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The Effect of Linkages on Science and Technology at Historically Black Colleges and Universities

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THE EFFECT OF LINKAGES ON SCIENCE AND TECHNOLOGY AT HISTORICALLY BLACK COLLEGES AND UNIVERSITIES

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This dissertation is dedicated to my husband, David, who shared the risks and sacrifices required to complete it while supporting me through this entire adventure. I cannot possibly thank him enough for supporting me over and over again, enduring my trials and tribulations and encouraging me to stick with it. I thank also my parents, John and Phyllis Rice for their endless encouragement and for inspiring me to succeed in life.

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LIST OF SYMBOLS OR ABBREVIATIONS

AUTM	Association of University Technology Managers
DOE	Department of Energy (U.S.)
ESI	Environmental Sciences Institute (at FAMU)
FAMU	Florida Agricultural and Mechanical University
FVSU	Fort Valley State University
HBCU	Historically Black College and University
NASA	National Aeronautics and Space Administration
NCES	National Center for Education Statistics
NIH	National Institute of Health
NSF	National Science Foundaton
R&D	Research and Development
RFP	Request for Proposal
S&E	Science and Engineering
S&T	Science and Technology
SACS	Southern Association of Colleges and Schools
SET	Science, Engineering and Technology
SMET	Science, Math, Engineering and Technology
STEM	Science, Technology, Engineering and Mathematics
SUNY	State University of New York
TWI	Traditionally White Institution
USDA	United States Department of Agriculture

SUMMARY

Historically Black Colleges and Universities (HBCUs) face the 21^{st} century with questions about change and adaptation to an increasingly science- and technology-oriented society. They face the challenge of finding a strategy by which they can utilize current resources and energy to maximize their science and technology development. Using a mixed methods research design, this study conducted an analysis of science and technology at HBCUs. The primary objective was to determine what theories (when implemented they are termed strategies) account for the development of science and technology at successful research-oriented HBCUs. This was accomplished through a secondary objective – to assess productivity outputs at HBCUs using various science and technology indices.

The results and findings can be summarized by stating that the selection of strategy is dependent on the maturity of the HBCU's science and technology program. An HBCU that is seeking to initiate a science and technology program should pursue a strategy of federal or state policy supportive of introductory efforts. HBCUs with established science and technology programs that are seeking growth strategies should look toward collaborations and partnerships for the purposes of forming networks and clusters. The formation of joint ventures, partnerships, and networks will further develop their science and technology programs. Leadership is a sustaining factor that enhances the effectiveness of both policy and linkages.

CHAPTER 1
INTRODUCTION

Historically Black Colleges and Universities (HBCUs) face the 21st century with questions about change and adaptation to an increasingly science- and technology-oriented society. They face the challenge of finding a strategy by which they can utilize current resources and energy to maximize their science and technology development. Using a mixed methods research design, this study conducts an analytical study of science and technology at HBCUs. The results of this study will assist HBCUs and those interested in supporting HBCU research institutions in determining productivity levels, characteristics of competitive universities, and effective strategies for science and technology productivity. The primary objective is to determine what theories (when implemented they are termed strategies) account for the development of science and technology at the most successful research-oriented HBCUs. (This is not meant to imply "best strategies" but strategies that appear to be useful and working well.) This will be accomplished through a secondary objective – to assess productivity outputs at HBCUs in various science and technology indices.

Universities have become increasingly important to society. They are the repository of human intellectual property; the physical focal point of much research and development; and the crossroads between businesses, resources, and the government. They are engaging in contractual arrangements and agreements with other universities, industry, and government, particularly in the science and technology arena, to the point where they are developing a network that impacts society and their role and mission in

society. HBCUs, universities that historically serviced a predominantly Black student body are a subset within the population of universities that have a unique historical background. While they participate in and contribute in all the aforementioned ways, there have been few, if any, studies that contribute to an understanding of what strategies or methods have evolved in this unique subset of universities to develop their science and technology productivity.

The theories introduced in this dissertation are drawn from three literature bases. One concept is highlighted throughout the reviewed literature – the concept of linkages. While the term linkages is more fully defined further in this report, this study operationalizes linkages as networks. The literature bases suggest that linkages offer an explanation as to how universities can best develop their science and technology capability.

However, the applicability of the linkages concept to HBCUs is questionable. The history of HBCUs is based on that of a separate identity, both because of historically racist policies by Whites and because of a continuing choice by Black universities to retain a separate identity despite the advent of integrated university systems. These two elements, racism and separation, run counter to the concept of linkages. Yet the linkages concept remains the dominant explanation for science and technology development. Since HBCUs are a subset of universities and there are few published studies to indicate what differences exist between HBCUs and traditionally White universities in relation to science and technology, this study maintains the hypothesis that linkages are the most effective strategy for HBCUs to adopt to develop science and technology capacity.

Using a qualitative exploratory approach, this study also examines several other theories to determine whether they have more validity for explaining the development of science and technology at HBCUs. These rival theories or strategies have emerged from literature bases on higher education, labor, and innovation. The quantum increase in funding for basic research and development as well as support for training of science personnel at universities has been attributed to government policy. A theory of leadership at universities by key scientists or administrators has been held to be responsible for important innovations and the systems that have arisen around them. Spatial proximity studies indicate that information transmission and spillovers occur in regions between universities and firms, which lead to enhanced development of science and technology. The demand for skilled science and technology personnel has resulted in support for an increase in the number of university students graduating in science and technology related. Finally, the theory of linkages uses the concept of networks/clusters to explain the science and technology benefits that accrue to universities that engage in partnerships and collaborations with other parties. Of the theories advanced to account for science and technology development, the concept of linkages has received the most attention. This is due to its ability to encompass a wide range of actions as well as its prominence in explaining the interaction that occurs in systems, particularly systems of innovation.

By reviewing these theories, this dissertation will explore how HBCUs have developed their science and technology productivity. The major question addressed by this dissertation is, “What strategies have been utilized by HBCUs that exhibit the most

success in developing their science and technology capacity?" The following subquestions will be addressed. Which HBCUs are the most productive in certain science and technology indicators? What are the characteristics of those HBCUs that are considered the most productive? Are linkages the most effective strategy HBCUs should adopt to be more productive in science and technology? Are there other effective strategies utilized by HBCUs to develop their science and technology capacity?

1.1 The Theoretical Bases

The theoretical basis of this dissertation study is taken from the intersection of three bodies of literature – competitive advantage literature, higher education literature, and systems of innovation literature. The strategies that account for the development of science and technology emerge from these various literature bases. The concept of linkages is an integral component that is present in all three literature bases.

The literature on higher education institutions, as it relates to science and technology, covers the evolution of these institutions from having a mission of preserving culture and transmitting knowledge to a mission of creating knowledge and interacting with industry, government and other universities to transfer that knowledge and potentially capitalize on it.

The concept of linkages in the literature on institutions of higher education can be traced back to WWII. Historical reviews on universities and science and technology explore the significance of a significant infusion of federal funds after WWII to universities for research. The dramatic increases in funding for research, personnel, equipment and libraries enabled a minor function at universities (research) to grow into a

significant component. Scientists and basic research became important leading to legislation that supported the growth of sponsored research offices at many universities. Another body of literature grew out of the passage of the Bayh-Doyle Act of 1980 exploring the significance and impact of universities retaining the rights and profits of their research. Patent production grew and the interaction between industry and universities increased. The interaction between universities and industry intensified leading academicians to study and write on the linkages or networks between government, universities and industry. The literature on higher education now maintains that the mission at many universities is to teach, research, and exchange knowledge. This is done through linkages or networks universities are building with other entities.

The role of universities in this network system is a key component of the literature on innovation. The system of innovation theory contends that the three major actors within the system are firms, government, and universities. Universities conduct the research that is often a foundation of new products. Universities train scientists and engineers and they interact with firms to transfer knowledge. While firms produce most of the innovation that occurs, they could not do so without the personnel and knowledge from the university and the funding and policies provided by government. A system of *linkages or networks* evolves, consciously or unconsciously, formal or informal that supports interaction leading to innovation. Knowledge spillovers occur in this network of information that benefits universities and firms in close proximity to the centers of information. Many academicians have striven to understand how this system evolves and what types of linkages are important to making innovation occur.

Some of these answers are provided by the extensive literature on competitive advantage. The theory of competitive advantage grew out of studies explaining the dynamics of industry growth and success or decline. Competitive or successful industries are often geographically close and they build upon technological innovation. This closeness and interaction leads to *linkages or networks* which the theory expands upon and terms “clusters.” This grouping of companies within an industry that operate vertically and horizontally with suppliers and distributors creates a force whose productivity is greater than the sum of its parts. Although the theory of competitive advantage is focused on firms and some of the implicit assumptions held in economics, the theory has been applied to universities due to their ability to claim property rights of new products and their close relationship with industry and government causing them to behave more like a firm.

The theory of competitive advantage gives this dissertation a dynamic explanation for how an industry like the university system can increase, improve, change or identify how to change their position. Using the competitive advantage model, this study analyzes strategies in light of their impact on growth and development.

It is clear that there is a great deal of overlap between the three literature bases. The literatures on higher education and innovation display universities as a major actor with research as a key contribution to new products. The intersection between higher education and competitive advantage comes from universities acting more like industries due to the tremendous increases in funding and their ability to own rights and profits from their inventions. Universities’ behavior of increasing their research functions,

establishing sponsored research offices, and partnering more frequently and intensively with industry enables the use of competitive advantage theory to be applied to universities. It becomes almost necessary to look at all three literature bases simultaneously to understand the dynamics of what is occurring in science and technology at universities.

1.2 Why HBCUs?

The 104 Historically Black Colleges and Universities (HBCUs) are a unique subset of the higher education system in the United States. Black colleges and universities were created, funded and supported by both Blacks and Whites as a result of legal segregation. This forced a separation between Blacks and Whites in almost all aspects of life in the southern part of the United States (where most Blacks resided). Most of the colleges and universities that were created to teach higher education to Blacks during the segregation era started with elementary and high school level education. Over time, they gained accreditation and became competitors with other majority colleges and universities who opened their doors to Black students. The majority of HBCUs that survive still serve a predominantly Black population. However, most HBCUs are small, serve a population that has been identified as more academically challenged, and are generally underfunded. Thus, the question is legitimately raised as to what HBCUs have to offer and why they should be selected as targets of study.

There are several reasons why HBCUs should be explored and why science and technology at HBCUs should be explored. HBCUs have demonstrated success at their mission of educating and graduating students. While the majority of Blacks attend

traditionally White institutions (defined as educational institutions with predominantly White student populations), HBCUs account for the majority of Black students that graduate in many fields (Allen, Epps, & Haniff, 1991; Hoffman, Snyder, & Sonnenberg, 1992). On the average, HBCUs have been proportionately more successful (compared to majority institutions) in graduating students in science and math fields (Thomas, 1991; Trent & Hill, 1994).

Perhaps more important is the need for America to maintain its economic edge and competitiveness. National demographics are changing. In the last decade, the minority population increased by 35%. As Shirley Jackson pointed out,

> While the non-Hispanic White population grew only 3.4%, the Hispanic population grew by 58%, Asian Americans by 50% and African-Americans by 16%. Since our traditional science, mathematics, engineering, and technology (SMET) workforce is nearly 82% White and more than 75% male, it appears unlikely that we can replace it with a similar population (Jackson, 2004).

As the Deputy Director of the National Science Foundation, Joseph Bordogna, stated,

> It [*the s&t workforce issue*] is NOT about the total number of scientists and engineers the nation may or may not need….It IS about including a larger proportion of women, underrepresented minorities and persons with disabilities in the scientific workforce, no matter the size of that workforce….we need a robust and varied mix, and that means broadening participation (Committee on Equal Opportunities in Science and Engineering, 2004).

Data on HBCUs reveal a growth trend amongst African American students graduating from science and engineering fields in post secondary schools (National Science Foundation, 2004c). Statistics show a growing percentage of foreign born students at the graduate level in the United States, while the number of White American students at the graduate level has remained consistent. There has been little growth in native born supply of labor over the last decade; much of the increase has come from

minorities (National Science Board, 2004b). This means that without an increase in domestic students, the estimated shortage of science and technology workers will not be filled by Americans. The United States had been turning to a foreign labor supply to meet their excess needs in science and technology (National Research Council, 2001). However, since September 11, 2001, the number of foreigners applying for visas and the number of foreigners applying for graduate education in the United States has declined considerably. Some universities have reported a decline of as much as 40% (Jackson, 2004). Thus, given the changing demographics, the increase in science and engineering as fields of study by African American students and other minorities, makes them an interesting phenomenon to study.

The National Science Foundation, the National Science Board, the Council on Competitiveness, and the Congressional Commission on the Advancement of Women in Science, Engineering and Technology amongst other organizations seek to “widen” (expand the circle of institutions seeking to increase output) and “deepen” (develop more talent within existing institutions), the institutional capacity of higher education to increase its science and engineering students, particularly students of color (BEST, 2004; Committee on Equal Opportunities in Science and Engineering, 2004). In this effort, strategies adopted by HBCUs are worthy of examination.

It is also interesting to look at HBCUs in the perspective of the Carnegie classification typology. There is a greater percentage of HBCUs that are research-oriented universities and colleges than in the greater population of universities (see Chapter 2). This and the factors mentioned above are why this dissertation study focuses

on HBCUs. It remains to be seen whether linkages or networks are a factor in HBCUs' achievements.

1.3 Research Design Methods

This dissertation study utilizes a mixed methods approach in its research design. A quantitative approach is nested within the overall qualitative approach. Each is addressed separately as each approach has different requirements. In both approaches the unit of analysis is the university. The variables in this research study were drawn from theoretical models in previous research on science and technology at universities.

A quantitative approach is used to determine the productivity level in science and technology at each HBCU. The dependent variable is science and technology productivity. Bibliometric techniques are combined with data from federal public databases to calculate a composite science and technology (S&T) index for each HBCU. Characteristics of the different levels of universities are explored. The goal of this part of this research is to a) determine which HBCUs are the most productive in science and technology and b) use the HBCU science and technology index ranking to select three research HBCUs.

