster in 1972, none were in the lowest cluster in 2007, 9 of the 44 universities were in the 2nd cluster and 19 were in the middle (3rd) cluster. The remaining 16 universities represented all the universities that were in the two highest clusters for 2007; 15 were in the 4th cluster and one, by itself, was in the highest (5th) cluster. In examining the 2002 clusters, none the 44 universities that were in the highest cluster in 1972 were in the lowest cluster. All 22 of the universities in the highest (3rd) cluster in 2002 were in the highest cluster in 1972. The other 22 universities that were in the highest cluster in 1972 were in the middle (2nd) cluster in 2002.

Table 4.11. *Mean R&D Expenditures of Clusters and Ratios Between Clusters*

year	1st cluster	2nd cluster	Ratio 2nd to 1st	3rd cluster	Ratio 3rd to 1st	4th cluster	Ratio 4th to 1st	5th cluster	Ratio 5th to 1st
1972	$1,804	$25,107	13.9						
1977	$2,560	$35,011	13.7						
1982	$4,703	$64,624	13.7						
1987	$9,786	$126,938	13.0						
1992	$6,306	$69,442	11.0	$184,304	29.2	$666,696	105.7		
1997	$12,129	$152,772	12.6						
2002	$10,412	$121,742	11.7	$366,301	35.2				
2007	$12,021	$115,626	9.6	$269,799	22.4	$478,566	39.8	$1,362,836	113.4

note: $s in yearly nominal values
note: $s in thousands

An examination of the mean R&D expenditures of the clusters revealed that the differences between the clusters remained relatively stable for the first four time points (1972, 1977, 1982, and 1987). Table 4.11 above presents the mean R&D expenditures (in nominal values) and the ratio of the means to the first cluster for each cluster. The ratio between the means of the clusters was just over 13 to 1 for each of the first four time points (ex: for 1972 the mean R&D

[11] Appendix E lists the 44 universities in the highest cluster in 1972 from the cluster analysis

expenditures of the 2nd cluster was $25,107 while the mean R&D expenditures of the 1st cluster was $1,804; for a ratio of 13.9 to 1). Starting in 1992 however, the differences in the mean R&D expenditures between clusters began to change. This was also the year more than two clusters began appearing in the cluster analysis. In 1992, the ratio between the 2nd cluster and the 1st cluster dropped to 11.0 to 1. However, the ratio between the 3rd cluster and the 1st cluster was 29.2 to 1 with the ratio between the fourth cluster and the 1st cluster being 105.7 to 1.

The second method placed universities into one of five groupings based on their percentage shares of the sum of all federal research expenditures. These groupings included the following: all universities with at least a two percentage point share of the total federal R&D expenditures, all universities between a one and a half and one and ninety-nine hundredths share, all universities between a one and one and forty-nine hundredths percentage share, all universities between a half and ninety-nine hundredths share, and all universities below a half percentage share. Table 4.12 below displays the number of universities within a group for the eight 5-year time points.

Table 4.12. *Number of Universities in Groups – % Share of All Federal R&D Expenditures*

year	above 2.00 %	Between 1.50% and 1.99%	Between 1.00% and 1.49%	Between 0.50% and 0.99%	Below 0.49%
1972	9	8	8	30	320
1977	8	9	8	33	317
1982	7	8	10	34	316
1987	4	10	12	34	315
1992	5	7	14	35	314
1997	5	5	19	34	312
2002	3	9	11	36	316
2007	2	9	14	34	316

As stated in chapter 3, this method of grouping was used in previous studies by Geiger and Feller (1995) and Geiger (1996). The lowest group, below 0.49% of all federal R&D

expenditures, had the largest number of universities (83% - 85% for a given year). The next two groups up (between 0.50% and 0.99% and between 1.00% and 1.49%) saw increases in the number of universities in these groups. The 2nd highest group (between 1.50% and 1.99%) remained relatively stable in the number of universities in the group over the years. The highest group (over 2.00%) saw a large decrease (77%) in the number of universities in the group as there were 9 universities in 1972, but only 2 in 2007.

As in the cluster analysis, if a university was in the lowest group (below 0.49%), it tended to remain in the lower group over the years. Of the 320 universities that were in the lowest group in 1972, 306 (95.6%) of them were in the lowest group in 2007. Fourteen (4.4%) of the universities in the lowest group 1972 were able to move “up”, but only to the next group (between 0.50% and 0.99%). None were able to move to the highest three groups. These patterns in 2007 were similar to how universities grouped in 2002. Of the 320 universities in the lowest group in 1972, 307 (95.9%) were in the lowest group in 2002. The remaining 13 universities that were in the lowest group in 1972 were in the next group (between 0.50% and 0.99%) for 2002. None were able to move up above this group.

Between 1972 and 2007 five universities moved “down” two groups while no university was able to move “up” more than one group. There were 23 universities who moved “down” one group and 24 universities that were able to move “up” a single group between 1972 and 2007. This indicates that only 52 (13.9%) of the 375 universities were able to change their grouping between 1972 and 2007. The five universities that moved “down” two groups are listed below in table 4.13 while the 24 universities that moved “up” one group are displayed in table 4.14

Table 4.13. *Universities That Moved "Down" Two Groups Between 1972 and 2007*

University	1972 group	2007 group
Harvard University	above 2.00 %	Between 1.00% & 1.49%
New York University	Between 1.50% & 1.99%	Between 0.50% & 0.99%
University of California – Berkeley	Between 1.50% & 1.99%	Between 0.50% & 0.99%
University of Chicago	Between 1.50% & 1.99%	Between 0.50% & 0.99%
Yeshiva University	Between 1.00% & 1.49%	Below 0.49%

In examining more closely the five universities that moved down 2 groups, all five were well established research universities. Four of the five were private universities (California-Berkeley was not), four of the five had a medical school (California-Berkeley did not), four of the five were members of the AAU (Yeshiva was not), two of the five had a hospital affiliated with it and four of the five were members of the Association of Research Libraries (Yeshiva was not). All five universities came from states with well developed higher education systems and had at least one other elite research university present (New York, Massachusetts, California, and Illinois).

Table 4.14. *Universities that Moved "Up" One Group Between 1972 and 2007*

University	1972 group	2007 group
Johns Hopkins	Between 1.50% & 1.99%	above 2.00 %
Duke University	Between 1.00% & 1.49%	Between 1.50% & 1.99%
University of California-San Francisco	Between 1.00% & 1.49%	Between 1.50% & 1.99%
Case Western Reserve University	Between 0.50% & 0.99%	Between 1.00% & 1.49%
Ohio State University	Between 0.50% & 0.99%	Between 1.00% & 1.49%
Pennsylvania State University	Between 0.50% & 0.99%	Between 1.00% & 1.49%
University of North Carolina at Chapel Hill	Between 0.50% & 0.99%	Between 1.00% & 1.49%
University of Pittsburgh	Between 0.50% & 0.99%	Between 1.00% & 1.49%
University of Southern California	Between 0.50% & 0.99%	Between 1.00% & 1.49%
Vanderbilt University	Between 0.50% & 0.99%	Between 1.00% & 1.49%
Boston University	Below 0.49%	Between 0.50% & 0.99%
Carnegie Mellon University	Below 0.49%	Between 0.50% & 0.99%
Emory University	Below 0.49%	Between 0.50% & 0.99%
Georgia Institute of Technology	Below 0.49%	Between 0.50% & 0.99%
Oregon Health Sciences University	Below 0.49%	Between 0.50% & 0.99%
University of Alabama at Birmingham	Below 0.49%	Between 0.50% & 0.99%
University of California-Irvine	Below 0.49%	Between 0.50% & 0.99%
University of Cincinnati	Below 0.49%	Between 0.50% & 0.99%
University of Illinois at Chicago	Below 0.49%	Between 0.50% & 0.99%
University of Kentucky	Below 0.49%	Between 0.50% & 0.99%
University of Maryland at Baltimore	Below 0.49%	Between 0.50% & 0.99%
University of South Florida	Below 0.49%	Between 0.50% & 0.99%
University of Texas Southwestern Med Ctr Dallas	Below 0.49%	Between 0.50% & 0.99%
University of Virginia	Below 0.49%	Between 0.50% & 0.99%

To examine more closely the universities that moved "up" one group from 1972 to 2007, the 24 universities (table 4.14) were broken up into two groups. Group "A" is made up of the ten universities that were in the 2nd group (between 0.50% and 0.99%) or above in 1972. Group "B" consists of the 14 universities that started in the lowest group (below 0.49%) in 1972. For group "A", the 10 universities come from only six states (Ohio, North Carolina, Maryland, Pennsylvania, California, and Tennessee), of which all but one (Tennessee) had another elite research university within its borders. Of the ten universities in group "A", all ten had a medical school, six were affiliated with a hospital, half (five of ten) were private universities, nine were members of the AAU (California-San Francisco was not), and nine of the ten were members of the Association of Research Libraries (California-San Francisco was not). Of the 14 group "B" universities, 12 had a medical school (Carnegie Mellon and Georgia Tech did not), nine had an affiliated hospital, three were private universities (Boston, Carnegie Mellon, and Emory), four were members of the AAU (Carnegie Mellon, Emory, California-Irvine, and Virginia), and eight were members of the Association of Research Libraries. The 14 group "B" universities came from 13 different states (Alabama, California, Florida, Georgia, Illinois, Kentucky, Maryland, Massachusetts, Ohio, Oregon, Pennsylvania, Texas, and Virginia).

Summary

The three sections in this chapter detailed the findings of the research questions. The first section identified the university characteristics that explain the amount of federal research funding received. The indentified university characteristics included: hospital affiliated with university, university grants medical degrees, ARL index score, research equipment expenditures, average salary for assistant professors, associate professors, and professors, the number of assistant professors, associate professors, professors, and graduate students. The second section evaluated the relative importance of the identified characteristics in explaining variations in federal research expenditures and how they change over time. The third and final section identified discrete university groupings or "clusters" based on university federal R&D expenditures using two different methods. In addition, universities that either moved their group or "cluster" between the specified years for both methods were identified.

CHAPTER 5

CONCLUSIONS, IMPLICATIONS, SUMMARY, AND FUTURE RESEARCH

The primary objectives of this study were to (1) identify university characteristics that explain the amount of federal R&D funding a university receives (measured by convention as research expenditures), (2) evaluate the relative importance of identified university characteristics in explaining variations in federal R&D expenditures, (3) identify discrete university groups or "clusters" and evaluate whether these groupings or "clusters" reflect the "hierarchy" posited by Geiger and Feller (1995), Geiger (1996) and Teich (2000), and (4) evaluate and identify changes for each of the first three objectives over time. In this concluding chapter the findings and the conclusions are discussed; the implications of the findings, the conceptual framework and research design are detailed and summarized; and finally, suggestions for future research are presented.

Discussion of Findings and Conclusions

For the first research question, whether there are university characteristics that explain the amount of federal research funding received and how to identify them, the answer appears to be yes: There were a set of university characteristics that explain the amount of federal R&D funding a university expends. These characteristics were identified by a series of principal component analyses (PCA). The four 2-year lag PCAs grouped 11 to 13 variables (depending on year/PCA) into three principal components (PCs), labeled accordingly as resources, salaries, and medical. As table 4.2 displays, there were 11 university characteristics (variables) that were retained in the 1992 2-year lag PCA and as well in the other three PCAs. These 11 university characteristics were hospital affiliated with university; university grants medical degrees; ARL index score; amount of research equipment expenditures; average salary for assistant, associate, and full professors; and the number of assistant, associate, full professors, and graduate students.