Results from the composite science and technology index are used to inform the direction of the qualitative approach. Based on the index ratings, three HBCUs are selected as case studies for further in-depth exploration to determine what strategies they utilized to develop their science and technology productivity. Interviews and archival analysis are used to provide further information on the development of linkages and the validity of rival explanations. Techniques identified for use with qualitative data will be

used – a) pattern matching using independent variables, b) rival explanations and c) time sequencing. Triangulation will be achieved by interviewing liaisons – individuals that work with but are external to HBCUs. The goal in the qualitative part of the research is to assess which strategies are utilized and which provide the most explanation for affecting science and technology development. This strategy is similar to the one utilized by Michael Porter in his nation-assessment of productivity (M. Porter, 1990).

1.4 Contributions to Literature

This study contributes to the literature on higher education by exploring in greater depth the subset of HBCUs. While HBCUs should be classified as a part of the university population, they also have sufficiently different and interesting characteristics that they can be classified in a unique category within the university typology.

In the intersection between higher education and national systems of innovation, studies on colleges and universities use generally accepted variables such as patents, funding and publications to assess the potential for innovation. While human capital is acknowledged as an important component, the number of graduates is not commonly operationalized. Rather, the actual number of scientists and engineers is often used as a direct measure of “knowledge labor” or “human capital.” However, graduates in science and technology related fields have been identified by many studies as part of the network that produces innovation. Graduates attract companies that need a literate and skilled base of employees and graduates help produce the linkages that transmit/transfer knowledge through liaisons, associations, and jobs in different companies. Therefore, there is validity in using graduates as a variable to assess innovation or potential for

science and technology. This study contributes to the literature by including the student body (graduates) as part of its assessment of universities.

In the intersection between competitive advantage and national systems of innovation literatures, this dissertation study contributes to the exploration of non-profit entities, such as universities, behaving in a manner similar to for profit organizations. Theories have emerged such as Triple Helix (Etzkowitz, Webster, & Healey, 1998) and Mode 2 (Gibbons et al., 1994) that suggest that universities are interacting more with industry and government. These theories use terms such as ‘entrepreneurial university’ and ‘capitalization of knowledge’. OECD (the Organization for Economic Cooperation and Development) has taken the theory of competitive advantage and applied it in a limited manner to universities but there are few academic studies that have explored the concept of competitive advantage and clusters at universities (OECD, 1999). Thus, this study seeks to contribute to that body of literature by exploring how a particular set of universities, HBCUs, seeks to enhance their competitive advantage in the fields of science and technology.

1.5 Policy Implications

The target audiences to which the findings are directed are HBCU leaders involved in policy, HBCU science and technology departments, and federal and state government agencies that are interested in identifying potential niches for support of science and technology development. Policy implications of this study are relevant, as the findings will help federal agencies better understand strategies for science and technology development and HBCUs will have models of strategy that are effective and productive.

Another target audience to which this dissertation is not directed but to whom the findings may contribute is those who review colleges and university classifications. The Carnegie Foundation classification has become the standard typology (Carnegie Foundation for the Advancement of Teaching, 2001). That organization (along with others) has been exploring whether to classify HBCUs and other ethnic colleges and universities as a unique classification. By determining whether HBCUs present a difference from majority universities, this study may contribute to that policy decision.

1.6 Overview of Chapters

This Introduction - Chapter 1 identifies the goal of this dissertation study – to determine effective strategies for HBCUs to adopt regarding their approach and adaptation to a technological society. It sets forth the questions, literature base, theoretical approach, and methodology by which the study will achieve its goal. It also describes the audience to whom this study is directed, the contributions to the field of academics, and the potential policy implications.

The next chapter, Chapter 2, takes a historical look at HBCUs and identifies the factors that contribute to defining and understanding HBCUs, particularly factors that affect their development of science and technology. From this chapter, one should be able to understand the context in which HBCUs exist. The chapter explores their historical legacy which impacts the choice of strategies that are utilized. It also examines current issues facing HBCUs and by implication, the nation.

Chapter 3 presents the theoretical propositions and the literature bases. It delves further into the three literature bases of higher education, national systems of innovation,

and competitive advantage. Out of the intersection of these three bodies of literature emerge the various theories/strategies that explain the development of science and technology at universities. The goal is to understand how these strategies can be applied to enhance the production and productivity levels of HBCUs.

It is hypothesized that linkages are the strategy that HBCUs should adopt to develop science and technology productivity. Chapter 4 discusses the various uses and meanings of linkages by different authors and organizations. The concept of linkages, as used in its various forms, is grouped into three categories. The third category, the most defined and mature form of linkages, networks and collaborations, is the definition adopted by this study. Rival theories are also presented as a contrast to the primary concept of linkages.

Chapter 5 presents the research design and the methodology. The unit of analysis, dependent and independent variables are identified for the quantitative approach. The research design utilizes a two phase approach. Phase I is a quantitative approach with one set of hypotheses and methods. The goal is to develop a science and technology index. The results of the index are used to select three research HBCUs for further in-depth study. Hence, the results of the quantitative phase are used to guide and direct the qualitative section. In Phase II, the primary question and a hypothesis are presented regarding what strategy should be adopted by HBCUs to develop science and technology capacity. The chapter provides information on data sources and data analysis.

Chapter 6 presents results from Phase I – the construction of the HBCU science and technology index. The results enable identification of HBCUs with high productivity

levels in science and technology indicators. Chapter 6 presents the 35 research universities and categorizes them into high, medium and low productivity. The categorization facilitates selection of three research HBCUs - Fort Valley State University (FVSU), Hampton University, and Florida Agricultural & Mechanical University (FAMU).

Chapters 7, 8 and 9 highlight the three case studies presenting FVSU, Hampton and FAMU respectively. Each chapter begins with an in-depth review of the university. This includes their characteristics, history, structure, science and technology achievements, and strengths and weaknesses. Information obtained from the website, books, archival, and policy documents is included in this background analysis. Following the review, the results of the interviews are presented. The analytic tools of pattern matching, rival explanation and chronology of events methodologies combine to uncover a unique history that unfolds behind the origin of various programs at HBCUs. The theories/strategies are compared within each case study for the purpose of determining which has the most validity.

Chapter 10 summarizes the results from Chapters 7, 8 and 9. It summarizes the results and findings from the study. What was learned? How do the results impact actions taken by HBCUs? What theories were most prevalent and why? Was the data obtained from interviews supported by data obtained from external liaisons? The findings from the interviews enables responses to the questions posed.

Chapter 11, the Concluding chapter, ties together the entire study. It summarizes the outcomes of both Phase I and II and seeks to determine how the findings from both

approaches impacts the direction taken by HBCUs as they seek to develop science and technology productivity. Chapter 11 discusses the limitations and vulnerabilities found in the design and implementation of the research. It explores impact on existing theory. Most importantly, it discusses the importance of the findings for policy and its relevance to policy personnel and administrators at HBCUs. Finally, the chapter examines what future questions emerge for further research study.

CHAPTER 2
HBCUS AND UNIQUE HISTORICAL FORCES

Despite evolving within a similar physical environment (the United States), HBCUs have had singular forces impacting their development as institutions of higher education. HBCUs and Traditionally White Institutions/Universities (TWIs) both started with weak educational infrastructures and a significant number of students needing remedial or pre-college courses (Jones & Weathersby, 1978). Both worked on improving the quality of their curriculum. The parallel pathways veered off track after WWII; however, when huge infusions of federal funds transformed many Traditionally White Universities into institutions with science and research capability. HBCUs did not share in that distribution of funds, which left them at a disadvantage in terms of facilities, buildings, faculty, and equipment. In order to remain competitive, HBCUs developed a niche by capitalizing on a tradition of teaching and matriculating African-American students. They utilized strategies adopted by other colleges and universities while developing strategies unique to their characteristics and their environment.

This chapter focuses on HBCUs. It defines the colleges and universities that are included within the designation, discusses historical and internal factors that affect the development of science and technology at HBCUs, and explores the concept of linkages and other strategies as they relate to HBCUs.

2.1 What are HBCUs?

Within the literature on universities, there is one subset of universities that has gone relatively unexamined – Historically Black Colleges and Universities (HBCUs: see

Appendix A for list of HBCUs). HBCUs represent 2.7% of the total colleges and universities' population (Carnegie Foundation for the Advancement of Teaching, 2001). Designated in 1980 by the United States White House Initiative on Historically Black Colleges and Universities, the term Historically Black Colleges and Universities can be found and defined in the Higher Education Act of 1965. HBCUs are defined as "any historically black college or university that was established prior to 1964, whose principal mission was and is the education of black Americans, and that is accredited by a nationally recognized accrediting agency or association determined by the Secretary (of Education) to be a reliable authority as to the quality of training offered or is, according to such an agency or association, making reasonable progress toward accreditation" (20 USC 1061 (2), Title III of the Higher Education Act of 1965).

Initially, 105 Black colleges and universities were designated by the White House Initiative on HBCUs in 1980; however, since then, other colleges and universities have been categorized as HBCUs while some have discontinued operation. This dissertation study utilizes the initial definition - being predominantly Black (upon inception) and created prior to 1964. This resulted in 103 current HBCUs as of 2003.

HBCUs were attended by a predominantly African-American/Black population[1] at their inception because during that time period they were legally restricted from attending predominantly White universities in the South and were not accepted by most universities in the North. Black colleges and universities were not racially restricted;

[1] African-American, Negro and Black are used interchangeably throughout this document despite having slightly different meanings. Different terms are associated with certain time periods. Additionally, all three terms are capitalized when used because they refer to a race rather than being used as an adjective.

however, despite the efforts of Blacks and some Northerners, the prevailing social customs held and the student bodies became overwhelmingly Black. Today, some of that has changed. While the vast majority of HBCUs have overwhelmingly Black populations, there are a few with significant White populations (sometimes a majority).[2] Many faculty at HBCUs are White and/or foreign born. In addition, there are colleges that have a predominantly Black population (such as some CUNY institutions in New York), that are not designated as HBCUs; these are usually referred to as Minority Serving Institutions (MSI). MSIs generally do not share the cultural and historical heritage that characterizes many of the HBCUs. For the purposes of this research, HBCUs shall be defined as the 103 institutions operating in 2003 that were designated in the initial White House legislation in 1980.

HBCUs are as varied as the total population of colleges and universities; however there are characteristics that are common to many of them. The "typical" HBCU is located in the Southeast (69.2%) and was created prior to 1900 (72%). The typical HBCU is a four-year college (85.4%), private (54.8%), rated as a Baccalaureate-General (38%) or a Master's I institution (24.3%), and has less than 2,000 students (51.9%). The rest of the HBCUs are located in the Northeast, the District of Columbia, Missouri, Ohio, Oklahoma, Texas, and the Virgin Islands. They include a mix of public four-year, public two-year, private four-year, and private two-year institutions. Many are more than 100 years old, with Cheyney University of Pennsylvania, being the oldest of these institutions founded in 1837.

[2] HBCUs with majority White populations include West Virginia State College, Bluefield State College, Saint Phillips College, Shelton State Community College, and Lincoln University in Missouri.

A typology of universities known as the Carnegie classification is widely used as a means of categorizing institutions of higher education in terms of their mission and research capability. Because these classifications infer a degree of research associated with advanced education, this dissertation study focuses on colleges and universities that have achieved the designation of Master's II through Doctoral-Intensive. Proportionally, HBCUs have slightly fewer institutions at the doctoral level (7% versus 8% at the Doctoral level). However, in the categories that are generally considered "research-oriented" institutions (Doctoral through Master's), HBCUs have more institutions proportionally (38% versus 22%) than their majority counterparts (Carnegie Foundation for the Advancement of Teaching, 2001; Rogers, Yin, & Hoffmann, 2000). See Table 2.1.

Table 2.1 Number of Doctoral and Master's HBCUs and Majority Institutions[3] (2002)

Category	Total Pop Frequency	Total Pop Percent	Total Pop Cumulative	HBCU Frequency	HBCU Percent	HBCU Cumulative
Doctoral/Research Universities—Extensive	151	4%	4%	1	1%	1%
Doctoral/Research Universities—Intensive	110	3%	7%	6	6%	7%
Master's Colleges and Universities I	496	13%	19%	25	25%	32%
Master's Colleges and Universities II	114	3%	22%	3	3%	35%

Source: Carnegie Foundation, 2002

Only one HBCU, Howard University, has received the highest level of Carnegie classification – Doctoral/Research Universities–Extensive; it is also the only HBCU that

[3] Majority Institutions includes Hispanic Serving Institutions (HSIs). In 2003, there were 207 HSIs of which 53% are Associate Colleges. HSIs are defined as having at least 25% Hispanic population and 50% low-income population (Laden, 2001).

has a medical school as part of its structure.[4] The impact of the lack of medical schools is significant economically. A report by RAND on federal R&D funds indicates that the majority of federal funds for 2002 are directed towards universities and colleges, and within that group, medical schools are the prime beneficiaries. Forty-five percent of total federal R&D funding to universities and colleges goes to medical schools (Fossum, Painter, Eiseman, Ettedgui, & Adamson, 2004).

While the 35 HBCUs at the Doctoral and Master's level have disproportionately fewer medical schools (compared to the larger university population), they have disproportionately more land-grant universities (17% of HBCUs versus 1% of TWIs). This is important to note because education and research at land-grant universities, due to their mission, is usually more applied; therefore, they may not fare as well in securing research and development dollars or in authoring publications (Graham & Diamond, 1997). Finally, the location of most HBCUs in the South, which on the average has lower academic high school ratings than other regions in the United States, may affect their development of science and technology (Holmes, 1934). Segregation resulted in an inequitable and inefficient distribution of funds. The appropriation of scarce resources to a larger number of schools than necessary caused the entire system to suffer educationally.

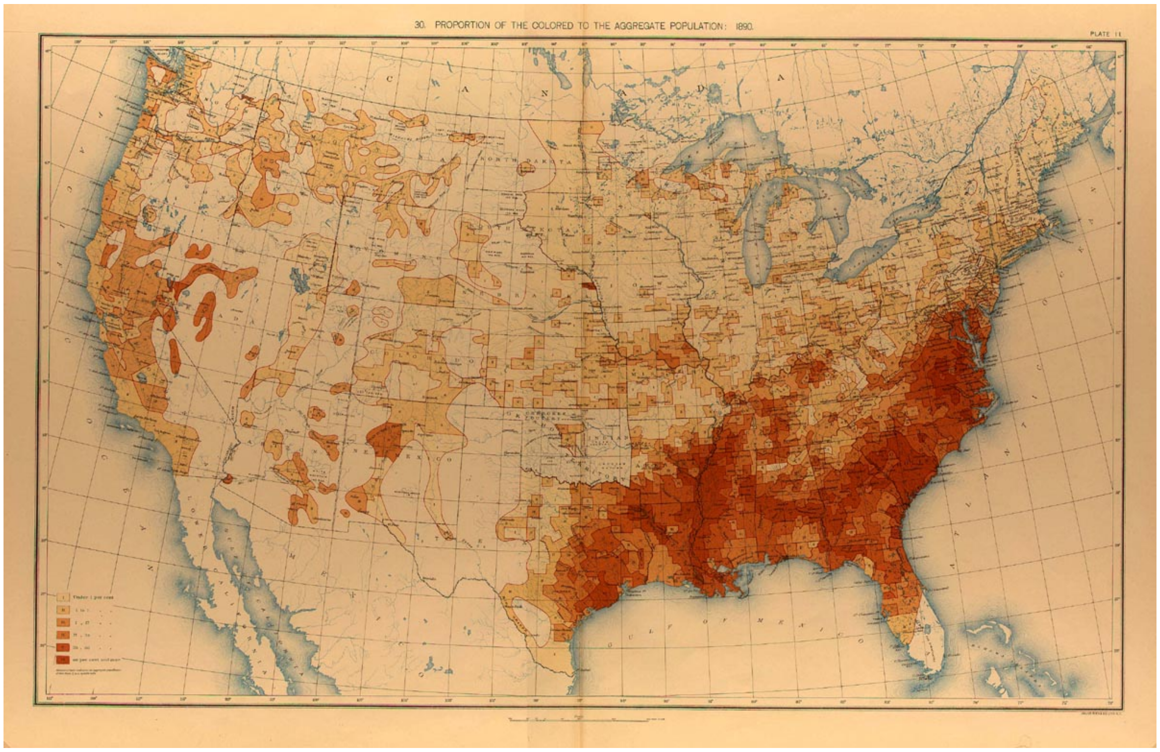
2.2 Historical Context

In 1866, the first year after emancipation of the slaves in the United States, about 90 to 95% of the Black adult population was functionally illiterate (Thompson, 1978).

[4] There are two other HBCUs that are medical schools (Morehouse School of Medicine and Meharry); however, they are not part of a larger institution. They are categorized as separate institutions.

To address their needs, the institutions they created focused primarily on training teachers. The majority of HBCUs were created in the South because that was where the majority of Black people resided. Institutionalized racism prevented Blacks from enrolling or participating in White educational institutions. Thus, in order to obtain an education they created their own educational institutions.

The Negro or Black population constituted over one-third of the population in the South and formed a majority in several states – South Carolina, Mississippi and Louisiana. In Alabama, Florida, Georgia and Virginia, the Black population ranged from 42 to 49% of the total population, while North Carolina, Tennessee and Texas reported their Black population as 37%, 26%, and 31%, respectively. With the Black population freed by the Civil War in 1865, a large, potentially political and social body that had heretofore been invisible and impotent became a presence to be dealt with in the South (Anderson, 1988). See Figure 2.1.



http://www.ushistoricalarchive.com/cds/1890.html

Figure 2.1 Colored Population in the United States in 1890[5]

Black churches and Northern White missionaries were primarily responsible for the creation of many Black schools. While many of the early higher education institutions used the title of “college”, most of them were teaching the majority of their classes at the elementary and secondary school level. The great need for teachers who could provide this education led to many of the schools adopting teacher training as all or part of their mission. And in this they were successful. Illiteracy rates for the Black population declined considerably (70% in 1880 to 16.3% in 1930) (Davis, 1933).)

[5] The darker the color the more concentrated the colored population. The term colored is used because the map includes Indians and Asians (who are more concentrated in the Midwest and the West.)

Conditions at White schools during this period were not much different. In 1865, the General Superintendent of Education conducted an inspection that included Negro colleges and observed that “in the District of Columbia, 75% of the Negro children attended school as against only 41% of the white children; that in Memphis, Tennessee 72% of the Negro children attended school, in Alabama 79% and in Virginia 82%” (Jones & Weathersby, 1978). He compared these figures with an attendance of 43% White students in the public schools of New York State and 93% in Boston, which probably ranked first in this respect among the cities of the entire country. Even as late as 1895, all of the White colleges in Alabama except the University of Alabama reported students at the elementary and high school levels. The University of Massachusetts, Boston College and Tufts reported pre-college enrollments in 1895 (Jones & Weathersby, 1978). For Black colleges, however, the presence of secondary education at the college level extended well into the 1930s while such practices faded at TWIs prior to 1910.

The American educational system is known for its plethora of institutions of higher education in contrast to the European system from which it emanated (Lucas, 1994). In this respect, Black colleges followed the American model by creating many institutions of higher learning. White colleges continued their path toward higher education, challenged by the obstacles of finding funds but undeterred by philanthropic interests seeking to derail their pursuits. Linkages are built on trust and relationships. The trust was undermined by industrial philanthropists’ support and funding of industrial education, which most Negores opposed. They belived it to be another action preventing them from acquiring the education needed to move ahead.

Black higher education was derailed by one of the three philanthropic groups that formed the power structure in black higher education. From 1865 to 1950, missionary philanthropy (northern white benevolent societies and denominational bodies), Black philanthropy (black religious organizations), and industrial philanthropy (large corporate foundations and wealthy individuals)[6] exerted great influence on the development of higher education for Blacks. The ideologies and philosophies of the different philanthropic groups were in sharp disagreement over the value and purpose of Black higher education. Each group imposed its educational policy and practices on their vision of the role Blacks should play in the New South.

Both missionaries and Black philanthropists believed Blacks could be contributing equal partners in the new society. They promoted and pursued classic liberal arts education for Blacks – languages, math, science, English and culture. The industrial philanthropists, the most influential, powerful and well financed group of the three favored industrial education. They were opposed to the potential political and social power which the Negro represented and thus supported the premise of teaching the Negro the "dignity of manual labor." Industrial education focused on applied training in agriculture, mechanical engineering, and military arts. It provided no instruction above the secondary level (high school), and no teaching of subjects that constituted a liberal arts education (Anderson, 1988; Holmes, 1934; LeMelle & LeMelle, 1969).

[6] Prominent individual industrial philanthropists included Ulysses S. Grant, Rutherford B. Hayes, James A. Garfield, Theodore Roosevelt, Jr., Julius Rosenwald, and others. The most well known industrial foundations included the John E. Slater Fund, the General Education Board, Ana T. Jeanes Foundation, the Phelps-Stoke fund, Carnegie Foundation, Laura Spelman Rockefeller Memorial Fund, and the Julius Rosenwald Fund.

It is noteworthy that the industrial philanthropists opposed higher education because industry and its ancillary organizations is responsible for most of the research funding today. Thus, for the hypothesis that linkages are responsible for the development of science and technology at universities to hold true for HBCUs, some of the racism industry had towards HBCUs and the distrust HBCUs had for industry must have been overcome.

HBCUs faced a choice. They could remain distinct entities that employed unique strategies or become more like TWIs and utilize strategies identified earlier in this study such as linkages. HBCUs took both paths. They remained distinct institutions that initiated new strategies; however, they also adopted strategies utilized by TWIs.

2.3 Policy and Funding

Prior to WWII, federal funding was not a significant source of revenue for most universities. The massive amounts of funding that White colleges received from the federal government after WWII was not received in equitable measure by Black colleges. Sixteen TWIs were considered preeminent in academic research; eleven of these were private institutions[7] (Graham & Diamond, 1997). The scientific advancements made during the war were instrumental in turning the course of the war and the subsequent balance of power to the United States. This prompted the federal government to support universities and academic research. From 1958 to 1968, the nation's universities experienced the Golden Era – quantum leaps (increases from seven fold to a thousand

[7] The sixteen private and flagship universities were Berkeley, Chicago, Caltech, Columbia, Cornell, Harvard, Illinois, Johns Hopkins, MIT, Michigan, Minnesota, Pennsylvania, Princeton, Stanford, University of California, Wisconsin, and Yale.

fold) in federal funding for science, research, equipment, personnel and facilities (Graham & Diamond, 1997). (See Chapter 3 – Literature Review for more detailed information.)

Yet very little of this trickled down to HBCUs. Until 1967, no federal formula funds (dedicated funding allotted to land-grants by the federal government) were received by HBCUs (Payton, 1992). The historically black land-grant universities that by law were supposed to receive funds from the federal government (Morrill Act of 1890) didn't begin to receive federal support until 1967, nearly 70 years later. Funding began in 1965 due to Congress approving Public Law 89-106 to provide the U.S. Secretary of Agriculture with a discretionary appropriation of $2 million. Beginning in 1967, a total of $283,000 was taken from this fund and divided among the sixteen 1890 institutions (as they are commonly referred to)[8] on the basis of a newly established formula for historically black land-grant institutions (Bonnen, 1992; Mayes, 1992). Over time, funding from the Department of Agriculture increased. In 2002, the Department of Agriculture was the largest provider of federal R&D funds to HBCUs.

In response to Civil Rights agitation and demonstration, policy became a major vehicle by which change occurred. With the passage of the Higher Education Act of 1965, Black colleges and universities were able to obtain direct institutional subsidy and federal student aid. The Civil Rights era also brought challenges to HBCUs. As

[8] The sixteen land-grant HBCUs are Alabama A&M, Alcorn State, Florida A&M, Fort Valley State, Kentucky State, Langston, Lincoln University (Missouri), North Carolina A&T State University, Prairie View A&M, South Carolina State University, Southern University A&M College, Tuskegee University, Universit of Arkansas at Pine Bluff, University of Maryland Eastern Shore, University of the Virgin Islands, Virginia State, and West Virginia State University

integration progressed, Black colleges and universities found themselves in direct competition with TWIs for the best students and faculty (Drewry & Doermann, 2001).

In 1980, efforts were made to redress past wrongs through a significant legislative policy that marked a shift in federal relations towards HBCUs - the White House Initiative on HBCUs. This initiative recognized Black colleges formed prior to 1965 as a historical group of institutions deserving of specific federal policy to “overcome the effects of discriminatory treatment and to strengthen and expand the capacity of HBCUs to provide quality education” (White House, 1998). From President Reagan to Clinton, the policy has been renewed and strengthened. Just as the federal government created EPSCOR (Experimental Program to Stimulate Competitive Research) to assist states that have historically received less federal funding, it also introduced policies to encourage science and technology research and development capacity at HBCUs. The White House initiative on HBCUs is a significant federal policy affecting Black institutions of higher education. It appears that since the policy was created, HBCUs have strengthened their science and technology capacity by establishing partnerships with federal agencies, procuring government contracts and funds, and conducting research. The White House Initiative on HBCUs supports and encourages HBCUs to a) develop linkages with federal agencies and b) develop their science and technology potential. In the1998 White House Initiative on HBCUs renewed by President Clinton, two stated goals support this:

> “To strengthen the communication linkages between HBCUs and federal agencies to increase the number of contractual relationships;

To encourage collaborations and partnerships among HBCUs and other organizations to produce the greatest leverage of federal and private dollars" (White House, 1998).

In addition, the 1998 White House policy on HBCUs advised the private sector to "*increase the number of graduates with degrees in science and technology by enhancing their career prospects*." The President's Board of Advisors on HBCUs also recommended support of HBCUs' long-term development plans for "*sources of alternative faculty talent in the science and technology disciplines*" (White House, 1998). The policy demonstrates the targeting of HBCUs in the federal arena as potential sources for graduates, networking, and science and technology production. Under President George W. Bush, the policy still exists but has been transferred from the White House to the Office of the Secretary in the Department of Education effectively downgrading the importance of the initiative (U.S. Department of Education, 2005).

2.4 Collaboration, Cooperation and Clusters

Public HBCUs, able to rely on public funds from state and local sources, have been more fiscally stable over time than other HBCUs (Hoffman et al., 1992; Jones & Weathersby, 1978). Several attempts at collaboration and cooperation were made by public and private HBCUs including the ACNY (Association of Colleges for Negro Youth), the SACS (Southern Association of Colleges and Secondary Schools), the ALGCU (Association of LandGrant Colleges and Universities), and the CCCP (Council on Cooperative College Projects). However, private HBCUs, mostly small and underfunded still found themselves vulnerable.

In 1944, Frederick Patterson, President of Tuskegee Institute introduced the idea of a membership association having as its primary purpose the raising of unrestricted operating funds for its members. This was a unique idea that had not been attempted by a group of universities. Twenty-seven private Black colleges and universities established the United Negro College Fund believing that the sum might be greater than its parts. They believed a united, nationwide appeal for funds would have more success than any individual campaigns. Foundations were becoming increasingly unwilling to grant unrestricted funds. Presidents realized they were spending inordinate amounts of time on fundraising (Drewry & Doermann, 2001). In this sense, the United Negro College Fund (UNCF) might represent the first formal network of universities (a small group of universities that have a formal agreement (implicit or explicit) for mutually beneficial goals).

Despite raising only half of their campaign goal in the first year ($750,000), the total amount was several times the total amount collected individually in previous years. The UNCF was considered a success and the Presidents of the private Black member colleges made a commitment to continue the effort. It provided funds to private HBCUs at a time when federal aid and industrial philanthropy was not available. Today, the UNCF is probably the most influential organization among private Black colleges. Part of its mission is to assist its members in maintaining fiscal stability (Drewry & Doermann, 2001).