The 1997, 2002, and 2007 2-year lag PCAs all contained the variable for the number of doctoral degrees awarded while the 1992 2-year lag PCA did not. Perhaps the inclusion of this variable in the later three PCAs indicates a shift in the importance of not only having graduate programs on campus in general, but that it is especially important to have doctoral programs to attract federal R&D funding. The inclusion of the number of faculty members (all ranks) in all four PCAs suggests that perhaps it is faculty research projects that are the most important in attracting federal R&D funding. Doctoral students generally work very closely with or under the direction of faculty members, while other research professionals (non-faculty researchers and post-doctorate researchers who incidentally were removed from all four PCAs) do not necessarily do so. The number of doctoral graduates, by completing their degree, provides an approximation of the number of advanced and highly trained personnel available to assist faculty on research projects. This may suggest not only that there is a need for highly trained researcher assistants, but also that those who are low cost (relative to the other research professionals) and work directly with faculty on research projects are becoming more important than they were in previous years.

The 2002 and 2007 2-year lag PCAs contained the variable for university control (public/private) while the 1997 and 1992 2-year lag PCAs did not. Apparently public-private university status has become more important than it was in the earlier years. Does this indicate that there is some stratification occurring between universities based on whether they are public or private? The percentage of public to private universities was roughly the same for both the sample and for all the universities that submitted data to the NSF's Survey of R&D Expenditures at Universities and Colleges. Public universities made up 65% of universities in this study while in each of the four years (1992, 1997, 2002, and 2007) of the NSF's survey, public universities made up 57-59% of all universities responding. Taking this one step further and examining the percentage of federal R&D expenditures, public universities accounted for 61-63% of all federal R&D expenditures in this study, while in the NSF survey all the public universities accounted for 59-62% of all federal R&D expenditures. This suggests that the sample in this study was representative of the public/private university mix of the NSF survey.

What makes this point interesting is the loading value for the control variable in the component and variable loading matrix of the PCAs. For both 2002 and 2007, being a public university had a strong negative loading onto the second PC (-0.680 in 2007, -0.636 in 2002). Meanwhile, the second PC was labeled salaries for the strong loading scores of the faculty salaries variables. This suggested that for these years, faculty members' salaries were associated with whether they worked at a public or private university. Specifically, the strong negative loading for public universities suggested that working at a private university had a positive affect on faculty salaries. This was in-line with findings from the annual reports on the economic status of the profession by the American Association of University Professors (AAUP). The annual reports from 1992 through 2009 showed that faculty members working at private universities were compensated at much higher rates than faculty at public universities. The reports also highlighted that the difference in the average faculty salary between public and private universities had grown since 1992. Table 5.1 presents these differences for the four time points of the PCAs (1992, 1997, 2002, and 2007) and the most currently available fiscal year (2009).

Table 5.1. *Average Faculty Salaries at Public and Private Universities*

Year	all universities	public universities	private universities	$ difference between public/private	difference between public & private universities
1992	$45,360	$45,260	$50,030	$4,770	10.5%
1997	$52,556	$52,044	$59,252	$7,208	13.8%
2002	$62,895	$62,024	$71,460	$9,436	15.2%
2007	$73,207	$71,362	$84,249	$12,887	18.1%
2009	$79,439	$77,009	$92,257	$15,248	19.8%

Note: dollars in nominal (yearly) values
Note: values are for all university categories (types) and faculty ranks
Source: AAUP (1992, 1997, 2002, 2007, 2009)

This is a matter of national concern because as the AAUP (2008, p.11) asserts, “when public universities cannot compete in terms of salary or other resources, private universities may be able to attract the best and most-productive scholars.” Put directly, private universities appear to be “raiding” public universities and significantly weakening them (AAUP, 2008). As Bok (2003) and Kirp (2003) point out, however, this has been happening across the academy: Both public and private universities are trying to hire “the best and the brightest” faculty; it is not just the private universities doing it. In reality it is the well-financed universities, whether public or private, that are raiding other universities in a Darwinian-style cycle of faculty poaching. Over the last decades, it may be just that more private universities have been in the enviable financial position of being more able to “raid” other universities.

Geiger (2004) states that, in general, university prestige is built on faculty scholarship and that the presence of “star” faculty scholars has become a prime consideration in efforts to land competitive research contracts and grants. This fits with the conceptual framework of this study, the resource based view of the firm, in explaining university behavior: Universities that can hire “the best and the brightest” have a competitive advantage over public universities in obtaining federal R&D funding. With the institutional control variable being retained in the PCAs for the last 2 years (2002 and 2007), this is just evidence that a tipping point may have been reached and that private universities now enjoy an advantage over public universities in obtaining "star" faculty and thus federal research funding.

Of particular interest were the variables that were removed from all four PCAs. The first variables removed in each of the four PCAs were the five Carnegie Classification variables. The variables for Land-Grant status and whether a university was a religious institution were also removed from all four PCAs, the former being removed during the second stage of data reduction, the analysis of communalities, while the religious variables were removed during the third stage, the check for complex structure. This repeated pattern of removal of the Land-Grant, religious, and Carnegie Classification variables in the PCAs simply suggests that the type of institution, per se, is not related to how much federal R&D funding a university obtains. "Research" universities by their nature will have different characteristics than a "masters" university. It is these differences in institutional characteristics that are important, rather than the specific classification that is assigned to a university in explaining federal R&D funding differences between universities.

The number of non-faculty researchers and post-docs were also removed from each of the four PCAs. The absence of non-faculty researchers and post-dos in the PCAs is of some interest as these individuals have been shown to be large contributors to research and to be highly involved in publications (Black & Stephan, 2009). Regarding the latter, perhaps it is that post-docs usually are individuals with less than five years of post-degree experiences and are generally classified as being in a training position (Stephan, 2008) that explains this finding. Federal R&D grants programs often funds large projects expensed over multiple years, and faculty members, in contrast to post-docs, are usually associated with a particular university for extended time periods. Comparatively, post-docs are less likely to bring funding with them or secure external funding while in their position. This finding, coupled with the retainment of the number of faculty members and graduate students in all four PCAs, suggests that researchers tied to the educational mission of the university, faculty or graduate students, are the most important individuals in determining the amount of federal R&D funding a university obtains.

As described in chapter four, since research question two required the development of PC regression models for all four years (1992, 1997, 2002, and 2007), for modeling and analytical purposes the same variables for each yearly model were tested. Hence, the 1992 model was the base model and the other three PCAs were developed with the same 11 independent variables as the 1992 model. These re-developed PCAs were the "official" PCAs for these years (the original PCAs are presented in appendix C).

All four PCAs grouped the 11 independent variables in a similar manner. Each of the four PCAs (statistically) grouped the 11 independent variables into three PCs labeled accordingly, "resources", "salaries", and "medical", based upon the variables loaded onto them. In general the independent variables loaded roughly in the same manner in each of the PCAs and were considered stable across the years. This stability was not only evident in terms of which PC the variables loaded onto, but also in regards to their factor loading scores (similar scores across the 4 PCAs). Tables 4.4a, b, c, and d from chapter 4 present this consistency in variable loading.

The first PC in all four PCAs was labeled "resources", as the ARL index score, equipment expenditures, number of faculty members (all ranks), and the number of graduate students variables loaded most heavily onto this PC. The first PC accounted for more than half (51.9 – 54.8%) of the standard variance among the variables. This means that these variables, which loaded heavily on the first PC, had the most influence on R&D funding among the independent variables tested. If a university is interested in increasing the amount of federal R&D funding it receives, it appears that investing in these areas (number of faculty, graduate students, research equipment and the library) is likely to be most promising for the largest return on their investment. Although, of course, this assumes that present resource investments already are “normative” or “typical”.

The second PC in all four PCAs was labeled “salaries”, as all three average faculty salary variables loaded most heavily onto this PC. This PC accounted for 17.4 to 20.3% of the standard variance among the variables in the various PCAs. While not as large an influence as the “resources” PC, the effect of faculty salaries was still sizable. This suggests that targeting resources on faculty salaries may well yield a competitive advantage in the federal R&D funding competition. Bok (2003), Geiger (2004), Kirp (2003) and Zucker and Darby (1996, 1999, 2007) discuss how universities have increasingly brought in or “bought” high profile faculty members from other universities. This finding supports this strategy.

The third PC in all four PCAs was labeled “medical”. Having an affiliated hospital or offering medical degrees loaded most heavily onto this PC. The third PC accounted for between 10.8 to 11.5% of the standard variance among the variables in the various PCAs. While not as large as the previous two PCs, the influence of the medical variables was still important, and points out the strategic advantage of possessing a medical program.

This is not surprising given that, for the four years (1992, 1997, 2002, 2007) of the PCAs, more than half of all federal funding to universities went into the life sciences (National Science Foundation, 2009), which are defined as the agricultural, biological, medical and other clinical and health professions disciplines (National Science Foundation, 2007b). As Teich (2000) points out, while the federal funding comes from over twenty different agencies, the largest shares, by far, come from just the NSF and NIH. Table 5.2 below presents the amount of federal R&D expenditures in the life sciences for the four years of the PCAs.

Table 5.2. *Federal R&D Expenditures in Life Sciences*[12]

Year	Total Federal R&D expenditures	Federal R&D expenditures in Life Sciences	Life Sciences % of total Federal R&D expenditures
1992	$11,092,716	$5,911,372	53.3%
1997	$14,314,924	$7,764,620	54.2%
2002	$21,862,995	$12,856,566	58.8%
2007	$30,440,745	$18,352,769	60.3%

note: dollars in nominal (yearly) values & in thousands
source: NSF Survey of R&D Expenditures at Universities and Colleges

Regarding the second research question the results point to three conclusions. First, the size of a university's graduate and academic programs appears to matter. The findings indicate that, and ceteris paribus[13](c.p.), the larger a university's graduate programs, library, and faculty, the more federal R&D dollars it expends. Specifically the partial regression beta coefficient of the general linear regression equation in all four PC regressions (table 4.8) showed that the number of graduate students, faculty members (all ranks) and ARL index score had a positive impact on the amount of federal R&D funding a university expended. This suggests that there might be some returns to scale in play. This is consistent with Adams and Griliches (1998) findings that research outputs, at the aggregate university level, follow a constant return to scale process. It may be that the number of faculty and trained personnel working alongside faculty in labs and research centers is what actually makes a difference. The number of graduate students provides an approximation of the number of advanced and highly trained (or in the process of being highly

[12] Table 5.2 represents all universities that submitted responses to NSF's survey including values from universities not in this study. The universities in the sample account for 91.8% of all R&D and 92.0% of Federal R&D expenditures in 2007. These percentages are similar to one another through all the years of the study (1972-2007).

[13] All other things being equal or held constant

trained) personnel available to assist faculty in their labs and on research projects. This suggests that universities that can invest in expanding their graduate programs can realize a good return on investment. This also fits with previous research (Feller, 1996; Savage, 1999) demonstrating that the number of graduate assistants makes a difference in the amount of external funding a university obtains.

Universities can turn to the Council of Graduate Schools (CGS) and the National Research Council (NRC) for guidance as to which of their particular academic programs to invest in. The NRC's upcoming release of the *Assessment of Doctorate Programs* is highly anticipated and will be a source of national data on faculty and graduate students. The release of the NRC, delayed numerous times over the last few years, is expected to be released in May 2010. The NRC collected data on faculty scholarly productivity, effectiveness of doctoral education, research resources, demographic characteristics of students and faculty, resources available to doctoral students, and characteristics of doctoral programs. The NRC ultimately will provide a range of rankings on programs and universities across the country. The CGS' Ph.D. Completion Project provides a comprehensive national database on doctoral students with up to ten year graduation and attrition data. The CGS most recent results can be found in the *Analysis of Baseline Program Data from the Ph.D. Completion Project* (2008), which provides data by broad science fields as well by individual disciplines.

Both of these national data sources focused on doctoral students providing universities with national benchmark data. This allows universities to see which of their academic programs might have a competitive advantage compared to other programs across their region and country and provide guidance into where a university should invest its resources. Universities should assess their academic programs and understand their strengths and weaknesses on a continual basis.

Strong programs and researchers should be identified by measurable marks of strength and quality. Programs that compare favorably to programs in other universities are the most likely areas in which a university might succeed in competing for federal R&D funding. Universities should not direct money into developing and supporting programs in the current "hot" discipline(s) just for the sake of being in it. As Bok (2003) points out, critics have consistently opposed the duplication of academic programs, particular at universities that have no history or particular strength in a discipline. Such universities often end up wasting resources. The CGS and NRC publications provide data that universities can use to compare themselves to others across their region and country and help identify which disciplines they may be most fruitful for investment.

Comparing the coefficients (see table 4.8 in chapter 4) for the number of graduate students over the four PC regressions, i.e. the four points in time over the 15 year time period, reveals that the influence of the variable has changed over the years. For the 1992 PC regression, the coefficient for graduate students was 4.41, indicating that for every graduate student a university enrolled, it realized $4,410 dollars in federal research funding[14]. This coefficient realized a high mark in 2002 at 6.16 but dropped to 5.92 for the 2007 PC regression. The difference between the coefficients in 1992 and the 2007 PC regression represented a 34.2% growth ((5.92-4.41)/4.41). Table 5.3 presents the means for each of the independent variables[15] and shows that there was an increase of 25.7% ((1297.0-1031.6)/1031.6), in the mean number of graduate students between 1992 and 2007. This indicates that while the amount of influence the number of graduate students had was the second smallest among all the variables, the growth in the mean was the

[14] The dependent variable, Federal R&D expenditures are listed in thousands$ of dollars.

[15] All variables with dollar ($) values are shown in 1992 model's real dollar values.

largest of the variables in the PC regressions. Taking the 2007 mean of graduate students (1297, table 5.3) multiplied by the 2007 coefficient (5.92, table 4.8), the amount federal R&D expenditures universities realized in 2007, on average and c.p., due to graduates students was $7,678,240. This was a sizable sum of federal R&D dollars that universities received and comes from the area where universities are experiencing the greatest growth. Even though the growth in influence of graduate students on the amount of federal research funding was one of the smallest, it still experienced a sizeable increase of 34.2%. However, it is the large increase (25.7%), comparably to the other variables in the study, in the mean number of graduate students that makes the admission to and enrollment in graduate programs a key place for universities to examine as they look to increase the amount of federal R&D funding received.

Table 5.3. *Means of Dependent and Independent Variables of PC Regressions*

Variables	1992	1997	2002	2007
Federal R&D (D.V.)[1]	$27,861	$31,122	$42,237	$50,767
Hospital Affiliated	0.17	0.17	0.17	0.17
Medical Degree	0.33	0.33	0.33	0.33
ARL Index Score	-1.83	-1.80	-1.66	-2.05
Equipment Expenditures[1]	$2,531	$2,604	$2,569	$2,926
# of Assistant Professors	139.5	137.6	139.8	162.7
# of Associate Professors	153.9	157.7	160.4	163.7
# of Professors	216.3	220.8	224.3	225.4
Avg. Salary Assistant[2]	$33,941	$34,341	$35,911	$37,498
Avg. Salary Associate[2]	$40,644	$40,961	$43,220	$44,530
Avg. Salary Professor[2]	$53,390	$54,232	$58,013	$60,331
# of Graduate Students	1031.6	1126.1	1107.4	1297.0

note: dollars in 1992 model values
note:1= dollar values in units of thousands
note:2= dollar values in units of ones

A close study of the ARL index coefficients (table 4.8) shows a considerable increase between the four PC regressions, with much of it incurring prior to 2002. The 2007 ARL index coefficient was 10,465.29 indicating that, on average and c.p., for every 1.0 point on the ARL index score, a university would realize $10,465,290 in federal R&D expenditures. This positive finding is in-line with previous research (Feller, 1996; Savage, 1999), that found that the quality and size of the campus library made a difference in the amount of external funding received. While this figure may seem large, it is important to realize that this index is a proxy for many library characteristics: The ARL index is computed based on the number of volumes in the library, the number of volumes added, the amount of library expenditures in the past year, and the number of professional and support library staff (Thompson, 2007).

Also, most of the universities in this study did not have an ARL index score and were assigned the lowest calculated ARL score for member universities. In a given year only 90 to 113 universities were members of the ARL, thus roughly 75% of universities in the sample were assigned the lowest ARL index score in each of the four PC regressions. Further, the range of scores on the ARL index typically ranged from 2.50 to -2.50 with the lowest ARL scores being negative. The actual number of universities in this study with positive scores on ARL index was very small in a given year, roughly 5-10%. Taking the 2007 mean value of ARL scores (-2.05, table 5.3) multiplied by the 2007 coefficient (10,465.29, table 4.8) shows that, on average and c.p., for all the universities in the study, the amount of federal R&D expenditures realized due to their libraries (ARL index) was actually -$21,453,845. This indicates that universities that were able to support large libraries realized more federal R&D expenditures although there were only a few universities with large libraries. Thus there were only a handful of universities that actually returned a positive dollar amount of federal R&D funding in the PC regressions, and in most cases, this variable was actually a negative influence on the amount of federal R&D expenditures. Taking a step back, this finding is not too surprising considering the cost of maintaining an elite library. The ARL index is based primarily on the size of holdings and staff, both of which are expensive to maintain. In short, the number of universities that actually maintain an elite library is not very large, as evidenced by the small number of universities that are members in the ARL.

Looking more closely at the three variables for the number faculty members, the partial regression beta coefficients in each of the four general linear regression equations (table 4.9) highlighted some real differences across the faculty ranks. The order of the amount of influence an individual faculty member had on the amount of federal R&D funding was in reverse order, considering the faculty member's tenure and experience. The coefficients for assistant professors were the largest, followed by associate professors, and then full professors. This pattern persisted in all four of the PC regressions. This was surprising in some ways, as faculty members with the rank of professor are typically the most well known in their field and presumably earned the rank through their research and teaching. These are individuals who have extensive experience and skill conducting research and whose achievements are consistent with the highest levels with their field. A plausible answer is that, comparatively, there are fewer assistant and associate professors who are inactive in grant work than is the case for full professors who already achieved the highest academic rank and tenure. A striking, relevant finding from other research is that the best predictor of faculty research productivity, as measured by publications, is being within five years of retirement and it is a negative predictor (Leslie, Rhoades, and Oaxaca, 1999).

Even though, on average, there are more full professors than assistant professors, again on average, the latter *in toto* brought more R&D funding to campuses than do the former. Taking the mean number of faculty members in 2007 (225.4, table 5.3) and multiplying it by the 2007 coefficient (40.36, table 4.8) shows that, on average and c.p., the amount of federal R&D

expenditures realized, due to the number of full professors in 2007 was $9,097,144. If we do the same for assistant and associate professors, we get on average and c.p., federal R&D expenditures of $9,376,736 realized due to the number of associate professors and $10,168,750 for the number of assistant professors. While the amount of federal R&D expenditures was still higher for both assistant and associate professors than professors, the difference in the mean total amount realized of federal R&D funding between the groups was actually much smaller (percentage-wise) than the coefficients presented.

Ultimately these findings suggest that, while assistant professors, individuals who usually have relative limited teaching and research experience, are competing for and being awarded federal research grants. It is likely they are highly motivated to earn federal research grants as part of the tenure review process and establishing themselves within their field. An argument can be made that faculty members near their tenure review (within a few years before and after) are perhaps at their most productive due to the motivation to gain tenure and prove themselves. It is also worth remembering that the universities in this study constitute the majority of the universities that received federal R&D funding within a given year. So the results from this study should closely represent what is occurring at all universities who receive federal R&D funding. While assistant professors are younger and less experienced than their colleagues, it appears they are much more cost effective in obtaining federal research funding.

Lending support to this is the second conclusion from the PC regressions that the higher the salary of faculty members, the more federal research funding is obtained. The theoretical argument, using the resource-based theory of the firm, is that universities that employ high salaried faculty members are at a competitive R&D funding advantage. The coefficients for faculty salaries are positive in all four PC regressions. This theoretically, is consistent with previous research showing that the number of faculty employed and the quality of their research abilities matter. Feller (1996), Teich and Gramp (1996), and Savage (1999) all found the more faculty members employed and the higher quality of the researcher positively impacts the amount of external funding a university receives.

Of the three PC regression coefficients for faculty salary, those for average salary of assistant professors were the highest in all four PC regressions. The coefficients for the average salary for associate professors were the second highest, those for full professors being the lowest. As with the coefficients for the number of faculty members, the findings that the lowest ranked faculty members had the highest coefficients was somewhat surprising. Again, the means (table 5.3) for the average faculty salary variables brought some insight to this finding. The means for the average salary for full professors were the highest, the mean average salary for associate professors next and that of assistant professors being the lowest. The mean average salary for professors was considerably higher than the other two across all four PC regressions.

Taking the mean average salary of full professors in 2007 ($60,331[16], table 5.3) and multiplying it by the 2007 coefficient (0.65, table 4.8) shows that, on average and c.p., the amount of federal R&D expenditures realized in 2007 due to the average salary of full professors was $39,215,150. Comparably, for assistant and associate professors, on average and c.p., the amount of federal R&D expenditures realized due to the average salary of associate professors was $42,748,800 and $48,747,400 for the average salary of assistant professors. The findings indicate universities are realizing more federal R&D funding per assistant professors salaries even though assistant professors were paid much less than either full or associate professors. In short, not only are universities spending less on assistant professors, they are also realizing a

[16] Dollar ($) values of average faculty salaries are shown in 1992 model's real dollar values.

greater return for each dollar they do spend on assistant professors than they did on associate or full professors.