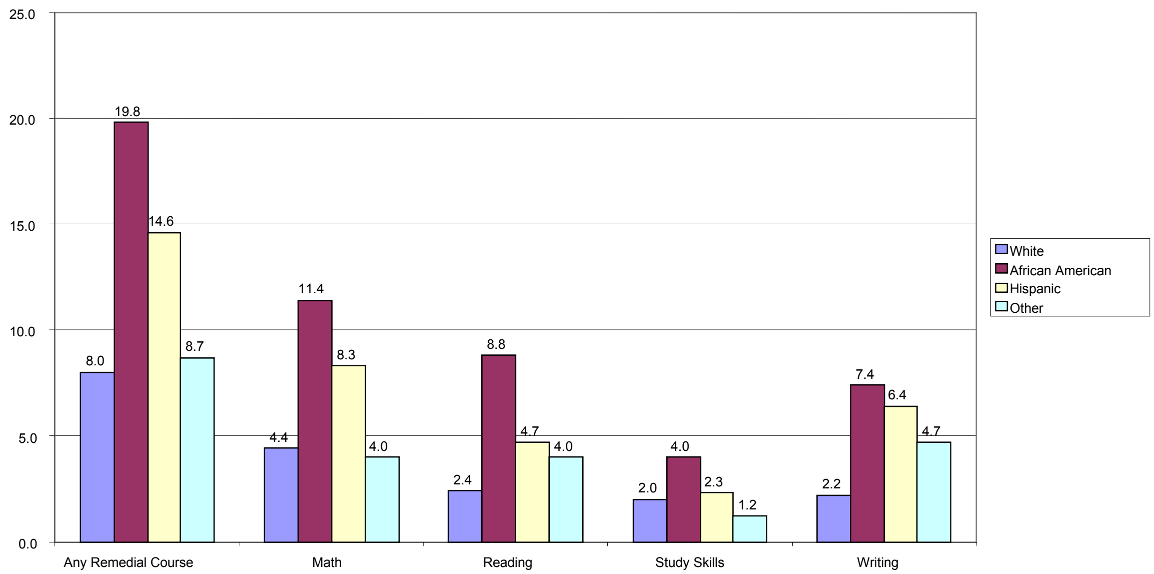
The success of UNCF led to the founding of another national organization, the National Association for Equal Opportunity in Higher Education (NAFEO). Founded in

1969 by a group of HBCU presidents, NAFEO was a professional association created to champion their interests with executive, legislative, regulatory and judicial branches of federal and state governments as well as with corporations, foundations, associations and non-governmental organizations. The mission of NAFEO is to build the capacity of HBCUs, to engage in policy and advocacy on behalf of HBCUs, and to seek and secure federal and private dollars for its members.

2.5 Effectiveness at Graduating Students

The period from 1860-1920 set the stage for forces that shaped funding strategies developed at Black higher education institutions. It established a culture dedicated to teaching which remains one of the foundations of HBCUs. According to several authors, this culture's tradition emphasizes individualized student attention (Mays, 1978), graduating students (Thompson, 1978), and faculty attentiveness to teaching (Wenglinsky, 1997). Indeed, many academicians attribute the success of HBCUs' ability to graduate at-risk students to the teachers who serve them.

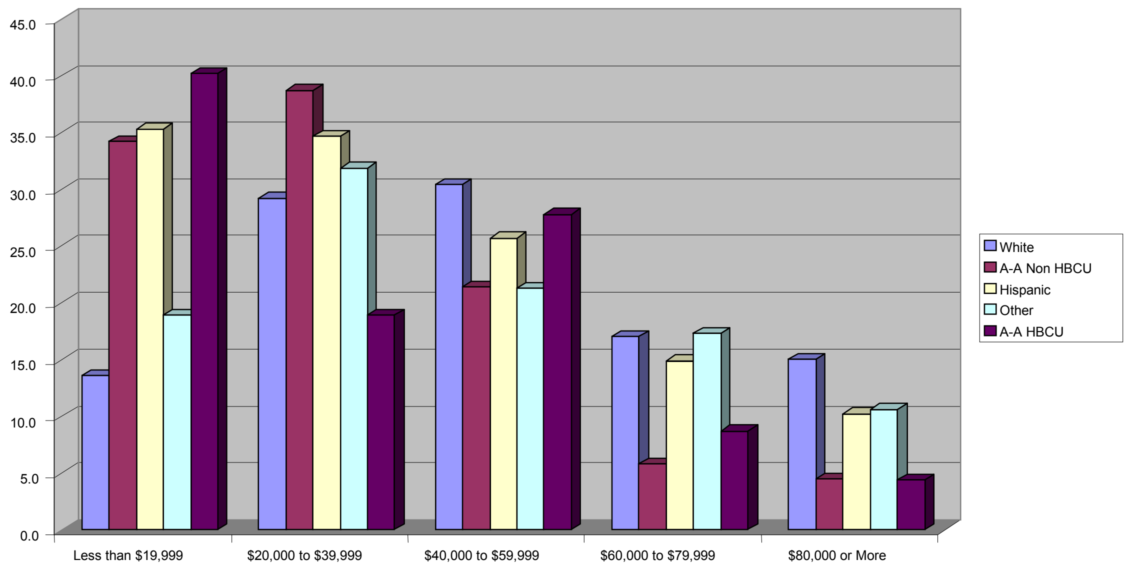
The emphasis on teaching continues today, in part to support students who need greater academic preparation. The following tables depict two factors that relate to African-American student educational preparedness. The first table (Table 2.2) indicates that, on average, a higher percentage of African-American undergraduate students need preparatory or remedial courses.



African-American Data Book
(Nettles Ph.D. & Perna, 1997)

Figure 2.2 Percentage of Undergraduates attending Four-year Institutions who receive remedial instruction: Fall, 1992

The second table (Table 2.3) indicates a higher percentage of African-American students with lower family incomes. On the average, lower socio-economic status is correlated with lower educational performance (Wenglinsky, 1997).



African-American Data Book
(Nettles Ph.D. & Perna, 1997)

Figure 2.3 Family Income of 1989/90 Beginning Post Secondary students seeking Bachelor's Degrees by Ethnicity

Despite the challenges of educating students that on the average come from lower socio-economic backgrounds and that require greater remedial work, HBCUs have been effective in graduating Black students. Several facts support this contention.

First, HBCUs educate 2.7% of the total two and four-year college and university population equivalent to 3.3% of the 6.8 million undergraduates who enroll in four-year colleges and universities. However, they accounted for 26.4% (191,158) of the total 723,326 African-American undergraduate students enrolled in colleges and universities in 1996. And they awarded 28.3% of the 89,412 bachelor's degrees received by Blacks in 1996 (Nettles, Wagener, Millett, & Killenbeck, 1999). Over 70% of Black students

attend TWIs; however, 70% do not matriculate (compared to 50% at HBCUs) (Trent & Hill, 1994).

Second, several studies indicate that students at HBCUs are more likely than students at majority schools to major in science and technology fields. Data indicates that African-Americans are underrepresented in science and technical fields (math, engineering, physical and biological sciences) in proportion to their population in the U.S. (McBay, 1978; Pearson Jr. & Bechtel, 1989; Thomas, 1989). Due to higher retention rates, HBCUs are disproportionately responsible for science and engineering degrees among African-Americans. Engineering and engineering technology programs have grown considerably at HBCUs. Students at HBCUs are more likely than Black students in general to major in business, engineering or the sciences (Thomas, 1989; Trent & Hill, 1994). In 1990, when 28% of Blacks attended HBCUs, these institutions awarded over 44% of Blacks' bachelors degrees in physical sciences, 41% in mathematics, 38% in computer sciences and life sciences, 37% in education, and 25% in engineering (Hoffman et al., 1992). The National Science Foundation (NSF) found that between 1989 and 1996, the proportion of graduates from HBCUs majoring in computer science has been about twice the comparable rate of TWIs (National Research Council, 2001).

Third, Nettles found that Black students from HBCUs have higher progression rates than Black students at TWIs. Progression is defined as the number of credits taken each semester toward completion of the degree (Nettles et al., 1999). These findings are supported by a study authored by Astin who found that controlling for prior student

achievement (e.g.; high school grades and SAT scores), institutional size, and institutional selectivity, Blacks from HBCUs are more likely to complete their degree than Blacks at TWIs (Astin, Tsui, & Avalos, 1996). Wenglinsky found in a study that compared students at HBCUs to Black students at TWIs that students at HBCUs were more likely to plan on entering a program in the sciences, engineering or business; to have higher retention rates (82% vs. 66%), obtain their Ph.D. (21% vs. 18%) and receive it quicker (5.57 years versus 6.14 years) (Wenglinsky, 1997).

To summarize, HBCUs afford an educational opportunity to students from lower socio-economic backgrounds that might not otherwise go to college. On the average, as noted above, Black students at HBCUs when compared to Black counterparts at majority schools are more likely to major in science and engineering, complete their degree, attend graduate school in science and engineering fields, pursue Ph.D.s, and obtain their degree of choice faster (Astin et al., 1996; Thomas, 1991; Wenglinsky, 1997). Thus, one can conclude that HBCUs are more successful than TWIs in preparing Black students for careers in engineering, science or business, graduate school and various professions.

Recent data by NSF indicates that TWIs may be eroding this traditional stronghold of HBCUs. The number of Black graduates (U.S. citizen and permanent resident Blacks who received Bachelor’s degrees) has increased in science and engineering fields by 26.6% from 1994-2001 (26,289 in 1994 to 33,290 in 2001). The number of students served by HBCUs has increased; however, their percentage of the total number of graduates with bachelors degrees in science and engineering has declined

from 29.7% to 26.1% (National Science Foundation, 2004c). It remains to be seen whether this trend will continue.

Within HBCUs' strength in graduating at-risk students may lay a weakness. As will be explained further in Chapter 3, many universities have taken on another mission – producing knowledge through research. To be competitive and move into the 21st century, universities have set up research offices and are encouraging their faculty to engage in more research. Scott has written about the lack of faculty production at HBCUs due to the heavy teaching workloads and the individualized student attention (Scott, 1981). Thus, the factors that make HBCUs effective at graduating students may be an impediment when it comes to pursuing a research agenda. Agesa's study on economics research at HBCUs confirms that a substantial portion of the economics departments at HBCUs are not engaged in scholarly activity in terms of published research. However, she also notes that this is not an attribute unique to HBCUs. In a study of liberal arts colleges, Agesa cites McCaughey's finding that 38% of the faculty never published in a professional journal, 69% had never published a book, and 49% were not engaged in research that would lead to a publication (Agesa, Granger, & Price, 1998). The importance of these findings is that firms seek interaction with universities primarily for research purposes and to find skilled personnel in science and technology. The demand for skilled personnel is a theory that explains development of science and technology at universities. The effectiveness of HBCUs in fulfilling this role may be a strategy which HBCUs can exploit to further develop their science and technology capacity.

2.6 Summary

A review of critical components in HBCU history that relate to science and technology reveal a niche that HBCUs have capitalized on – graduating students in science, engineering and business fields. The niche evolved over time due to circumstances unique to African-Americans. A tradition of emphasis on teaching was created from the large number of African-Americans that desired an education after being freed by the Civil War. Given the demand, a large number of Black colleges focused on producing teachers. A culture developed that emphasized faculty attention to student achievement. This culture enables HBCUs to graduate African-American students in greater numbers than TWIs. The ability to graduate students in greater proportions extended itself to the science, math, engineering and business fields.

What strategies have been used or have been proven useful in developing this niche and other elements of science and technology? Until the late 1960s, HBCUs were opposed in principle (by industrial philanthropists who opposed higher education for Blacks), segregated (by legal and de facto racism in the South), and underfunded (disregarded in the Golden Era of funding for science and research). All three factors run counter to the establishment of linkages. Yet events have transpired that have overcome some of these factors.

Policy has been critical. The Higher Education Act of 1965 became the basis for a number of policies that attempted to redress the inequities that resulted from segregationist policies. Examples include the initiation of funding to land-grant colleges and universities, federal aid to students that attended HBCUs, and the White House

Initiative on HBCUs. A multitude of policies, both formal and informal emerged from the Civil Rights era in support of HBCUs.

The need for collaboration and partnerships also played a critical and unique part. The development of the United Negro College Fund in 1944 was a unique and creative response to the vulnerability experienced by many Black private colleges and universities. However, this response reflected an internal collaboration. Linkages with external entities such as corporations, other universities and the federal government, even on the basic level of communication and interaction did not begin until the 1960s-1970s.

Demand for sciences and engineering graduates also appears to be a factor. Data of graduates as early as 1987 indicate an already large increase in the number of students at HBCUs selecting a science or engineering related major. A body of literature has emerged on the selection of career choices by Black students. Although many conjectures have been made, there are no empirical studies found by this author to indicate whether students selected science and technology fields by personal encouragement, advertising or marketing from various sources or whether they perceived a lucrative job market available and, therefore, chose the field (Llewellyn & Usselman, 2001; Thomas, 1984).

Leadership always plays an important role in change. It is difficult to separate the influence of leadership from other factors. This historical review has purposefully focused on trends, shifts, and factors that have been experienced or exhibited by groups. Thus, the factor of leadership has been downplayed. The creation of the UNCF, an innovative response to a serious problem by Patterson is a notable exception.

The strategy of proximity does not appear to be a notable strategy thus far in HBCU development of science and technology.

HBCUs have overcome some of the challenges stemming from a legacy of a large illiterate population and the opposition of industrial philanthropists to higher education for Blacks. As strengths, they have developed an emphasis on teaching, demonstrated the ability to collaborate with other HBCUs, and exploited a niche in graduating students in science and technology fields. While they have overcome much, there is still change and improvement that needs to occur. HBCUs must move from a teaching agenda to university missions that includes research. And while they have begun to develop linkages they still face obstacles and challenges that constrain their competitiveness. HBCUs need to continuously adapt, improve and be flexible in order to be or remain competitive with their peers and counterparts. This study is being conducted to determine whether linkages has become an integral part of HBCUs' development of science and technology.

CHAPTER 3
LITERATURE RELATING TO THE DEVELOPMENT OF SCIENCE AND TECHNOLOGY AT UNIVERSITIES

Chapter 3 identifies the key theoretical propositions and literature reviews related to the development of science and technology at universities. Several bodies of literature – higher education, the national systems of innovation, and competitive advantage – converge to offer a hypothesis for this study. Each offers a critical piece to understanding how science and technology develops at universities.