How did these coefficients change over time? The change in the coefficient for the average salary for assistant professors had the largest change of all the coefficients (Table 4.8), having more than doubled, rising from 0.61 to 1.30 over the course of the four PC time periods. The average salary for associate professors and professors, both grew by roughly 60%. In short, the influence on the amount of federal R&D expenditures for the salaries universities paid assistant professors grew more rapidly over the last fifteen years than it did for the salaries for associate and full professors. Whereas Bok (2003) Kirp (2003) and Zucker and Darby (1996, 1999) point out that often universities have invested considerable time, resources, and effort to hire “star” established faculty member, the findings herein suggest is that universities focus upon the recruitment of assistant professors if growth in federal R&D funding is sought. Coupled with the findings on the number of faculty members, the results suggest that universities able to pay assistant professors more succeed in choosing the assistant professors who are most successful in obtaining federal R&D grants.

The third conclusion from the PC regressions is that universities with research, academic programs, and facilities in the medical fields brought in more federal R&D funding than the universities that did not. The two variables in the PC regressions were whether a hospital was affiliated with the university and whether the university granted medical degrees. Both of these variables were binary in the models, a simple yes or no. The coefficients for these two variables were very large, indicating that if a university had either of these programs or facilities it received a relatively large amount of federal R&D funding.

The hospital affiliation variable had the largest coefficient of any of the variables in all four PC regressions. This coefficient (table. 4.8) dropped between 1992 and 1997 before returning to the 1992 level in 2002. However, between 2002 and 2007 this variable experienced tremendous growth of 47.6% ((35,097.17-23,773.30)/23,773.30). In terms of real dollars[17], if a university had a hospital in 1992, it was “worth” $23,812,900 of federal R&D funding; $19,658,110 in 1997; $23,773,300 in 2002 and $35,097,170 in 2007. For the medical degrees variable, the pattern for the coefficients was similar. There was a drop in the coefficient (table 4.8) between 1992 and 1997, a return to the 1992 level in 2002, and tremendous growth in the influence of this variable, 41.9% ((28,501.79-20,072.40)/20,072.42), between 2002 and 2007. In real dollars[18], if a university offered medical degrees, it was worth $18,920,590 of federal R&D funding in 1992, $16,668,250 in 1997, $20,072,400 in 2002 and $28,501,790 in 2007.

The magnitude of the coefficients and large growth between 2002 and 2007 of both these medical variables are not surprising since the majority of all federal R&D funding goes into life science fields in all four years of PC regressions (table 5.2). In 2007, the life sciences disciplines accounted for over 60% of all federal R&D funding at colleges and universities. Several previous studies (Feller, 1996; Teich and Gramp, 1996; Savage, 1999) found that the quality and size of research facilities mattered in a university’s ability to obtain external research funding. The preponderance of federal funding in life science fields makes the case for having medical units and programs.

For research question three, both methods of grouping universities demonstrated that discrete university groups or “clusters” existed. Over the 35 years of the study data, universities primarily

[17] Dollar ($) values of federal R&D expenditures are in the 1992 model real dollar values.

[18] Dollar ($) values of federal R&D expenditures are in the 1992 model real dollar values.

were paired with universities with whom they were grouped with in the earliest year's (1972) groupings. This was true under both cluster analysis and by distribution of the percentage of the sum of all federal research expenditures. These findings support the hierarchy conclusion of Geiger and Feller (1995), Geiger (1996), and Teich (2000). If a university was in the lowest or highest group initially, it usually remained in that group(s) through the years. Only a few universities were able to change their grouping, again consistent with the conclusions of Geiger (1996) and Geiger and Feller (1995) regarding university research competiveness in the 1980s. Placing universities into quartiles, Geiger (1996) and Geiger and Feller (1995) found that while a number of universities did move "up" and "down" in their research competiveness, it was usually in parallel with their peers, as the vast majority moved only within their quartile; only a small number of universities were able to switch quartiles.

From the cluster analysis, findings show that 262 of the 331 universities (79.2%) that were in the lowest cluster in 1972 remained in the lowest cluster in 2007. The remaining 69 universities clustered in the next two lowest clusters without a single university able to move "up" past the middle cluster. All of the universities in the top two clusters in 2007 had been in the highest cluster in 1972. This stability was also evident in the groupings by the percentages of share of the sum of all federal research expenditures. Here, hierarchy stability was more evident as 306 of the 320 (95.6%) universities that were in the lowest grouping in 1972 were still there in 2007. Only fourteen (4.4%) of the 320 universities from the lowest grouping in 1972 were able to move "up" out of the bottom group. Nine of the 14 (64%) universities that moved out of the lowest cluster in the cluster analysis (table 4.10 from chapter 4) were among the 24 universities (table 4.14 from chapter 4) identified by the percentage of share of all federal research expenditures grouping method.

Although the hierarchy was viewed as "stable" in this dissertation, most universities would be interested in why some moved up, why some moved down, and why some remained unchanged. Stability is in the eye of the beholder. To an individual university, it is primarily its own relative position over time – and why? – that is of particular interest. Among the universities that moved "up" by either grouping method, three common characteristics were identified. First, most had a medical school, a hospital, or both. Among the 14 universities that moved out of the lowest cluster in 1972 to the middle cluster in 2007 under the cluster analysis method (table 4.10), thirteen (93%) had medical schools and eight (57%) had hospitals. Of the 24 universities that moved up one group between 1972 and 2007 under the percentage of the sum of all federal research expenditures grouping method (table 4.15), twenty-two (92%) had medical schools while fifteen (63%) had a hospital affiliated with them.

The "medical explanation" for universities moving up the hierarchy is strongly supported by the findings from the second research question, the much greater federal R&D funding for universities affiliated with a hospital or offers a medical degree. Also, the coefficients (table 4.8) for having a hospital or offering medical degrees, increased between 1992 and 2007. Additionally, consider table 5.2, which showed that the vast majority of federal R&D funding came from life sciences disciplines and that their proportion of all federal R&D funding grew recently too. In sum, the universities that moved "up" in the hierarchy, did so in large part by having facilities and academic programs in the fields that garnered most of the federal R&D funding available and that had a very large influence on federal R&D funding (as evidenced by the coefficients in the PC regressions, table 4.8).

Second, most of the universities that were able to move "up" the hierarchy also had well established libraries. The 14 universities that moved out of the lowest cluster in 1972 to the middle cluster in 2007 under the cluster analysis method (table 4.10), 12 (86%) were members of the ARL. Of the 24 universities that moved up one group between 1972 and 2007 under the percentage of all federal research expenditures grouping method (table 4.14), 17 (71%) were members of the ARL.

While the coefficients (table 4.8) for the ARL index score were not as large as either of the medical variables in any of the four PC regressions, they still showed rather large influences on the amount of federal R&D funding received. While the size of the library and its resources were important in influencing the amount of federal R&D funding received, perhaps membership in the ARL signaled primarily a larger "commitment" to research by a university. As Teich and Gramp (1996) point out, regardless of scale, conducting research costs money and the level of support must be comprehensive across the university. It should not be surprising that a majority of universities that move "up" the research hierarchy were ones that made a full and comprehensive commitment to research.[19]

Third, most of the universities that were able to move "up" the hierarchy came from just 17 states, as represented by the 29 universities that moved up in either the cluster analysis (table 4.10) or the percentage of the sum of all federal research expenditures grouping method (table 4.14). More than half (9 of 17) of the states had at least one other elite research university within its borders. Additionally, 20 of the 29 universities (69%) that were in either grouping method were public universities[20]. This suggests that a majority of these states have shown a strong and

[19] It should be noted that since the early 1990s, the number of published articles in the U.S. from science and engineering has "plateaued" while the cost of conducting research has increased. Possible reasons cited for this include a rise in the complexity of research, faculty salaries, expanded use of post-docs, the funding of doctoral students, and research raw materials and equipment (National Science Foundation, 2010).

[20] 9 universities were in both grouping methods, hence a total of only 29 universities being represented in either group.

continued commitment to public higher education.

Feller (1996) suggested that geographic location and state financial resource base were factors that influenced the amount of external funding a university received. Using Census Bureau data, (2010a, 2010b) the majority, 13 of 17 (77%), of the states represented by the universities that moved "up" (tables 4.10 and 4.14) were states that had either a very large population or had experienced dramatic population growth (over 10%) since 1990. In 2007, 8 of the states represented were in the top ten while 13 of the 17 (77%) were in the top 20 in terms of total population. Nine of the 17 (53%) states represented have experienced population growth over 10% since 1990. Put directly, universities located in states with a large established population or had recent large population increases were more likely to be able to move "up" the research hierarchy.

Summary of Findings and Implications

The findings in this study provide a number of insights into the factors that affect a university's ability to attract federal R&D dollars. The major role of the Federal Government in university research is only heightened by the amount federal R&D funding available to universities and it is clear that federal R&D funding has grown tremendously over the last 35 years, a growth that appears likely to continue as the Federal Government seeks to promote economic development. As technology transfer continues to be a principal driver in the economy, comprehending the influence of university characteristics on the amount of federal R&D funding received appears to be of major importance for universities.

The findings of this study demonstrate that specific university characteristics do make a difference in the amount of federal R&D funding a university receives. The first implication to discuss is that universities should carefully consider their entire staffing plan. This would include the mix of faculty by rank and experience. The findings show that assistant professors are more cost effective in bringing in more federal research funding than their more established colleagues. However focusing on hiring and maintaining assistant professors would be short sighted, because assistant professors only stay assistant professors for short period of time. Faculty members do not aspire to being assistant professors for their entire career, and universities would be hard pressed to keep talented assistant professors on campus at the assistant rank. Assistant professors typically either earn tenure after a few years and move up to associate rank or move on to another university or organization. Kirp (2003), Bok (2003), and Geiger (2004) all describe how faculty members are "sought" and "bought". If a university does not want to promote and provide a raise to a talented faculty member, another university will.

Bringing in a top senior research, with a great track record and a great prospect for future grants, is not to be discounted as these individuals will likely return large amount of grant money. What the results indicate is that the mix of faculty and how to keep them productive, in terms of research and research grants, needs to be fully considered. Staffing plans should be considered very broadly and over long periods of time. How easily is tenure or promotion granted? How rigorous is the entire process? How can senior faculty be encouraged to remain active in research and seeking grants? How can the related expectations be monitored and enforced? Much of this may depend upon faculty peer groups, fellow department and university faculty members' and their values and expectations towards research and grant writing.

In the initial hiring decision, what attention is paid to the candidate's potential in the research and research grant domain? If tenure and higher ranks (associate and full professor) are to be granted at appointment, how can continue productivity be assured? Promotion and tenure standards, and adherence to these standards in post-tenure and promotion review, needs to be undertaken and maintained. Certainly if associate and full professors are to be appointed, a demonstrable research and grant record presumably should be required. None of this will be easy, but that makes it no less important.

Additionally, the format of the study data made it virtually impossible to track which specific faculty members earned federal R&D grants and which ones did not; Therefore, it cannot be known how many assistant professors actually earned federal grant(s) either as a member of a team or on their own. Having a few grant-productive faculty members is unlikely to result in a successful department, let alone research university. In reality it is a comprehensive system of tenured and junior faculty, along with graduate students, facilities, library, equipment, and administration that yield the desired result. Faculty, however, cost time, space and money. Hiring faculty members often means lab space and research support as well as salary and benefits. In a time of global recession and large budget cuts, expanding or even maintaining faculty numbers, regardless of rank, becomes a difficult proposition for many universities. As Bok (2003), Kirp (2003), and Geiger (2004) illustrate, universities frequently invest considerable time, resources, and effort to bring in the best tenured faculty. Perhaps what the findings herein impart is that universities should give the same careful consideration to which junior faculty members are brought to campus as they do with who receives tenure and which tenured faculty members are recruited.

A second implication is that the finding that bigger is better might be true for individual universities, but not necessarily for higher education at large. The findings on faculty salaries, number of faculty members, number of graduate students, and research equipment expenditures all indicate that the more a university has of these, the more federal R&D funding it will receive. Institutions that are able to invest across all faculty levels, from having a large number of positions to having high average salaries, are likely to realize a return on that investment in the form of federal R&D expenditures. Merton's (1968, 1988) Matthew Effect, where the rich get richer and the poor get poorer, argues that historically there has been a skewed distribution of resources, and institutions that have demonstrated research accomplishments have attracted far larger shares of resources of every kind, human and material, than institutions that had yet to make their mark. The findings from this study suggest this still holds true today, universities with large well-established programs remain at a competitive advantage over universities with smaller, less-established programs.

There has been a long-standing concern of government officials that large amounts of federal research funding are sent to just a few universities. In 1978, to directly address this concern, the NSF began the Experimental Program to Stimulate Competitive Research (EPSCoR). The mission of EPSCoR was to "to strengthen research and education in science and engineering throughout the United States and to avoid undue concentration of such research and education" (NSF, 1999 p.1). EPSCoR was designed to stimulate competitive research within universities through a dollar for dollar matching program of federal with state R&D funding. The EPSCoR program sought to create systemic changes within a university infrastructures thus building capability for long-term improvement in the ability to compete for subsequent federal R&D funding (National Science Foundation, 1999). Five states began the program, which subsequently has grown to include 27 states and 2 territories (Puerto Rico and Virgin Islands). An evaluation of the EPSCoR program in 1999 demonstrated that EPSCoR programs had helped universities, particularly public ones (53 of the 56 participating universities, 95%) in increasing the amount federal R&D funding obtained, although the increases realized were small (National Science Foundation, 1999).

The findings from both the cluster analysis and the percentage share of all federal research expenditures grouping method are in-line with the EPSCoR evaluation that it is difficult for universities, who were not an elite research university in the early 1970s, to increase their share of federal R&D funding. Universities from the EPSCoR states, typically were in the lowest cluster or group in 1972 and had difficulty moving up the hierarchy. Specifically, only 3 of 14 universities identified moving up by the cluster analysis (Table 4.10) and only 2 of 24 universities identified moving up by the percentage share of all federal research expenditures grouping method (Table 4.14) came from EPCSoR states. This is not surprising as Teach and Gramp (1996) demonstrate that to move up the hierarchy is extremely costly and these states had limited amounts of resources to provide to their universities.

Perhaps the most important concern is how universities not near the top of the hierarchy conduct themselves in efforts to attract federal R&D funding. As Dill (1996) and Feller (1996) both point out, regardless of their position, universities seek to increase the amount of research funding received. Institutional isomorphism is rampant: organizations tend to seek to resemble and take on characteristics of others, notably of those viewed as "successful" (DiMaggio and Powell, 1983). Isomorphism might not be best action when the U.S. and even individual states are considered broadly (Geiger, 1996, Geiger and Feller, 1995; Teich and Gramp, 1996; Teich, 2000)". Taking on the characteristics of a top-tiered university with the purpose generating more external funding could be very detrimental to a university in the lower tier, as well to the states and communities in which it is located. States and local communities may need research as well as non-research universities in order to serve the various roles related to teaching, service, and research.

As pointed out in chapter 3, a limitation of this study is that data are presented at the aggregate university level and not at discipline or even a field of science level. Previous work by Adams and Griliches (1998) demonstrates that there are many difficulties in measuring research productivity below an aggregate university level. This study is no exception as only the two medical variables were included in the analysis, and it is thus impossible to distinguish differences between universities at discipline levels. A main problem is the very limited data available at the discipline level. The major, useful data source, the Integrated Postsecondary Education Data System (IPEDS) database of the National Center of Educational Statistics (NCES), contains just the two variables (hospital affiliated and offers medical degrees) across the years that can be used as a proxy for academic programs and facilities in a discipline. Additional variables accounting for the presence of academic programs and facilities in other disciplines could be compiled from the IPEDS completion data, but would require a large amount of work, beyond to size and scope of a dissertation, to generate variables for the presence of different disciplines for all 35 years and 375 universities in this study. See section below on suggestions for future research for further discussion on this topic.

A final implication of this study is that a university hierarchy has been present in the past and continues to exist in regards to universities' ability to obtain federal R&D funding. This may be both good and bad. One the one hand, concentrating federal R&D funding within a relatively few well positioned universities may well be more efficient than dispersing the funds to too many, poorly positioned universities. On the other hand, politically a broad distribution of resources might prove more popular and less likely researching funding to be cut in tough economic times.

An examination of the universities that were able to move up the hierarchy shows that the majority of them had made large investments in libraries, graduate programs, and faculty, and had either a medical school or a hospital, or both, and were located in states with either a large population or had experienced a recent population growth. This bigger is better mantra, while appearing to be accurate in terms of obtaining more federal R&D funding, is a much more difficult to achieve in practice. Dill (1996) and Feller (1996) provide illuminating examples of the fierce competition among universities over research funding. While there are numerous universities seeking to move up into “elite” status, there are almost as many seeking to protect and retain their position at the top. To move up in the hierarchy, as Teich and Gramp (1996) point out, costs. It costs, in terms of money, human resources, time, and planning.

The findings from this study do provide some evidence as to where universities could invest their resources if they are looking to increase their federal R&D funding and move “up” the hierarchy. But the concerns over isomorphism and the Matthew Effect, as outlined above, are real and should be considered. Bok (2003) perhaps gives the best advice when he suggests that universities should only invest in academic programs in which they are strong and only after researching, benchmarking, and careful consideration. While universities, particularly public ones, have large and varied constituencies to consider, investing in faculty (in terms of numbers and salary) and research support such as libraries, equipment, and graduate students seems to be the best direction to take for universities developing policies and goals to increase its amount of federal R&D funding.

Summary of Frameworks and Research Design

Policy analysis, planning, and decision making is based on upon the assumption that valid and reliable information is available in a form that is readily comprehensible to decision makers. Frequently, a number of indicators related to university research must be considered to arrive at valid judgments about universities. This study took a large number of university characteristics, which had been identified in previous studies, and distilled them down into an essential few that largely determine the amount of federal R&D funding a university receives.

The resource-based theory of the firm was adapted from the field of strategic management and applied, as a conceptual framework, to determine its usefulness in providing insights into how universities compete for federal R&D funding and why which universities end up with the funding they do. The theory posited that an organization's unique assets and capabilities, those that are difficult for others to imitate, could position an organization to outperform its competition in the marketplace (Powers, 2004). The fundamental competition for universities is in the currency of ideas, which is the intellectual gain from research (Feller, 1996), and counting research expenditures has been the most commonly used measure to rank and classify university research competiveness (Teich and Gramp, 1996; Geiger 2004). When applied to this study, universities were viewed conceptually as organizations and research was viewed as an "output" or "product" of interest. The premise was that universities' particular characteristics would largely explain what federal R&D funding they received. University characteristics such as the number of students and investments in faculty and facilities were considered resources and used as independent variables in an analysis that composed a series of PCAs and constructed PC regression models. In summary, the conceptual framework appeared to work well in explaining universities' ability in obtaining federal R&D funding.

The analytical framework was guided by the series of research activity index (RAI) studies (Ashton, 1984; Ashton and Leslie, 1986; Groth, 1990; Groth, Brown, and Leslie, 1992; and Leslie and Brown, 1988). The RAI studies evaluated university characteristics and ranked universities according to their research productivity. The RAI studies differed from this study in that the former evaluated university research activity in a broad context while this study solely evaluated university research expenditures. The RAI studies were very important in that they provided a process to identify and test university characteristics. The RAI studies' methodologies had been thoroughly tested and validated in a number of studies involving university characteristics and research.

The research design for this study was developed and executed taking guidance from the conceptual and analytical framework. A PCA was selected as the statistical technique for identifying university characteristics that explain the amount of federal research funding a university receives (measured by the convention of research expenditures). The PCA reduced a set of variables, identified from previous studies, into a smaller number of variables and into sets of PCs. The 1992 PCA model was selected as the base model for all models in the analysis. This required the other year models (1997, 2002, and 2007) to only include variables present in the 1992 model with monetary variables indexed to 1992 and 1990 (to account for the 2-year lag) dollar values. A PC regression was selected as the statistical technique for evaluating the relative importance of identified characteristics, developed out from the PCAs, in explaining variations in federal research expenditures and how they change over time. The PC regressions included a series of transformations of the independent variables ultimately resulting in the generation of regression coefficients for each independent variable in a general linear regression equation. Lastly, two methods for grouping universities were used to determine if a hierarchy existed among universities posited by Geiger and Feller (1995), Geiger (1996) and Teich (2000). The two methods were a cluster analysis and the percentage share of all federal research expenditures. Both methods grouped universities at 8 different time points across 35 years (5 year increments) from 1972 to 2007.

Suggestions for Future Research

One area worth exploring is to examine the impact of the presence of other disciplines within universities, in particular engineering and agricultural, on amount of federal R&D expenditures. Engineering and agricultural programs, as well as other disciplines, could lead to greater understanding of how university characteristics impact the amount of federal R&D funding received. Although data on the amount of R&D expenditures by field of science and individual disciplines is available through NSF's Survey of Research and Development Expenditures at Universities and Colleges, the associated data are not readily available for the number of faculty members, graduate students, average faculty salary, equipment expenditures, number of post-docs, and non-faculty researchers (by discipline). Inclusion of a variable for whether a university has an engineering or an agricultural school would not be as labor intensive as it would be to include variables for each discipline and would include the three major disciplines (life sciences/medical being the other) that receive a large portion of federal R&D funding.

A second area to explore is the addition of location variables, to include the presence of nearby universities and industries. A number of studies on higher education and economic development (Feldman, 1994; Mita and Formica, 1997; Yusuf, 2007) show that clusters of universities and industries create an infrastructure that supports and facilitates new research. Data are available through IPEDS for zip codes of universities. A number of states appear to have good quality data on the number of industries, by type, in particular locations (typically in metropolitan statistical areas), although creation of useful indices reflecting number, types, and size of industries or even colleges and universities within a certain geographical proximity could prove difficult. Location variables were not included in this study because of the time constraints and the difficulty of obtaining the data.

Although this dissertation focused on federal R&D funding, state and regional policy no doubt has an impact on the amount of federal R&D funding a university obtained. Examining the interaction between state and regional policies, particular as they relate to economic development, facilities, and retaining key faculty, would be helpful in further understanding federal R&D funding.

Reflecting on Bowen's (1980) revenue theory of cost, one could consider how universities structure their human resources to maximize R&D revenues. Over the past decades, new staffing patterns have come about as many post-docs, adjuncts, part-time faculty, and other personnel have been hired. Have these structures altered the roles faculty and others, particularly in regard to research? What has been the overall impact of the new staff added? This area may be worthy of further inquiry in regard to impacts on federal R&D funding obtained by universities.