An overlap of agreement on the concept of linkages (defined fully in Chapter 4) exists among the three bodies of literature. According to the literature on **higher education**, the evolution of universities from storehouses of knowledge to producers of knowledge and innovation is occurring as a result of the intimate links between universities and firms. **Innovation systems** literature takes a different perspective on the same subject. It takes a systems perspective and looks at the process. Linkages between the university and a number of other participants create an environment in which innovation emerges and hopefully flourishes. The **competitive advantage** literature is concerned neither with universities nor innovation per se. It provides a dynamic interpretation by which industries (and in this study we include universities as an industry) can change or adapt to achieve certain ends. The concept of clusters or linkages between firms/universities and the entities with which they conduct business is critical to the way in which firms/universities learn, modify and adapt new strategies and innovations to become better and more competitive.

Several theories emerge from the literature that explains the development of science and technology at universities. They include the influence of government policy, the impact of internal university leadership, the effects of spatial proximity, and the demand for skilled science and technology personnel. The literature provides evidence for each; this study attempts to discern whether one theory operates more strongly than the others at HBCUs.

Finally, the chapter looks at gaps and issues within the literature bases as an indication of what may not have been considered. They also represent areas where future studies may be conducted. The Chapter concludes with contributions that a study of this nature can make to the literature.

3.1 Theoretical Bases

There are several literature bases (higher education, innovation, and competitive advantage) that blend together to shed insight into universities and their role in developing and maintaining science and technology programs. Certain points seem to emerge in all three literature bases – the increasing entrepreneurial nature of universities, the significance of research and innovation to economic growth and therefore the greater significance of the institutions that produce it, and the importance of competitiveness to institutional or industry growth.

3.1.1 Literature on Higher Education

Universities are dynamic institutions. Originally, universities were conceived to preserve culture and transmit it to the next generation. In that context, the focus was primarily on storing knowledge and graduating students; trained students were considered

the primary “product” of universities. In Europe, universities were considered ‘elitist’; they were institutions that defined and educated either the professionals or the rich and upper class. In contrast, the different approach taken by the relatively new country, the United States, sowed the seeds for changes that would take place in higher education. In the United States, the federal government rejected the European system of elite universities and elected to leave education and its funding to the states. This led to a multitude of secondary schools (high schools), colleges, and universities in the 1800s, most of which were weak (Lucas, 1994). Their educational offerings included elementary level courses; they were not considered as operating with the same educational rigor as European universities.

The divergence in educational structures is key to understanding how the American system evolved into a world renowned educational system. The European universities protected their role as the guardians and storehouses of knowledge by upholding high standards and rigorous entry into the system. Enrollment rates reveal the result of different approaches. In 1910, France had 16 universities enrolling 14,000 students while America had 1,000 colleges and universities enrolling 333,000 students (Graham & Diamond, 1997). In Germany, distinguished professors or Chairs dominated the educational environment and its research and personnel while administrative decisions were made by ministry officials. The European system that proved too rigid to accommodate the upcoming pace of scientific change. In contrast, openness-to-change in the competitive educational system of the United States enabled American universities to exploit and take advantage of the changes in science in the 1940s and 1950s while the

European system fell far behind. Some claim the European-like resistance to change can be attributed to many HBCUs. An emphasis on traditional education at the expense of pursuing scientific and engineering or technological opportunities has impeded progress at HBCUs while some TWIs have moved ahead (see Chapter 2).

3.1.2 Universities in the Present

The 1950s to the present constitutes the second phase of changes within the higher education system. World War II led to dramatic changes in almost all aspects of society. As universities evolved, they took on a new mission – creating new knowledge. A new product emerged – research. Research for the purposes of war produced many new products including nuclear technology, radar, and cryptography that secured for the United States not only their victory in WWII but also the subsequent control of the arms race in the world. Vannevar Bush underscored the preeminence of science with his famous report that eventually triggered federal support for research, "Science – the Endless Frontier". It was a highly influential policy paper that made a forceful Polanyi argument (i.e., developments in science are independent of economic influence). It called for the independence of scientific research conducted by peer review removing it from the control of industry or government (Laursen & Salter, 2002).

At the same time, America was ripe for the concept that every student should be entitled to a college education regardless of ability to pay. Higher education became a highly competitive industry with huge infusions of federal dollars, greater numbers of students, and strong market demand for research and innovations (Martin & Etzkowitz,

2000). Federal funding for research in science and technology grew in quantum leaps. In 10 years (1958 to 1968) the following occurred (Graham & Diamond, 1997):

- The nation's total academic research expenditures more than tripled;
- Federal R&D funding increased 523% (when controlled for inflation);
- Federal funds for basic university research rose from $178 million to $1,251 million – a seven-fold increase; and,
- The number of academic research personnel in doctorate granting universities grew 77%.

Other areas in the educational environment experienced a huge influx of funding as well. From 1963 to 1968, funds for construction, classrooms, laboratories and libraries increased from $84 million to $983 million, an increase of 1,166%. Whereas federal assistance had been targeted to a small number of privileged universities, it spread to 92% of U.S. colleges and universities.

The impact of this dramatic increase in funds elevated American universities to premiere status in the world. Prior to WWII, from 1901 to 1931 only four of ninety-two Nobel prizes were won by Americans. During the 1950's, "American scientists not only won more Nobel prizes than any other nation, they won more than all other nations combined. By the mid-1970s, the United States had more Nobel laureates than any other country, having won ninety-one prizes between 1943 and 1976" (Graham & Diamond, 1997, 10).[9]

[9] On can assume, given the pre-eminence of some European universities, that some Nobel laureates were trained in places other than the United States.

An enormous economic payoff for the national economy resulted from the innovations in science and technology. Science and technology continue to be the forward troops in the quest for economic growth. It pulled the US out of its doldrums in the 1970s into the forefront of tremendous technical advances and economic growth through innovations in medicine, computers, biotechnology, television in the 1990s (Malecki, 1997). The effect of huge infusions of federal funding has transformed American colleges and universities causing them to emphasize research, innovation and collaboration with industry and government (Adams, 2001).[10]

3.1.3 The Future - the Entrepreneurial University

The emphasis on research with the reward of substantial federal funding made many universities invest in changes to their infrastructure in order to increase their science and technology productivity (Graham & Diamond, 1997; Pavitt, 2001). Policy also responded to market demand. In 1980, Congress approved the Bayh-Dole Act which permitted universities to "own" and profit from their inventions. Prior to this point, there had been little motivation for universities to engage in research leading to commercial innovation. A literature base on patents, leasing and university commercialization has been built that explores the significance and results of this policy (Hu & Jaffe, 2001; Kash & Kingston, 2001; Mowery, Nelson, Sampat, & Ziedonis, 2001). The number of patents from universities has increased dramatically since the Bayh-Dole Act (Laursen & Salter, 2002; Pavitt, 1998). Offices of sponsored research (or similar positions) now exist at most universities in the United States. While only a small number of colleges and

[10] As is true of many professions, a small proportion of U.S. colleges and universities are responsible for the bulk of the research conducted in the United States.

universities experience a significant revenue base from their patents or inventions, research is still seen as a positive benefit for the university due to its value to industry, associated lucrative partnerships that form, attractiveness for students, and so forth.

As a result of such influences, universities have begun to act more and more in their own best interest. Their behavior simulates industry/firm behavior (Crow & Tucker, 2001; Hall, 2000; Laursen & Salter, 2002; Martin & Etzkowitz, 2000). The rise of the "knowledge driven economy" is causing science to become more dependent on the economy and vice versa. A central point within the theory behind a knowledge economy is that the way new ideas are generated, diffused and used in the economic system can have important implications for national competitiveness. New ideas found to be economically useful are often generated through investments in the science system. Many countries have made efforts to link their science system to the economic needs of industry (OECD, 1999). Distinctions among the roles of the actors involved (government agencies, industry, and scientists and researchers) are become more blurred as consultants, contractors and projects interact. Theories such as Mode 2 (Gibbons et al., 1994), triple helix (Etzkowitz et al., 1998), and the entrepreneurial university (Martin & Etzkowitz, 2000) have arisen to describe this evolution. The linkages between these actors are becoming more complex leading some to assert that universities are becoming more entrepreneurial (Etzkowitz et al., 1998; Jacob, 2001; Kjolhede, Husted, Monsted, & Wenneberg, 2001).

3.2 Literature on National Systems of Innovation

The literature on national systems of innovation complements the literature base on the evolving entrepreneurial nature of universities. It attempts to understand the systemic conditions necessary for the development of innovation. Developed almost simultaneously by three academicians who worked together on various projects, the national systems of innovation literature describes universities as one of the three major institutions necessary for innovation to occur (industry and government are the other two (Freeman, 1988; Lundvall, 1992; Nelson, 1993). This literature base emphasizes the triangular dynamics among university, government and industry in creating conditions for innovation. The dynamic is also called linkages. The literature on linkages examines the nature of interaction between the three aforementioned major actors, the environment, and the culture. It brings more of an anthropological and sociological perspective on research, universities and innovation than the other literatures mentioned.

Key to this model is the idea of linkages, relationships, and networks. Repeatedly, studies indicate that the difference in socio-economic performance between systems or economies is often related to the network of relationships or linkages that evolve in that particular region to support the process of innovation. This historical development of relationships is variously described as associations/network (Cooke & Morgan, 1998), as culture (Saxenian, 1994), as trust (Malecki, 1997), as systems (Nelson, 1993), as linkages (de la Mothe & Paquet, 2000), and relationships/interdependencies/collective action (Storper, 1997). Although institutions are often thought of as the primary vehicles of innovation, this literature argues

otherwise. It contends that the nature of relationships/linkages between various institutions ignites the innovative forces which Schumpeter insisted was a key element in economic growth (Schumpeter, 1934).

Richard Nelson's work in 15 countries, considered one of the premiere studies on innovation, not only identified the three major institutions involved but also differentiated the units of study (countries) across different criteria (size, income, geographical location) to enable comparison on different aspects. Nelson and subsequent studies determined that certain factors were important in shaping the system of innovation that evolved in each country. These factors included natural resources, national security concerns (including but not limited to military), aggressive industrial development, competitive firms, an educational base that provided knowledge and skills to support industry needs, and a package of fiscal, monetary, and trade policies that supported competition, education and innovation (Malecki, 1997; Nelson, 2000).

Linkages, particularly between university and industry, are crucial to the development of an innovative system. In order to be competitive, firms must continue to either develop new products or improve on existing processes and products. This requires research. While firms conduct the bulk of research and development, they are also dependent on basic research conducted at universities. Thus, each country/regional system becomes defined based on what institutions are responsible for its research, the funding required to support it, the level of funding provided, and the linkages that develop between institutions to diffuse/transmit knowledge and information (Markusen, Hall, & Glasmeier, 1986; Storper, 1997). Thus, on one hand you have a system like

Italy's where research is conducted amongst small firms interacting with little influence or resources from government. The innovative flexible products and process that results are very different from those in Japan's. There, research is a highly supported government priority resulting in, as an example, a high technology, automated assembly lines.

What Nelson and other studies indicate is that the existence of various factors such as a highly literate work force or natural resources or a progressive government policy is not enough to stimulate innovation. There must be linkages between institutions that facilitate collaboration to support industry. Industries within different countries that accomplish this become competitive.

Other studies have taken the theory a step further by examining the spatial aspects of innovation. Researchers such as Varga, Saxenian, and Feldman study the effects of spatial concentration of high technology regions (Feldman, 2002; Saxenian, 1994; Varga, 2000). A few studies look at spinoffs and entrepreneurial startups (Malecki, 1997), some focus on technology or knowledge transfer spillovers (Acs, FitzRoy, & Smith, 1996), and others measure the spatial distribution of innovation and the influence of being in a high technology area (Varga, 2000).

By identifying important factors, as Nelson did in his worldwide study in 1993, he hoped potentially innovative regions could be identified and supported. Others have contributed to Nelson's work with their own studies leading to a large body of work on innovation. While the strengths of this literature base is its identification of important

factors, its weakness lies in not clearly defining the interrelationships between actors that are necessary for the development of innovation.

3.3 Competitive Advantage Literature

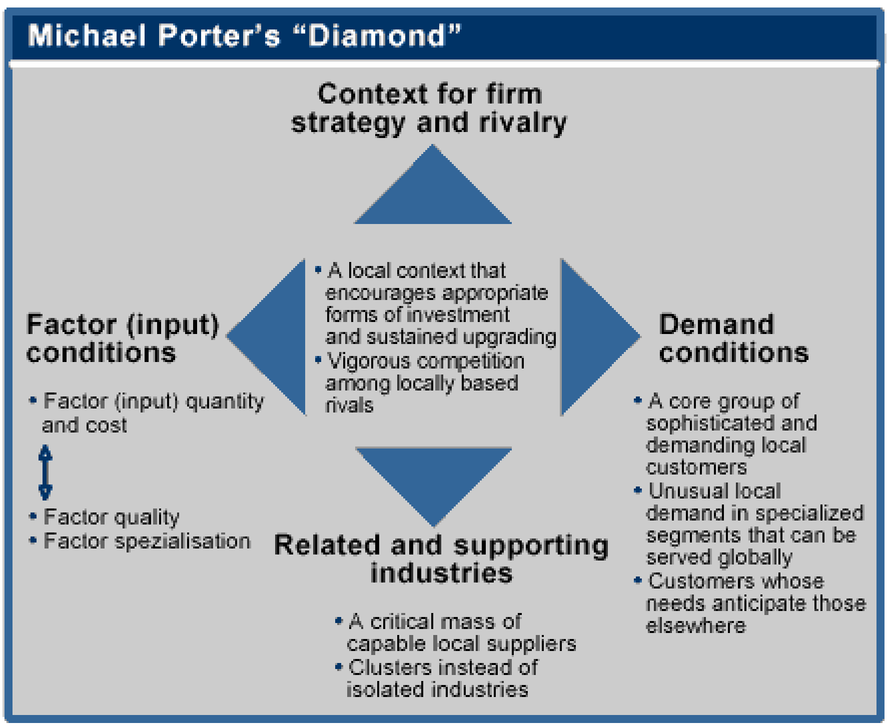
In order to describe and explain the changes occurring in science and technology at universities, a concept was needed that was both dynamic in nature and explanatory in practice. The economics literature on competitive advantage plays an important part by providing an understanding of the dynamic nature of change and how strategies, niches, and trends develop (M. Porter, 1990; Tsipouri, 2001). A team led by Michael Porter conducted a study of 111 narrowly defined industries within ten nations. Looking for underlying themes across widely varying countries and environments, the theory of competitive advantage evolved based on the critical concept of "clusters." Porter defines clusters as

> industries related by links of various kinds…That is, successful industries or companies are often geographically close, they build upon technological innovation, and they operate in a system of vertical activities that includes relationships with upstream suppliers and downstream distributors… They also provide a framework for understanding why national industries wither and die. (M. Porter, 1990, p 131).

This dissertation takes the theory of competitive advantage and applies it to the university (depicted in the higher education literature) and the system in which it operates (depicted in the system of innovation literature) to understand the current context of universities and their ability/capacity to change; i.e., to develop a strategy.

3.3.1 Porter's theory

Porter's theory transformed general economic thought on development from a belief in comparative advantage (a country/industry can be assessed based on its available assets/resources) to an understanding of competitive advantage. An industry can enhance its competitiveness by manipulating certain factors (e.g., its assets, resources, capabilities and strategies), thereby, affecting demand and economic growth. A model of these factors is embodied in the "diamond" concept. See Figure 3.1.



(copied from http://www.wiram.de/toolkit/index.html?/toolkit/tools/tools-diamond.htm)

Figure 3.1 Concept of Economic Factors Model

Universities can be viewed in this same manner using definitions applied to industry. The factors in the diamond for universities can be manifested as follows:

Factor Conditions for universities would include the state/regional/city economic environment, general education environment, funding, and other factors that are part of the local spatial and social environment.

Related and Supporting Institutions would be not only those institutions that provide input to universities (government agencies and secondary schools), but also institutions to which universities provide their output (industry and government).

Strategy, Structure and Rivalry would behave as does industry. Universities exhibit an array of structures (private, public, landgrant) and levels (doctoral granting universities, associate colleges, professional degree granting, and so forth) that result in a competitive rivalry for students, faculty, resources, funding, publications, research and so forth. Strategies used to compete would include the theories presented – leadership, policy, proximity and linkages.

Demand Conditions refers to the nature, composition, growth, size and quality of the domestic market's needs and pressures for research and trained personnel.

3.3.1 Application to Industry

In order to understand how competitive advantage theory applies to universities, it is appropriate to very briefly explain how the theory works with firms. Porter takes several case studies to explain the chain of events that causes the rise of an industry. One of the strongest empirical findings to emerge from the research was an "association between vigorous domestic rivalry and the creation and persistence of competitive advantage in an industry" [Porter, 1990 #107]. Using case studies of the printing industry in Germany, the ceramic tile industry in Italy, the robotic industry in Japan and several others, Porter

reveals that the linkage between a number of actors (suppliers, distributors, consumers, and competing firms) is crucial to obtaining competitive advantage. The process of growth generally starts with one firm or individual that innovates or significantly improves upon a product. The improvement or innovation enables the company or individual to obtain an "edge" over its competitors. As the product is diffused into the market, other companies desiring to maintain their share of the market adopt or adapt to the new technology. Suppliers are important actors in this diffusion of information and the adoption of new technology or innovation. They interact with various companies in the same product line and become a frontline force for knowing what is new and the source of innovation. Companies often choose to locate closer to the "first mover" in order to better understand the new technology and how it works. As additional companies adapt to the new technology, they are able to offer similar products or services. Feedback from consumers is provided by distributors who are liaisons between firms and users. They relate information on the level of demand and the comments, problems and suggestions from end users. This information is used to modify and improve the product which in turn, is used by the company to maintain or obtain a competitive edge. A vigorous rivalry emerges between the various companies aided by the exchange of information that occurs in close settings as a result of the linkages between suppliers, distributors, retail outlets, consumers, and manufacturers. In order to retain market share corporations stimulate demand, work with suppliers and distributors, and manipulate strategies to become more efficient. The rivalry contributes to an

increasingly more efficient and improved performance, which ultimately results in a competitive advantage.

3.3.2 Application to Universities

Universities are not profit-oriented institutions yet they mimic firms in using strategy to improve their status. Universities compete with one another for better faculty and students, more grants and contracts, more production of research, and higher rankings. The transformation of inputs such as students, faculty, facilities, equipment, and applications of funding into outputs such as graduates, research, publications, and government and industry funding occurs through networks and clustering (linkages) between universities, government and industry.

It is in the area of strategy that the competitive advantage theory can be applied to universities because they are dynamic institutions. Although it is unclear how much entrepreneurship can be attributed to the Bayh-Dole Act of 1980, it is clear that entrepreneurial activity at universities has increased. “Among the 84 universities that have responded consistently to AUTM’s surveys over the period 1991-200, disclosures of new inventions by academic investigators shot up an impressive 84%, new patent applications rose 238%, license agreements 161%, and royalties more than 520%” (Washburn, 2005).

As one of many examples, Rosenberg describes how Stanford introduced computer science as a curriculum in the 1960s by bringing in private-sector electrical engineers to teach integrated circuitry (Rosenberg, 2003). Other American universities followed Stanford’s lead and began to introduce computer science curriculum at a time

when no other foreign universities were considering it. American universities obtained a similar advantage with their support of bio-medical research. Support for bio-medical research has catapulted the life sciences (biology, medicine, agriculture) over the physical sciences (physics, chemistry, astronomy) as the dominant research concern. In 2000, “the latter received less than 10% of total academic R&D spending in the U.S. (total was $30.2 billion in 2000), while engineering disciplines (including computer science) received less than 20%, and the life sciences received well over half of the total” (Rosenberg, 2003). American universities have responded to the commercial opportunities available in both computer science and bio-medical research quicker than their European or foreign university counterparts (Rosenberg, 2003).

As stated above, American universities are not profit-oriented and, therefore, do not mimic firms in every component of the diamond. However, American universities are flexible. They enact strategies to improve their standing. Linkages, a central component of clusters, play a part in universities’ ability to make those changes. The collaborations/linkages between universities, industry, and government provided the means to introduce new curriculum, obtain support to shift to new fields like life sciences, and so forth.

This study addresses the question of what strategies HBCUs should adopt to adapt to an increasingly science and technology oriented society. Linkages are highlighted in the competitive advantage literature particularly through the concept of clusters. Proximity and economic benefit work together leading to localization economies. Social capital gets built through the networks and relationships that evolve from proximity. The

value added benefits accrue to firms causing them to experience benefits greater than what would result from its own efforts. How does this work for universities?

Linkages in the form of Networking or Clustering are defined as at least three institutions working together formally or informally to gain some form of benefits. Thus, an input like students can be transformed into graduates by the networking or clustering of an HBCU. The efforts of an HBCU, a government agency and another university may result in a dual-degree program which results in highly trained graduates. Or the collaboration between industry, government and an HBCU that results in support of a research program or an Institute may turn the inputs of faculty, laboratories, and funding applications into outputs such as research, publications, and additional funding.

Other strategies universities can adopt are presented later in this paper. Based upon the advantages presented by Porter and the benefits presented in other literature bases, linkages appear to be a successful strategy for universities and HBCUs to adopt to enhance science and technology development.

3.4 Summary of the Literature

The intersection of the three literature bases depict universities as dynamic institutions that are becoming more like industry with research as their “product” and linkages as their means to change/grow.

Each body of literature emphasized the importance of “linkages” to the success of innovation, economic growth, and productivity. By taking this intersection of the three literature bases, one can analyze the position of HBCUs, understand what factors

contribute to science and technology productivity, and identify what may be significant strategies for HBCUs to use (see Figure 3.2).

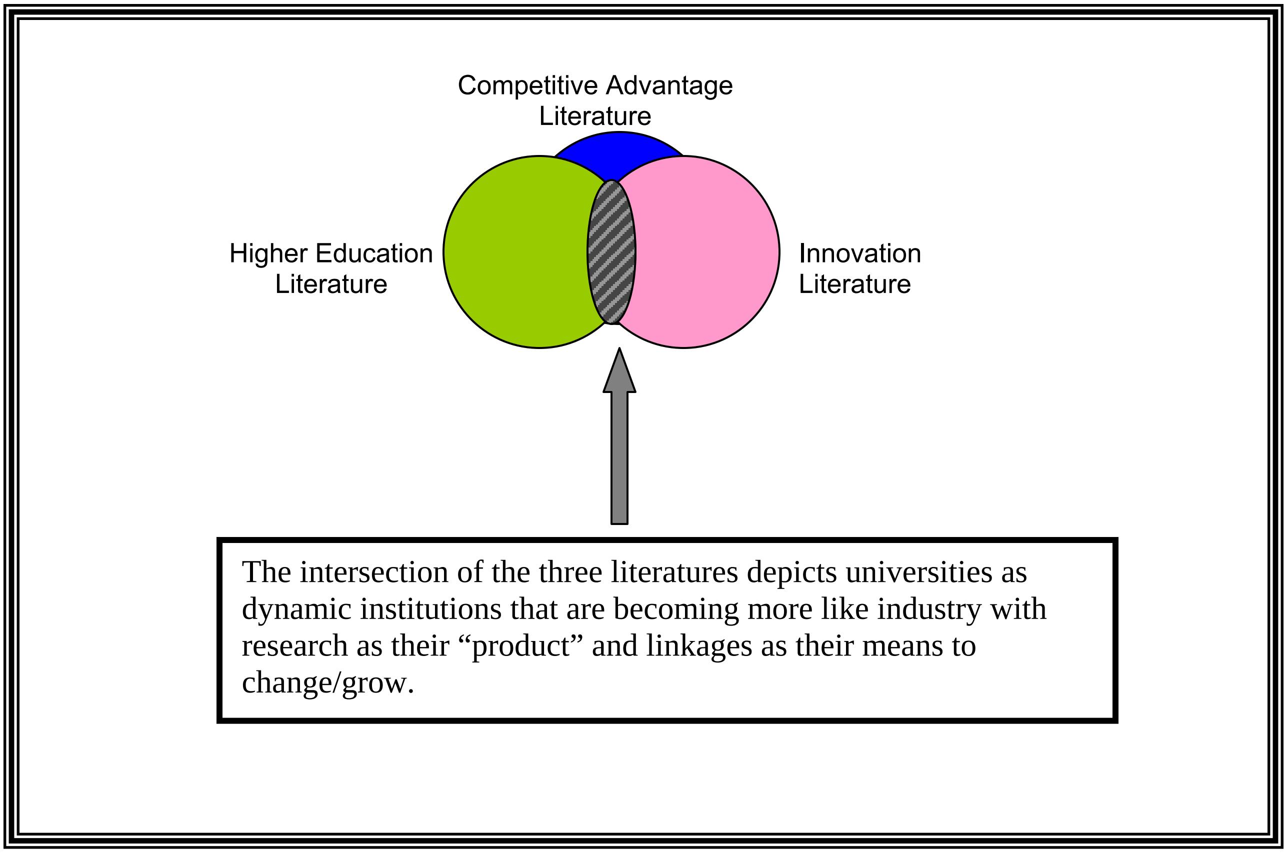


Figure 3.2 – Linkages at the Intersection of the Three Literature Bases

3.5 Gaps and Issues in the Literature

Several literature bases have been covered – higher education, the national systems of innovation, competitive advantage, and HBCUs (in Chapter 2). A huge gap exists in literature addressing science and technology at HBCUs. Most studies to date of science and technology at HBCUs focus on the digital divide; i.e., are campuses with minority students equitably equipped with the same number and level of computers,

Internet access, optic fiber and cable connections, and so forth compared to TWIs. The larger question of what this equipment is used for (research, innovation, and economic growth) has not yet been addressed.

Another issue/gap exists in the application of an economic concept (competitive advantage) to a nonprofit institution. This is an interesting and controversial issue since it is not yet generally accepted that universities are behaving in an entrepreneurial manner. A limited number of studies applying the concept of competitive advantage to universities are coming to light. Researchers at OECD (Organization for Economic Cooperation and Development) paved researcher's way by crossing two disciplines – economics and science and technology. This encouraged academicians and practitioners to put into practice the concepts of clusters enabling the development of science, technology and innovation.

A weakness of the literatures is the vagueness of linkages as a concept. Everyone seems to understand and acknowledge the necessity of linkages. Few seem to understand or be able to explain how they work, what precisely they are, or to establish a causal nature between linkages and economic growth or impact. Thus, gaps exist on several levels – defining linkages, categorizing them, explaining how they are causal agents, and understanding how they work on an intimate level.

The subject of HBCUs also suggest issues on several levels. In addition to the challenges faced by all universities, HBCUs present questions caused by their unique nature. Have they uncovered potentially new and different ways of conducting research due to the constraints caused by a lack of funding, resources and equipment? Do the

tools and techniques developed by the larger population of universities work the same or differently in the HBCU environment? Has the land-grant nature of HBCUs enabled them to develop relationships with industry more easily? Do they exhibit more of an entrepreneurial nature than other universities? Do or should HBCUs seek to mirror majority universities in their approach to science, technology and research? These are just some of the questions that come to mind when examining science and technology at HBCUs. As information accumulates, it will become easier to see where HBCUs diverge from the general population of universities and where they are similar. HBCUs represent an interesting arena of study for future scholars.

3.6 Contributions to the Literature

This dissertation contributes to the literature by addressing a few of the aforementioned gaps and issues. This study specifically addresses an important gap in the literature – the development of science and technology at a set of universities with a historical orientation and culture that differs from most universities. This is important from an internal and external perspective. The data presented will determine how HBCUs are faring in generally accepted science and technology indicators. Also, the information gathered will show how HBCUs, with underfunding, disparities in resources and equipment, and with a unique student body, approach developing science and technology. Internally, HBCUs will be able to use this information as a means of understanding what tools and strategies they can currently (and potentially) utilize. Externally, other agencies can use the data to better understand what strengths and weaknesses are exhibited by HBCUs and what needs can/should be targeted.