Finally, adding additional university variables, specifically ones tied to economic development might provide a more robust analysis. A large portion of recent university research is tied to economic development (Bloch, 2007; Teich, 2000). Expanding the analysis to include variables such as universities' publications, patents, and licenses probably would lead to a better prediction of the amount of federal R&D expenditures for universities. This would also be well received, as government pressure on universities to contribute to economic development is likely to continue for the foreseeable future.

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APPENDIX A

COMBINED CAMPUSES OF UNIVERSITIES IN NSF SURVEY (R&D EXPENDITURES)

- Auburn University
    - Auburn University Main Campuses
    - Auburn University – Montgomery
- Bowling Green State University
    - Bowling Green State University – Main Campus
    - Bowling Green State University - Firelands
- Brigham Young University
    - Brigham Young University – Main
    - Brigham Young University - Hawaii
- Indiana University
    - Indiana University – Bloomington
    - Indiana University – Kokomo
    - Indiana University – South Bend
    - Indiana University – Northwest
    - Indiana University – Southeast
    - Indiana University - East
- Kent State University
    - Kent State University – Kent
    - Kent State University – Ashtabula
    - Kent State University – East Liverpool
    - Kent State University – Stark
    - Kent State University – Trumbull
    - Kent State University – Tuscarawas
    - Kent State University – Salem
    - Kent State University – Geauga
- Long Island University
    - Long Island University – CW Post Campus
    - Long Island University – Brooklyn
    - Long Island University – University Center
- Louisiana State University – All Campuses
    - Louisiana State University & Agricultural & Mechanical
    - Louisiana State University Health Sciences Center at New Orleans
    - Louisiana State University Health Sciences Center – Shreveport
    - Louisiana State University @ Alexandria
    - Louisiana State University @ Eunice
    - Louisiana State University @ Shreveport

- Miami University
    - Miami University – Oxford
    - Miami University – Hamilton
    - Miami University – Middletown
- New Mexico State University
    - New Mexico State University – Main Campus
    - New Mexico State University – Dona Ana
    - New Mexico State University – Alamogordo
    - New Mexico State University – Carlsbad
    - New Mexico State University - Grants
- New York Institute of Technology
    - New York Institute of Technology – Old Westbury
    - New York Institute of Technology – Manhattan
- Ohio University
    - Ohio University – Main Campus
    - Ohio University – Eastern
    - Ohio University – Chillicothe
    - Ohio University – Southern
    - Ohio University – Lancaster
    - Ohio University - Zanesville
- Ohio State University
    - Ohio State University – Main Campus
    - Ohio State University – Agricultural Technical Institute
    - Ohio State University – Lima
    - Ohio State University – Mansfield
    - Ohio State University – Marion
    - Ohio State University – Newark
- Oklahoma State University
    - Oklahoma State University – Main Campus
    - Oklahoma State University – Center for Health Sciences
    - Oklahoma State University – Oklahoma City
    - Oklahoma State University - Okmulgee
- Pennsylvania State University
    - Pennsylvania State University – Main Campuses
    - Pennsylvania State University – Erie-Behrend
    - Pennsylvania State University – Great Valley
    - Pennsylvania State University – College of Medicine
    - Pennsylvania State University – New Kensington
    - Pennsylvania State University – Shenango
    - Pennsylvania State University – Wilkes-Barre
    - Pennsylvania State University – Worthington Scrant
    - Pennsylvania State University – Lehigh Valley
    - Pennsylvania State University – Altoona
    - Pennsylvania State University – Beaver
    - Pennsylvania State University – Berks

- Pennsylvania State University – continued
    - Pennsylvania State University – Harrisburg
    - Pennsylvania State University – Delaware County
    - Pennsylvania State University – Dubois
    - Pennsylvania State University – Fayette-Eberly Ca
    - Pennsylvania State University – Hazelton
    - Pennsylvania State University – McKeesport
    - Pennsylvania State University – Mont Alto
    - Pennsylvania State University – Abington
    - Pennsylvania State University – Schuylkill
    - Pennsylvania State University - York
- Purdue University
    - Purdue University – Main Campus
    - Purdue University – Calumet Campus
    - Purdue University – North Central Campus
- Rutgers, The State University of NJ
    - Rutgers University – New Brunswick/Piscataway
    - Rutgers University – Newark
    - Rutgers University – Camden
- Texas A&M University
    - Texas A&M University – Main
    - Texas A&M University – System Health Science Center
    - Texas A&M University – Corpus Christi
    - Texas A&M University – International University
    - Texas A&M University - Galveston
- University of Akron
    - University of Akron – Main Campus
    - University of Akron – Wayne College
- University of Cincinnati
    - University of Cincinnati – Main Campus
    - University of Cincinnati – Clermont
    - University of Cincinnati – Raymond Walters
- University of Colorado
    - University of Colorado @ Boulder
    - University of Colorado @ Colorado Springs
    - University of Colorado @ Denver and Health Sciences Center
- University of Kansas
    - University of Kansas – Main Campuses
    - University of Kansas – Medical Center
- University of Michigan
    - University of Michigan – Ann Arbor
    - University of Michigan – Dearborn
    - University of Michigan – Flint

- University of Minnesota
    - University of Minnesota - Twin Cities
    - University of Minnesota – Crookston
    - University of Minnesota – Duluth
    - University of Minnesota – Morris
- University of Mississippi
    - University of Mississippi - Main Campus
    - University of Mississippi – Medical Center
- University of Nebraska
    - University of Nebraska – Lincoln
    - University of Nebraska – Kearney
    - University of Nebraska – Omaha
    - University of Nebraska – Medical Center
- University of New Mexico
    - University of New Mexico – Main Campus
    - University of New Mexico – Gallup
    - University of New Mexico – Los Alamos
    - University of New Mexico – Valencia County Branch
    - University of New Mexico – Taos Branch
- University of Oklahoma
    - University of Oklahoma – Norman
    - University of Oklahoma – Health Sciences Center
- University of Pittsburgh
    - University of Pittsburgh – Main Campus
    - University of Pittsburgh – Bradford
    - University of Pittsburgh – Greensburg
    - University of Pittsburgh – Johnstown
    - University of Pittsburgh – Titusville
    - University of Pittsburgh – Medical Center – Shadyside School
    - University of Pittsburgh – Medical Center – Health System
- University of South Carolina
    - University of South Carolina – Columbia
    - University of South Carolina – Aiken
    - University of South Carolina – Beaufort
    - University of South Carolina – Lancaster
    - University of South Carolina – Salkehatchie
    - University of South Carolina – Sumter
    - University of South Carolina – Union
    - University of South Carolina – Upstate
- University of Toledo
    - University of Toledo
    - Medical College of Ohio (merged in 2007)
    - * all data for U of Toledo was merged with MCO data for years previous to 2007

- Wright State University
    - Wright State University – Main Campus
    - Wright State University – Lake

APPENDIX B

0-Year Lag PCAs (1992, 1997, 2002, 2007)

Table B.1 - Variables kept in 0-year lag PCAs

2007	2002	1997	1992
Hospital Affiliated	Hospital Affiliated	Hospital Affiliated	Hospital Affiliated
Medical Degree	Medical Degree	Medical Degree	Medical Degree
ARL Index Score	ARL Index Score	ARL Index Score	ARL Index Score
Equipment Expend	Equipment Expend	Equipment Expend	Equipment Expend
Avg. Salary Assistant	Avg. Salary Assistant	Avg. Salary Assistant	Avg. Salary Assistant
Avg. Salary Associate	Avg. Salary Associate	Avg. Salary Associate	Avg. Salary Associate
Avg. Salary Professor	Avg. Salary Professor	Avg. Salary Professor	Avg. Salary Professor
# Assistant Professors	# Assistant Professors	# Assistant Professors	# Assistant Professors
# Associate Professors	# Associate Professors	# Associate Professors	# Associate Professors
# Professors	# Professors	# Professors	# Professors
# Graduate Students	# Graduate Students	# Graduate Students	# Graduate Students
# Doctoral Degrees	# Doctoral Degrees	# Doctoral Degrees	# Doctoral Degrees
Control	Control		
	AAU Status		

Table B.2 - Eigenvalues for 0-year lag PCAs

Principal Component	2007	2002	1997	1992
Prin_1	6.761	7.356	6.635	6.728
Prin_2	2.458	2.350	2.120	2.123
Prin_3	1.189	1.148	1.188	1.250
Prin_4	0.631	0.834	0.638	0.662
Prin_5	0.559	0.621	0.361	0.341
Prin_6	0.447	0.379	0.315	0.282
Prin_7	0.319	0.319	0.251	0.196
Prin_8	0.254	0.272	0.142	0.127
Prin_9	0.104	0.231	0.122	0.091
Prin_10	0.096	0.153	0.086	0.077
Prin_11	0.075	0.107	0.075	0.068
Prin_12	0.064	0.091	0.066	0.055
Prin_13	0.044	0.072		
Prin_14		0.067		

Table B.3a - Component and variable loading matrixes – 2007 0-year lag PCA

Variable	Resources	Salary	Medical
Institution has Hospital	0.123	0.104	0.912
Institution grants medical degree	0.360	0.118	0.809
ARL Index Score	0.667	0.381	0.178
$ Research Equipment Expenditures	0.674	0.200	0.322
# of Assistant Professors	0.891	-0.098	0.133
# of Associate Professors	0.900	-0.053	0.119
# of Professors	0.930	0.209	0.129
Average Salary Assistant Professors	0.318	0.875	0.126
Average Salary Associate Professors	0.228	0.910	0.126
Average Salary Professors	0.313	0.888	0.198
# of Graduate Students	0.873	0.222	0.177
# of Doctoral Degrees Awarded	0.847	0.293	0.235
Public University (Control)	0.341	-0.659	0.068

Rotation Method: Varimax with Kaiser Normalization.

Table B.3b - Component and variable loading matrixes – 2002 0-year lag PCA

Variable	Resources	Salary	Medical
Institution has Hospital	0.161	0.108	0.906
Institution grants medical degree	0.364	0.115	0.807
ARL Index Score	0.766	0.314	0.189
$ Research Equipment Expenditures	0.683	0.259	0.277
# of Assistant Professors	0.854	-0.042	0.199
# of Associate Professors	0.866	-0.072	0.187
# of Professors	0.941	0.147	0.129
Average Salary Assistant Professors	0.297	0.863	0.125
Average Salary Associate Professors	0.231	0.895	0.126
Average Salary Professors	0.331	0.863	0.158
# of Graduate Students	0.873	0.179	0.149
# of Doctoral Degrees Awarded	0.878	0.256	0.174
Public University (Control)	0.328	-0.634	0.054

Rotation Method: Varimax with Kaiser Normalization.