This study takes the competitive advantage concept and applies it to a unique subset of universities - HBCUs. While the contribution is not novel, it will provide further insight about how the competitive advantage concept works when applied to universities.

Furthermore, this study utilizes a new variable of measurement that is not generally used when measuring science and technology productivity, research or innovation at universities: number of graduates in science and technology related fields. All studies on innovation and research acknowledge the importance of literacy and a skilled workforce. However, universities' primary output, graduation of students, should be considered a factor when evaluating their production and productivity. In addition, graduate students in science and technology fields are an important ingredient in the development of innovation, research, and science and technology. They have the potential to attract businesses, share information, contribute to increasing industrial competitiveness and foster a culture of science and technology growth.

CHAPTER 4
LINKAGES AND RIVAL STRATEGIES

This chapter clarifies and categorizes the concept of linkages. The term "linkages" is frequently used but rarely defined. The number of ways in which the term is used can be dazzlingly confusing and quite often the term is used without efforts to constrain and categorize its meanings. In order to clarify the definition of linkages and to utilize the concept as a meaningful variable, this paper takes the concept of linkages as used in its various forms and groups them into three categories – Initial (Communication/Interaction), Expanding (Relationships/Contracts) and Mature (Networking/Clustering). Each phase builds on the other; that is, the Expanding phase includes elements of the Initial phase while the Mature phase finds the factors present in the other two, albeit with greater depth and impact. This study assumes that linkages affect science and technology productivity and that it is a strategy HBCUs should adopt.

Although linkages are recognized at several different levels, this study operationalizes linkages as Networking and Clustering (the Mature level). At the two lower levels – Communication/Interaction and Relationships/Contracts, the ability to separate linkages from other strategies becomes too difficult because communication and relationships are embedded in many strategies. Thus, Linkages in this dissertation study focuses on Networking and Clustering.

4.1 Linkages as a Concept

Linkages are particularly useful to those interested in the development of science and technology. Several sources offer basic definitions. Webster's Dictionary defines it

as “the act of linking; a system of links; the fact or state of having something in common.” The Council of Science and Technology Advisors in Canada offers the following definition, “The concept of s&t linkages is about fostering relationships across the national science and innovation system in the pursuit of s&t for mutual interest and benefit….Linkages can cover the full spectrum of relationships, from the simple sharing of information, to broader, more integrated networks, to more formal, sophisticated collaborative arrangements” (Sussex Circle Inc./Le Cercle Sussex Inc., 2003). The sharing of information, depending on the milieu, is also referred to as technology transfer, spillovers, learning capital, knowledge economy and so forth. Linkages are needed for the diffusion of innovation. When a first-mover (the company that first introduces a new product) innovates, the individual company benefits. As the technology transfers to other companies, economic benefits spread, industry leaders develop and the region or a society benefits. Hence, linkages are a basic, influential, pervasive and critical concept. The following diagram (Figure 4.1) categorizes linkages based on the different uses and meanings presented in various studies and books. A fuller description of each category follows.

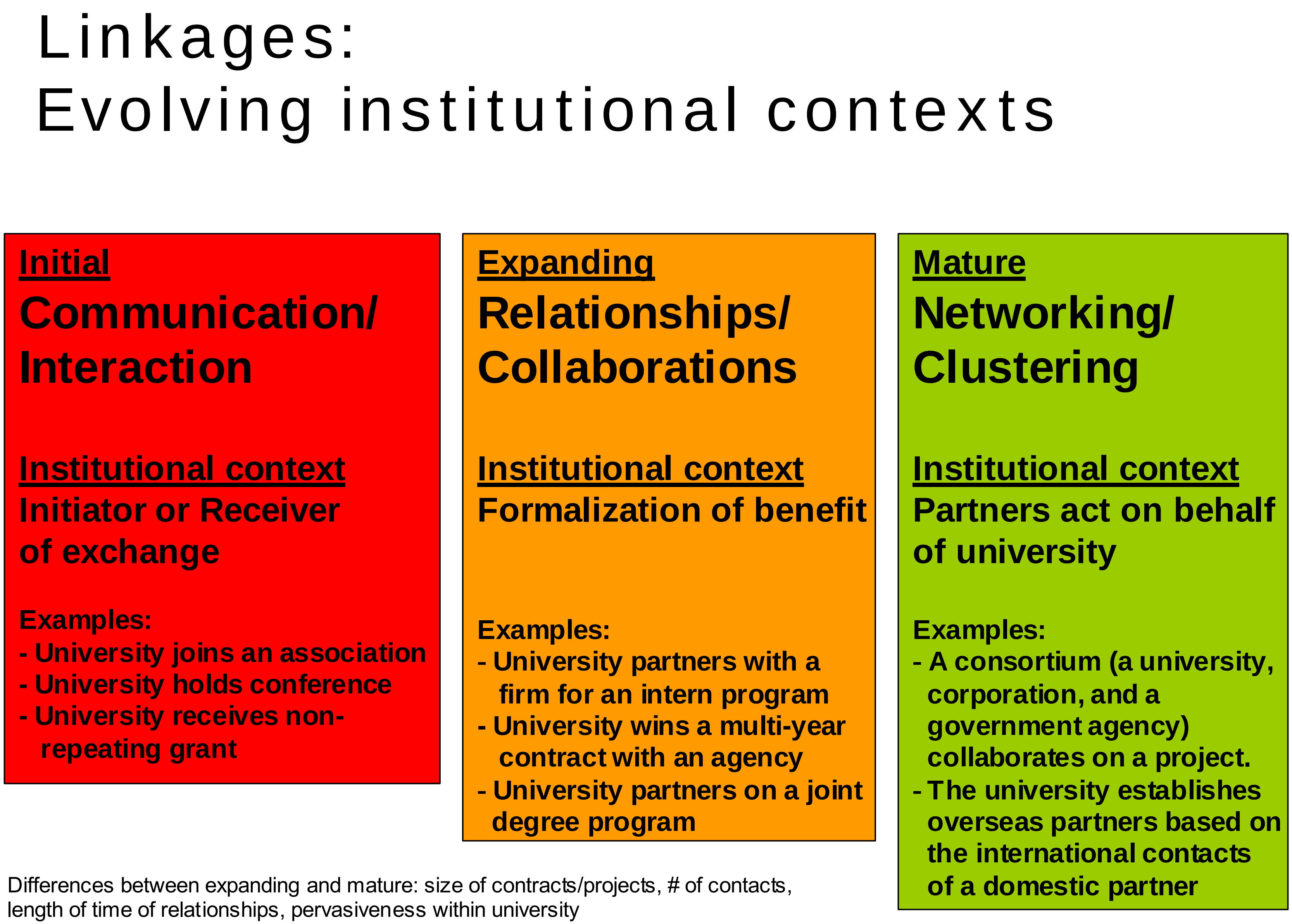


Figure 4.1 Evolving Institutional Linkages

4.2 Initial Stage

In the Initial stage, linkages stem from Communication/Interaction. They can be thought of as “flows” between parties. These flows can take the form of information, communication, knowledge, products and so forth. Linkages in the initial stage generally do not have significant impact on producing outputs or outcomes. They represent the early stages of communication or interaction that over time becomes more important. Malecki uses the term linkages in a number of different ways – from flows of information, resources, transport and data resulting in multiplier effects; to flows of capital and labor for interregional growth; to flows of services from one firm to another (Malecki, 1997). Malecki’s terminology can be summed up to be a flow of goods or services between parties to accomplish a purpose.

The national system of innovation theory emphasizes the use of linkages as interaction (formal and informal) between institutions…and the flows of intellectual resources between institutions (de la Mothe & Paquet, 2000). Markusen used linkages to describe the flow of information that resulted in Silicon Valley from employees sharing their knowledge base as they moved from one company to another or shared meals or other personal interactions (Markusen et al., 1986). OECD describes the “science link” as the interface or flow between the science system and the enterprise sector (OECD, 1999).

Examples of universities using linkages in the initial stage would include holding or attending a conference, joining an association, participating on a panel, or obtaining a non-repeating grant. Scientific knowledge can be accessed and used in a variety of ways – published in journals, embedded in new instruments and methodologies, transmitted via

personal contacts and participation in scientific networks, embodied in the skills and abilities of graduates, and so forth (OECD, 1999). The role of the university is initiator or receiver and the activity is to engage in communication and initial interaction. At this stage, participants are aware of each other. Contacts are made and information is shared that may or may not meaningfully impact productivity. The Initial stage does not directly cause greater science and technology development/productivity. It can act as an aid thereto, but communication/interaction alone is not sufficient to cause greater science and technology productivity.

4.3 Expanding Stage

In the Expanding stage, linkages consist of Relationships and Contracts. The interaction between universities and other organizations becomes more substantive. The introductory stage has passed and participants engage in activity that is designed to prove meaningful to the parties involved. The “trust” and “reciprocity” that are part of social capital are being built at this stage (Cooke, 2002). Porter writes that linkages occur when “the way in which one activity is performed affects the cost or effectiveness of other activities” [Porter, 1990 #107]. This stage is differentiated from the Initial stage by a formalization of the interaction. There are agreed upon objectives for the purpose of realizing a benefit.

Each party involved receives a benefit from the relationship or contract leading to a feedback loop. For example, the conference that was held in the Initial stage may have resulted in two scientists meeting each other and exchanging information. When they decide to publish an article together the exchange has entered the Expanding phase because an objective has been agreed upon that establishes benefit for both parties.

Another example could be a conversation that starts between two individuals resulting in a corporation agreeing to a summer intern program composed of students from the university. Agreement is reached on the activities and boundaries of the relationships whether it be formal or informal.

Examples of linkages at the Expanding stage include the university partnering with a firm for an intern program, two scientists at different universities agreeing to co-publish an article, a federal agency granting a multi-year award to a university, or two universities agreeing to offer a joint degree program. Linkages at the Expanding stage (Relationships/Contracts) can lead to greater science and technology development and productivity.

4.4 Mature Stage

In the Mature stage, linkages are defined as Networking and Clustering. Collaborations become institutionalized. Therefore, this dissertation study defines linkages as the act of networking and clustering. This should not be confused with the physical network or cluster. Defining and understand what the physical network and clusters are aids in understanding the sophisticated level at which the linkages are operating.

The concept of networks and clusters evolved from the theory of the ‘industrial district’ (a large number of firms that are geographically proximate and who contribute in some form or fashion to the production of a product). The firms are separate from each other but through social capital (trust, cooperation and collaboration) they form relationships which evolve into networks or clusters (Bergman & Feser, 1999).

With the help of previous work by Stuart Rosenfeld, Cooke provides a clear definition of networks and distinguishes them from clusters (Cooke, 2002). Networks rely on active civic cooperation. Based upon the trust they establish with each other, firms seek to enhance their own welfare by working with other firms or organizations toward agreed upon objectives. Cooke cites five characteristics of networks.

1) Relatively few firms are involved.
2) Membership is restricted and often takes the form of horizontal relationships between firms of comparable size.
3) Networks rely on links derived from trust, reputation or reciprocity. The cooperation between firms is used to compete more effectively against other firms.
4) Networks are formalized, implicitly or explicitly.
5) The existence of the network implies a high degree of agreement about the pursuit of common objective (otherwise commitment may be low or a lack of consensus may occur).

Clusters, on the other hand, do not actively seek to work cooperatively with a small number of firms. The agglomeration effects of proximity help them realize the advantages of sharing information, spillover effects and developing learning capital. Because of this they seek to establish relations within the cluster. Porter put forth the first generally accepted definition of clusters as “a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities” (M. Porter, 1990). However, the definition does not distinguish clusters from networks and it does not make clear whether companies are

actively engaging in cluster-like attributes or whether clusters occur just because companies connected to a product exist in proximate circumstances. OECD's definition better captures the learning component of clusters. "Clusters are networks of interdependent firms that capture all forms of knowledge sharing and exchange" (OECD, 1999). Cooke and Morgan's definition provides further clarification by including another important ingredient - the infrastructure (a third party) needed to make the cluster an active body. They define a cluster as "geographically proximate firms in vertical and horizontal relationships involving a localized enterprise support infrastructure with a shared developmental vision for business growth, based on competition and cooperation in a specific market field" (Cooke, 2002).

With these definitions, Cooke provides a clear distinction between networks and clusters (Figure 4.2).

Networks	Clusters
Small scale, inter-firm	Large scale
Restricted membership	Open membership
Competitive through cooperation	Competitive with cooperation
Formal prtnership	Informal interaction
Interdependence	Input-output linkages
Agreed objectives	Mainly exchange relations

Source: (Cooke, 2002)

Figure 4.2 Distinctions Between Networks and Clusters

In essence, networks are a more purposeful endeavor that can, through active civic cooperation, result in enhanced benefits for all parties involved. Clusters are a more market-driven concept that takes advantage of the benefits offered by the environmental

proximity. In clusters, the natural competitive nature exhibited by companies is transformed into cooperation if the companies can be shown that by working collaboratively they can achieve greater results than when working individually. The support infrastructure that convinces other firms of the benefits of working cooperatively consists of intervening parties such as an association, an economic development authority, a government agency, a third party, or even another firm (Cooke, 2002).

Networking and clustering are linkages that can create added value to the system. As Porter writes, “Linkages are more than the aggregate sum of the firm’s [university’s] activities, they cause synergies to arise from the interactions and dynamics between economic actors” (M. Porter, 1990). Examples include California’s Silicon Valley and Route 128 in Massachusetts where the commercial and economic growth generated in those regions led to and influenced significant growth in not only that region but also the American economy.

4.5 Networking and Clustering as they Apply to Universities

As discussed in the Literature Review, this study categorizes universities as an industry. Generally, colleges and universities are considered part of the supporting infrastructure. They assist in identifying networks and clusters, help negotiate collective learning, and moderate the cooperation that develops between competitive firms.

Examples of networking by universities should reflect civic cooperative activities that result in agreements (formal or informal) on specific objectives. That would include consortiums in which universities work with other universities, government agencies and firms; and, international collaborations that often involve at least two universities and a foreign agency. Science and technology centers and departments at universities can be

the results of networking if they emerged due to a process that involved other organizations. Any project that has multiple partners may be a result of networking.