Table B.3c - Component and variable loading matrixes – 1997 0-year lag PCA

Variable	Resources	Salary	Medical
Institution has Hospital	0.166	0.114	0.904
Institution grants medical degree	0.364	0.111	0.806
ARL Index Score	0.788	0.308	0.169
$ Research Equipment Expenditures	0.704	0.256	0.256
# of Assistant Professors	0.837	-0.070	0.218
# of Associate Professors	0.846	-0.102	0.208
# of Professors	0.944	0.127	0.129
Average Salary Assistant Professors	0.307	0.850	0.131
Average Salary Associate Professors	0.237	0.881	0.135
Average Salary Professors	0.342	0.850	0.161
# of Graduate Students	0.870	0.155	0.152
# of Doctoral Degrees Awarded	0.891	0.242	0.163
Public University (Control)	0.302	-0.648	0.075
AAU Status	0.684	0.377	0.150

Rotation Method: Varimax with Kaiser Normalization.

Table B.3d - Component and variable loading matrixes – 1992 0-year lag PCA

Variable	Resources	Salary	Medical
Institution has Hospital	0.112	0.123	0.898
Institution grants medical degree	0.342	0.071	0.824
ARL Index Score	0.756	0.293	0.292
$ Research Equipment Expenditures	0.704	0.294	0.315
# of Assistant Professors	0.904	-0.005	0.102
# of Associate Professors	0.892	0.042	0.082
# of Professors	0.928	0.194	0.083
Average Salary Assistant Professors	0.219	0.933	0.051
Average Salary Associate Professors	0.129	0.961	0.060
Average Salary Professors	0.218	0.923	0.182
# of Graduate Students	0.853	0.285	0.195
# of Doctoral Degrees Awarded	0.845	0.280	0.257

Rotation Method: Varimax with Kaiser Normalization.

APPENDIX C

2-Year Lag PCAs (1992, 1997, 2002, 2007)

Table C.1 - Variables kept in 2-year lag PCAs

2007	2002	1997	1992
Hospital Affiliated	Hospital Affiliated	Hospital Affiliated	Hospital Affiliated
Medical Degree	Medical Degree	Medical Degree	Medical Degree
ARL Index Score	ARL Index Score	ARL Index Score	ARL Index Score
Equipment Expend	Equipment Expend	Equipment Expend	Equipment Expend
Avg. Salary Assistant	Avg. Salary Assistant	Avg. Salary Assistant	Avg. Salary Assistant
Avg. Salary Associate	Avg. Salary Associate	Avg. Salary Associate	Avg. Salary Associate
Avg. Salary Professor	Avg. Salary Professor	Avg. Salary Professor	Avg. Salary Professor
# Assistant Professors	# Assistant Professors	# Assistant Professors	# Assistant Professors
# Associate Professors	# Associate Professors	# Associate Professors	# Associate Professors
# Professors	# Professors	# Professors	# Professors
# Graduate Students	# Graduate Students	# Graduate Students	# Graduate Students
# Doctoral Degrees	# Doctoral Degrees	# Doctoral Degrees	
Control	Control	AAU Status	

Table C.2 – Eigenvalues for 2-year lag PCAs

Principal Component	2007	2002	1997	1992
Prin_1	6.805	6.859	7.092	5.877
Prin_2	2.442	2.433	2.259	1.910
Prin_3	1.192	1.154	1.227	1.261
Prin_4	0.595	0.678	0.788	0.619
Prin_5	0.577	0.579	0.424	0.348
Prin_6	0.344	0.352	0.319	0.287
Prin_7	0.301	0.300	0.238	0.213
Prin_8	0.279	0.233	0.218	0.198
Prin_9	0.144	0.107	0.138	0.138
Prin_10	0.099	0.090	0.098	0.084
Prin_11	0.093	0.084	0.079	0.065
Prin_12	0.068	0.076	0.062	
Prin_13	0.062	0.055	0.058	

Table C.3a - Component and variable loading matrixes – 2007 0-year lag PCA

Variable	Resources	Salary	Medical
Institution has Hospital	0.132	0.084	0.913
Institution grants medical degree	0.366	0.104	0.806
ARL Index Score	0.775	0.294	0.242
$ Research Equipment Expenditures	0.659	0.227	0.303
# of Assistant Professors	0.898	-0.071	0.113
# of Associate Professors	0.894	-0.050	0.117
# of Professors	0.935	0.172	0.130
Average Salary Assistant Professors	0.328	0.856	0.113
Average Salary Associate Professors	0.224	0.908	0.089
Average Salary Professors	0.319	0.883	0.187
# of Graduate Students	0.865	0.197	0.176
# of Doctoral Degrees Awarded	0.851	0.279	0.241
Public University (Control)	0.328	-0.680	0.366

Rotation Method: Varimax with Kaiser Normalization.

Table C.3b - Component and variable loading matrixes – 2002 0-year lag PCA

Variable	Resources	Salary	Medical
Institution has Hospital	0.152	0.113	0.907
Institution grants medical degree	0.361	0.112	0.812
ARL Index Score	0.760	0.333	0.199
$ Research Equipment Expenditures	0.708	0.299	0.230
# of Assistant Professors	0.871	-0.084	0.186
# of Associate Professors	0.876	-0.085	0.176
# of Professors	0.939	0.141	0.117
Average Salary Assistant Professors	0.308	0.883	0.115
Average Salary Associate Professors	0.237	0.893	0.112
Average Salary Professors	0.310	0.886	0.188
# of Graduate Students	0.872	0.212	0.156
# of Doctoral Degrees Awarded	0.864	0.292	0.211
Public University (Control)	0.332	-0.636	0.051

Rotation Method: Varimax with Kaiser Normalization.

Table C.3c - Component and variable loading matrixes – 1997 0-year lag PCA

Variable	Resources	Salary	Medical
Institution has Hospital	0.128	0.114	0.908
Institution grants medical degree	0.360	0.073	0.818
ARL Index Score	0.795	0.287	0.216
$ Research Equipment Expenditures	0.711	0.273	0.222
# of Assistant Professors	0.862	-0.063	0.116
# of Associate Professors	0.873	-0.008	0.117
# of Professors	0.935	0.148	0.079
Average Salary Assistant Professors	0.189	0.938	0.046
Average Salary Associate Professors	0.088	0.957	0.047
Average Salary Professors	0.241	0.917	0.162
# of Graduate Students	0.855	0.242	0.205
# of Doctoral Degrees Awarded	0.882	0.274	0.209
AAU Status	0.647	0.376	0.186

Rotation Method: Varimax with Kaiser Normalization.

Table C.3d - Component and variable loading matrixes – 1992 0-year lag PCA

Variable	Resources	Salary	Medical
Institution has Hospital	0.100	0.089	0.902
Institution grants medical degree	0.334	0.052	0.827
ARL Index Score	0.731	0.266	0.296
$ Research Equipment Expenditures	0.685	0.260	0.362
# of Assistant Professors	0.913	0.077	0.113
# of Associate Professors	0.901	0.105	0.076
# of Professors	0.910	0.208	0.095
Average Salary Assistant Professors	0.218	0.891	0.023
Average Salary Associate Professors	0.149	0.946	0.072
Average Salary Professors	0.236	0.911	0.137
# of Graduate Students	0.829	0.296	0.230

Rotation Method: Varimax with Kaiser Normalization.

APPENDIX D

Scree Plots (1992, 1997, 2002, 2007)

Chart D.1a – Scree Plot 2007 2-Year Lag PCA

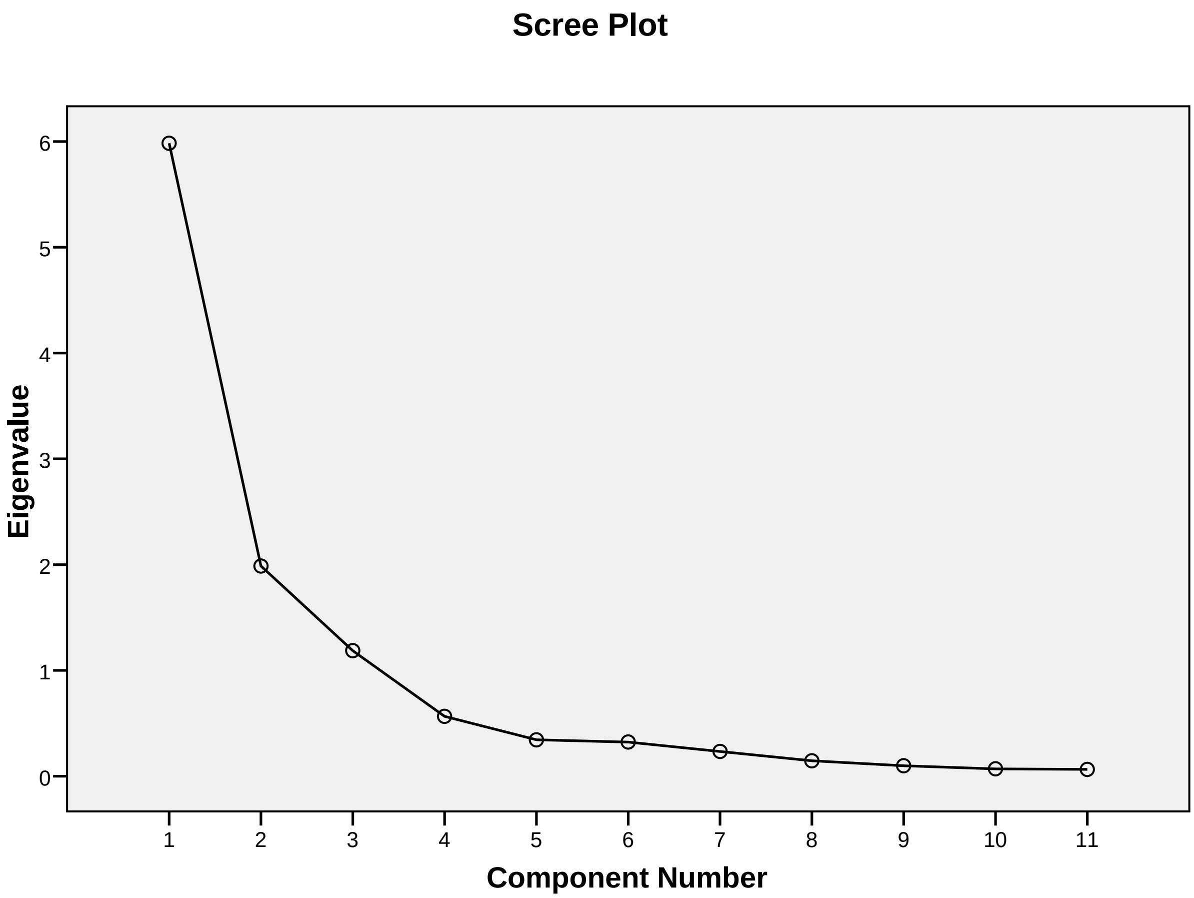


Chart D.1b – Scree Plot 2002 2-Year Lag PCA

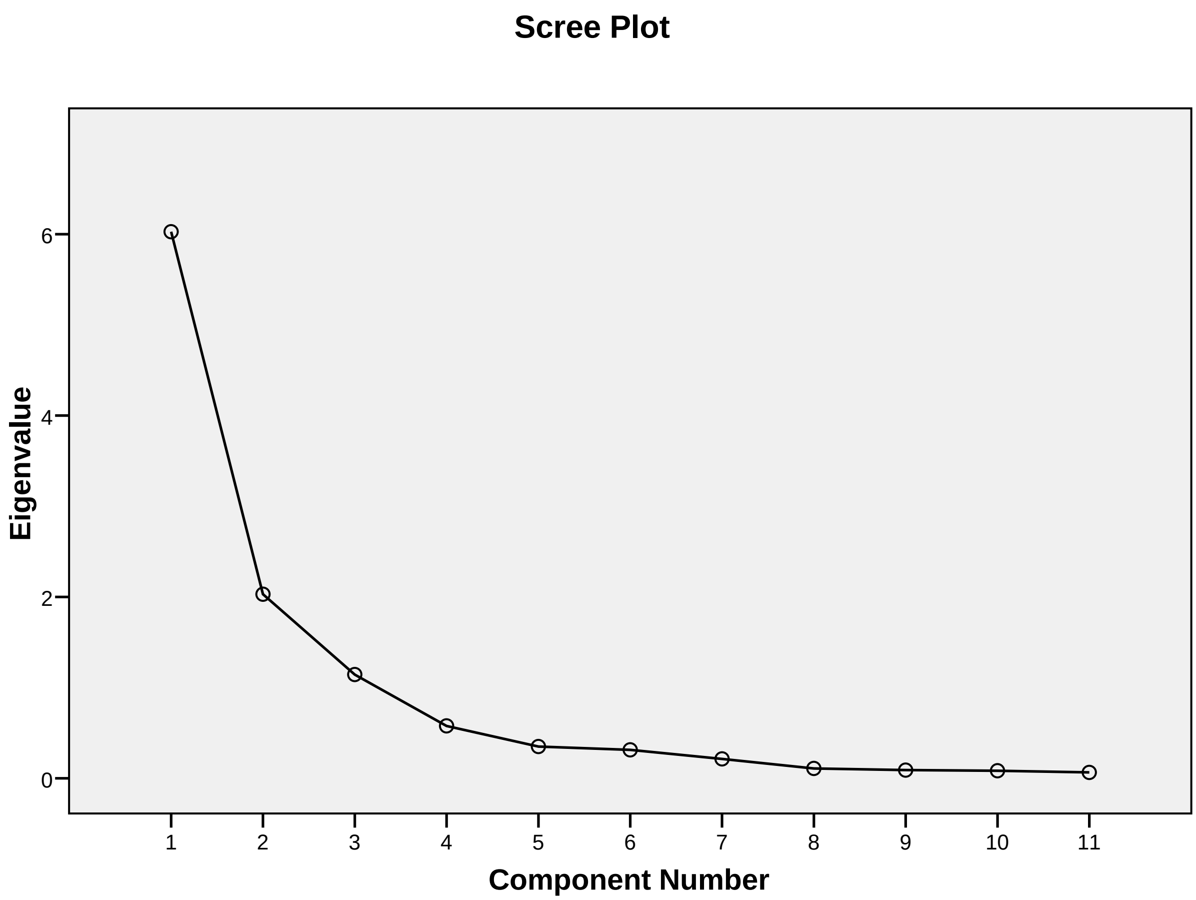


Chart D.1c – Scree Plot 1997 2-Year Lag PCA

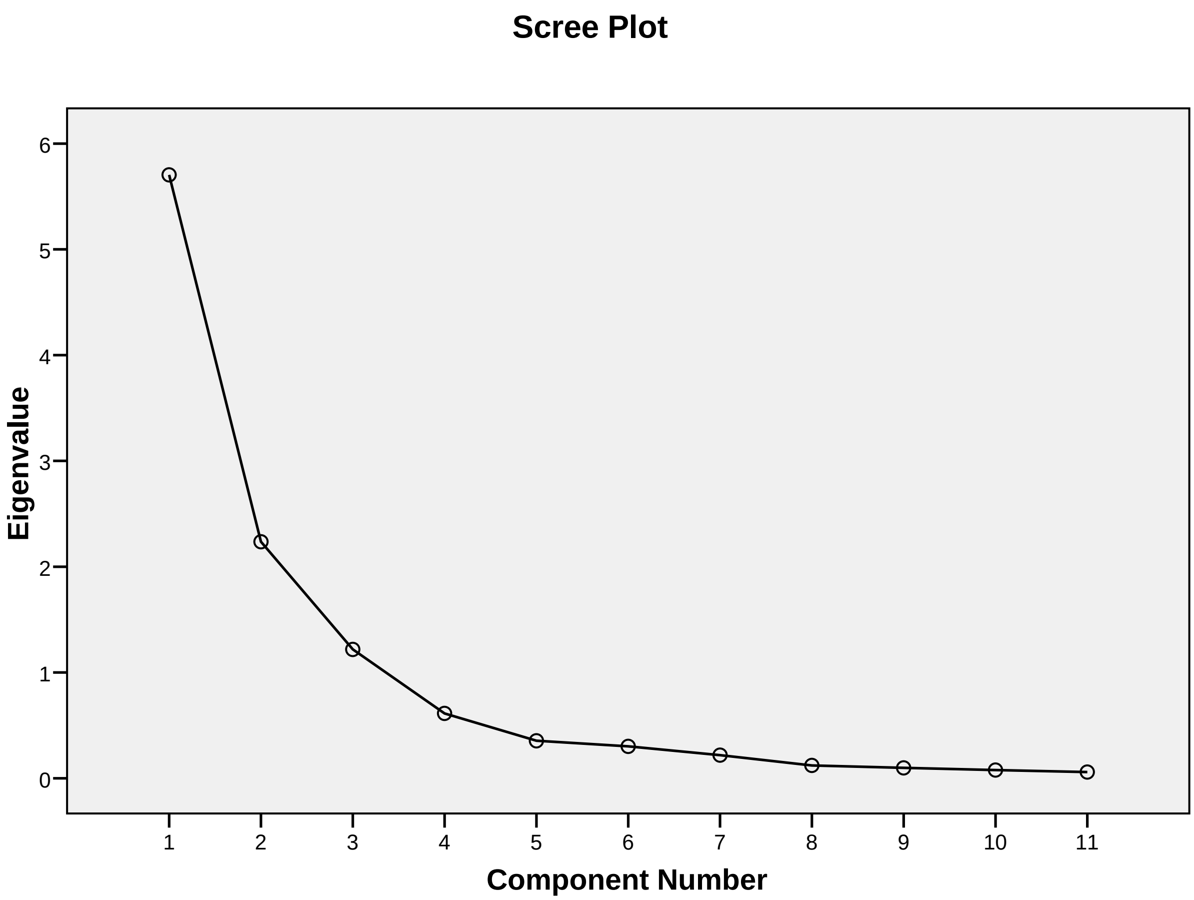
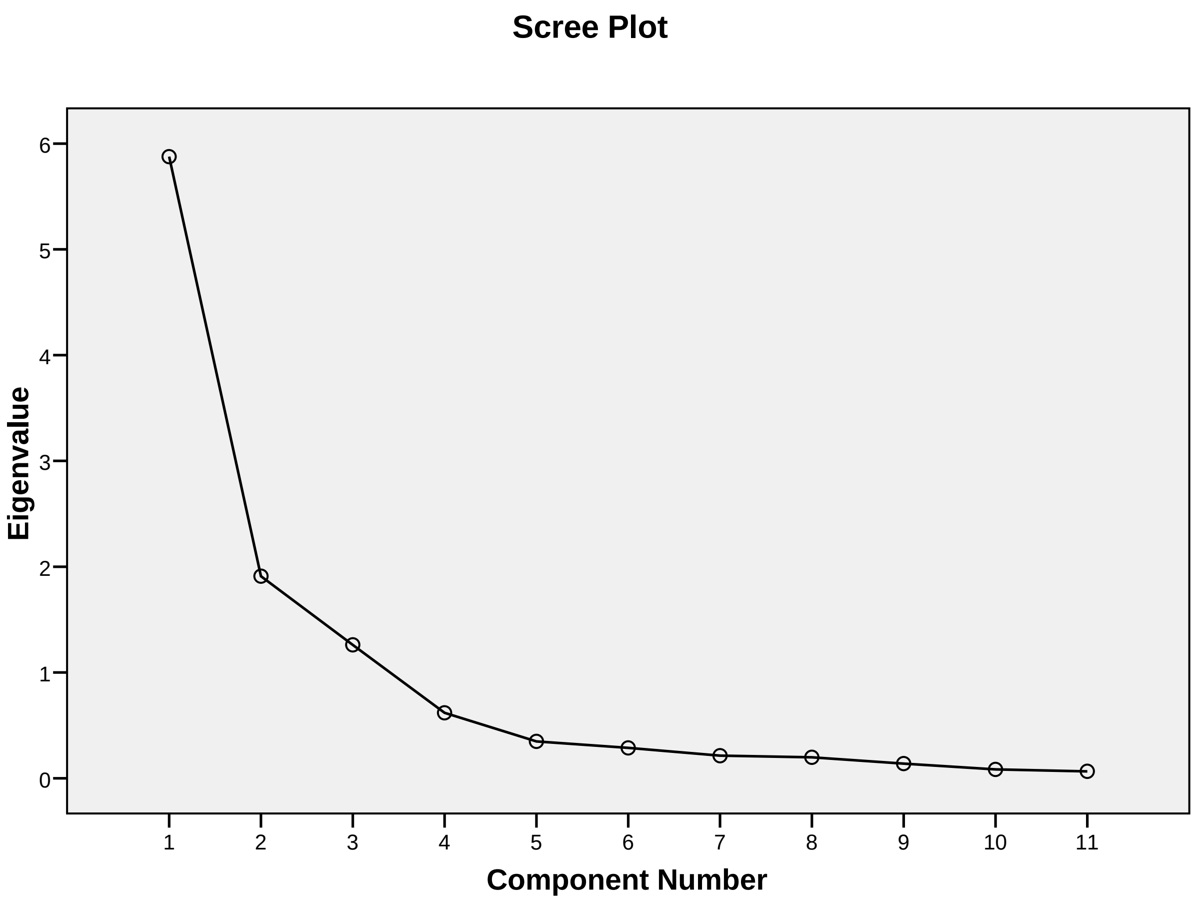


Chart D.1d – Scree Plot 1992 2-Year Lag PCA



APPENDIX E

Universities in top cluster 1972 (from cluster analysis)

California Institute of Technology
Case Western Reserve University
Colorado State University
Columbia University in the City of New York
Cornell University, All Campuses
Duke University
Harvard University
Indiana University, Bloomington
Johns Hopkins University
Massachusetts Institute of Technology
Michigan State University
New Mexico State University, All Campuses
New York University
Ohio State University, Main Campus
Pennsylvania State U, Main Campus
Princeton University
Purdue University, Main Campus
Stanford University
Texas A&M University, Main
University of California-Berkeley
University of California-Davis
University of California-Los Angeles
University of California-San Diego
University of California-San Francisco
University of Chicago
University of Colorado, All Campuses
University of Hawaii at Manoa
University of Illinois at Urbana-Champaign
University of Miami
University of Michigan, Ann Arbor
University of Minnesota, Twin Cities
University of Missouri, Columbia
University of North Carolina at Chapel Hill

University of Pennsylvania
University of Pittsburgh, Main Campus
University of Rochester
University of Southern California
University of Texas at Austin
University of Utah
University of Washington - Seattle
University of Wisconsin-Madison
Washington University
Yale University
Yeshiva University