Examples of clustering by universities should reflect collaborations that evolve out of geographical proximity assisted by market-driven opportunities. This would include university spin-offs, joint ventures with firms and other universities for research or commercial products (i.e., IUCRCs – Industry-University Cooperative Research Centers), large projects with federal agencies in which multiple partners are involved, and generally any project in which spillover effects occur.

Universities deviate somewhat from the traditional definition of clusters in that they may collaborate with institutions that are not geographically proximate. Yet, Perroux in his theory of growth poles wrote that economic space may be closer than geographical space (Malizia & Feser, 1999, cited in). And universities collaborate with institutions to obtain the same results as industry – to benefit from agglomeration effects stemming from collaborating with institutions engaged in the same service or product.

In this study, the proposition is that of all the theoretical propositions advanced in the various literature bases, linkages represented by Networking or Clustering appear to be one of the most powerful factors influencing science and technology development at universities. Therefore, this study tests whether linkages is a strategy for HBCUs to adopt to develop their science and technology productivity.

4.6 Rival Theories to Explain University Science and Technology Productivity

This research focuses on linkages as the key force behind science and technology productivity but at least four other theories have been offered as explanations for

universities' ability to develop their science and technology productivity. Explanations such as policy; leadership or the influence wielded by key individuals; proximity or location that enhances the development of clusters; and demand for research, scientists and innovation have also been advanced. The following text introduces and reviews each rival theory

4.6.1 Policy

Graham and Diamond developed a methodology to determine new entrants into the list of research universities. When the authors examined the reasons for entry into the list of leading research universities, in each case, there was an agreement at the regional or state level to select one or a few entrants as the focal repositories for research development. Funds were generated to these institutions and, over time, they developed their infrastructure and capacity resulting in the institution entering the list of key research universities (Graham & Diamond, 1997). The policy, or the agreement by government agencies to develop certain universities was the identifying factor present in each case to explain how these universities increased their productivity and enhanced their competitiveness. Cooke describes policy as an effective strategy for economic restructuring that led to innovation in many European regions (Cooke & Morgan, 1998). Policy has been credited with promoting science and technology at HBCUs. Shirley McBay, a mathematics professor at Spelman, cited policy at the national level as the primary impetus for change in the doubling of science majors at Spelman and other HBCUs (McBay, 1978; Scriven, 2006). In the summer of 1972 (the same year that federal funding was extended to include land-grant HBCUs), special programs were established at the national level to support the improvement of science education at

minority institutions. It is McBay's belief that, "the primary factor responsible for more than doubling the number of science majors at Spelman is believed to be the summer program that began in 1972" (McBay, 1978).

4.6.2 Leadership

The influence of key individuals has been offered as another explanation for the ability to create science and technology capacity at a university. De la Mothe describes the importance of leadership as enabling inter-institutional and inter-sectoral partnerships to develop and become operational (de la Mothe & Paquet, 2000). The 'star' theory has evolved as an explanation of how key scientists can influence the direction of a science department or be a key component of the commercialization of a particular product (Darby & Zucker, 1996). New administrators can be instrumental in causing departments to adopt new policies or strive for greater science and technology efficiency. Bozeman and Papadakis found that 87% of projects (federal laboratory-industry partnerships) were initiated by either the companies' top management or their research managers (Bozeman & Wittmer, 2001). The importance of leadership at HBCUs has been voiced by many authors as the difference between institutions that survive and those that do not (Anderson, 1988; Drewry & Doermann, 2001).

4.6.3 Proximity

A growing body of literature devotes itself to the spatial proximity factors of universities, industry and innovation. Based on county innovation factors in the United States, evidence indicates that innovation activity is concentrated in geographical clusters as is industrial research and development (Niosi, Saviotti, Bellon, & Crow, 1993; Oinas & Malecki, 2002). While university research is more evenly distributed spatially than

innovation, it also is found in clusters. In the U.S., the top ten counties carry out one-third of the total university R&D ($1,600 million out of $4,800 million) (Varga, 2000). There is an overlap of the largest university research clusters (measured in university R&D funds) with clusters of innovation activities, causing the term ‘local innovation system’ to arise. The characteristics of a ‘typical city’ in which a critical mass of innovation occurs and where university research translates into a feedback loop of commercialization, technology transfer and employment, are a size of about 3 million with employment in high-technology production facilities and business service firms numbering around 160,000 and 4,000, respectively (Varga, 2000). The implications from this research are that a university can increase its science and productivity by locating in an ‘innovative region’.

Proximity may be more relevant to HBCUs since they are predominantly located in the Southeast portion of the United States. Despite the South’s lack of innovative activity compared to the rest of the United States, the proximity of many HBCUs provides potential for the development of a cluster. Cooperation between HBCUs has been a theme in the literature on Black higher education (Branson, 1942; Clement, 1942; MacLean, 1942; Roach, 1998).

4.6.4 Demand for Research and Skilled Personnel

The demand for personnel skilled in the fields of science and technology is not new. During WWII, it was noted that there was a great need for physicists, engineers, chemists, and mathematicians to do work and research for the war effort. For example, the American Institute of Physics reported that, "estimates indicate that the need (for physicists) is now growing at the rate of 1,500 to 2,000 per year, and that the current

annual supply from schools is no more than 500" (Branson, 1942). Bulletin No. 26, Higher Education and National Defense, issued by the American Council on Education, April 30, 1942, showed that of 103 professional occupations, shortages existed in 62 of them in January 1942. Of the 62, thirty were listed under engineering and physical sciences. The author suggests that since Negroes were 10% of the population, they should contribute 10% of the personnel (Branson, 1942).

In 1997, the National Academy of Sciences sponsored a report on the labor shortages in information technology. A 1997 study by the Information Technology Association of America (ITAA) estimated a shortage of 340,000 information technology (IT) personnel. In September of 1997, the Department of Commerce released a report concluding that there was a shortage of IT workers; and the Bureau of Labor Statistics projected that the U.S. would require more than 1 million additional IT workers between 1994 and 2005, compared to the U.S. bachelor's degrees awarded in computer and information sciences annually (24,553 in 1994) (National Research Council, 2001). The shortage of skilled personnel in information technology and other science, engineering, and technical fields; the large number of immigrants that have been hired by domestic companies in the U.S.; and the large number of foreigners at higher levels of education in science and technical fields have led the U.S. to pour resources into identifying promising science and math students; encouraging minorities to enter science, engineering and mathematics fields; and strengthening science and technology infrastructure at colleges and universities [National Research Council, 2001 #393.

4.7 Summary

Linkages are highlighted in the literature as a key component of the development of science and technology in the New Economy. This chapter categorized the various ways in which Linkages have been used and defined. This dissertation study utilizes the most developed form of Linkages - Networking and Clustering. The depiction of networks and clusters is used to enhance understanding of the level at which linkages are operating. Often used interchangeably, networks and clusters are defined as two different concepts. The end goal of both concepts is to maximize the utility of the participating members; however networks are more a result of civic cooperative action; clusters are more reflective of market driven actions. Despite the barriers and challenges faced by HBCUs to develop linkages, the nature of collaboration is such that it may be essential for the development of science and technology according to many studies.

In order to strengthen the test of the primary hypothesis, rival theories are also posed and tested. Rival theories include the influence of government policy, the impact of leadership, the effects of proximity, and the demand for skilled personnel.

Despite the challenges and barriers, HBCUs must still build trust and form partnerships and collaborations in order to develop their science and technology productivity. This study tests that proposition by examining the influences of the various strategies on the development of science and technology at selected HBCUs.

CHAPTER 5
RESEARCH DESIGN

This chapter presents the research design for determining what theories account for the development of science and technology at HBCUs. The research design utilizes a mixed methods approach which consists of a quantitative methodology nested within a qualitative design. The methods are conducted sequentially for several reasons – to respond to different questions within the study, to accommodate the different methodological requirements of each approach, and to use the results from the quantitative approach to inform and guide the direction of the qualitative approach. The two approaches combine to provide greater insight into the findings.

5.1 Unit of Analysis

The unit of analysis is the university. Porter's methodology utilizes the industry as the unit of analysis; however, the findings upon which he bases his 'diamond' are case studies of superlative companies that shifted the direction of the industry. Since this study focuses on a subset within the industry of universities (HBCUs), the appropriate unit of analysis is the university.

5.2 Dependent Variable

The variables in this research study are drawn from models in previous science and technology research (Barre, 2001; Kleinknecht & Bain, 1993). The most commonly used traditional measures are included in the Innovative Capacity Index by Porter and Stern (M. E. Porter & Stern, 2001), the Composite Indicator of Science and Technology by NISTEP in Japan (Science and Technology Agency, 1995), the Technology Achievement Index composed by the United Nations Development Programme (United

Nations Development Programme, 2001), the State Technology and Science Index at the Milken Institute (Devol, Koepp, & Ki, 2004), and so forth (see Figure 5.1 of variables in the above cited indexes). Each composite index utilizes different indicators; however, certain categories appear to be common. All the composite indicators utilized a workforce indicator (scientists, researchers and engineers). Four of the five indices included a knowledge component (publications, patents, leasing, etc.). Three of the five included a financial indicator (research and development expenditures or inputs, and innovation financing).

The dependent variable for this study is science and technology productivity operationalized as a science and technology index consisting of six variables:

1) federal R&D expenditures at colleges and universities from 1985-2001;
2) industry R&D expenditures at colleges and universities from 1985-2001;
3) institutional R&D expenditures at colleges and universities from 1985-2001;
4) state and local R&D expenditures at colleges and universities from 1985-2001; (the first four represent an R&D indicator);
5) bachelors and master's degrees awarded in science and technology fields from 1987-2000 (the workforce indicator); and,
6) publications, notes and abstracts from 1986-2002 (the knowledge component).

R&D expenditures represent funds spent on research; students conduct research; and publications reflect the diffusion of research. A productivity measure was obtained by dividing the scores of the above variables by full-time faculty. (See Appendix B for definition of science and technology fields for graduates.)

	NISTEP Composite Indicator Japan	Summary Innovation Index European Union	Innovative Capacity Index Porter	Technology Achievement Index United Nations	State Technology and Science Index Milken Institute
	13 major indicators	4 major indicators	5 major indicators	4 major indicators	5 major indicators
1	R&D expenditures	Human resources	Science & engineering manpower	Technology creation	Research & development inputs
2	Nbrs of Researcher	Knowledge creation	Innovation policy	Diffusion of recent innovations	Risk capital and entrepreneurial infrastructure
3	Nbr of Scientist	Transmission and application of knowledge	Cluster innovation	Diffusion of old innovations	Human capital investment
4	Nbr of Engineer	Innovation finance, output and markets	Innovation linkages	Human skills	Technology and science workforce
5	Value of technology imports		Company innovation orientation		Technology concentration and dynamism
6	Nbr of papers				
7	Nbr of citations				
8	Nbr of internal patents				
9	Nbr of external patents				
10	Nbr of patent citations				
11	Value of industrial product production				
12	Value of high tech product production				
13	Value of technology exports				

Figure 5.1Summary of S&T Index Indicators

This study uses the same method employed by Rogers, Yin and Hoffmann in their study to develop a technology transfer effectiveness index (Rogers et al., 2000). Developing standardized scores was preferable to a simple ranking of the universities because it permits a more accurate comparison of results. A standardized score can tell us that University 1's score is twice greater than University 2 and so forth. It provides greater accuracy in the ranking.

The six variables are measured in different units – dollars, number of students and number of publications. Each variable was summed across the years. A productivity measure was obtained by using full time faculty as an input measure.[11] In order to compare different units, each variable was converted to standardized scores (z-scores).[12] Each variable was given equal weight as none has been proven to be of more importance than the others. The composite index is obtained by averaging each HBCU's z-scores for the six variables and then putting them in rank order on the basis of their score. A rank score of 1 to 103 is assigned with 1 being the highest score.[13] The index allows identification of the top performing institutions in science and technology productivity. The index does not determine the "best" HBCUs, so much as it identifies the institutions that have manifested certain levels of comparable success in achieving science and technology productivity.

The first indicator, research and development expenditures may be seen as an input in contrast to graduates and publications which are outputs. The funds received are

[11] Full time faculty was used in Graham and Diamond's study on productivity of research universities.
[12] A z-score measures each observation in terms of standard deviation units from the mean, hence it's usually referred to as a standard score.
[13] The lowest score should be 103; however, the last 14 institutions have equal scores. The fourteen institutions do not receive any research and development funding, do not produce any science or technology related publications and do not have graduate students in science and engineering fields (or data is not provided).

used for programs and research which can result in publications and graduates. In the case of HBCUs, the application for research dollars is often preceded by an internal decision to purposefully increase science and technology capacity. Since the data for the number of applications is not available, the award of research and development dollars is used as a proxy to indicate university efforts at increasing science and technology output.

5.3 Independent Variables

The independent variables for Phase I, the quantitative section, are university characteristics that impact science and technology indicators. Region (South, Mid-Atlantic, Southwest, Mid-west), size (Very Small, Small, Medium, and Large), control (private, public and landgrant) and Carnegie classification (Research, Baccalaureate, and Associates and Others) have been identified as such factors (see Appendix __ for further clarification on definitions).

The independent variables for Phase II, the qualitative section, are linkages and the four rival theories – policy, leadership, proximity, and demand for personnel. In Phase II, linkages are defined as Networks/Clusters and constructed as a dummy variable (yes- this is networking/clustering, no- this is not networking/clustering). Linkages as Networks/Clusters are operationalized by participation in a joint venture, contract, agreement, Center, or Department in which three or more universities or agencies agree to work together toward a common objective(s).

The rival theories are also set up as dummy variables (yes/no). Policy initiatives are operationalized as external governmental policy - federal legislation or policy, regional policy, state legislation or policies. Leadership is defined as internal action by the HBCU President, Dean or Key Scientist (faculty). The variable representing

proximity is location and participation near a science park or a noted science/engineering/technology facility or center. Demand is understood as internal university action to increase number of students enrolled in science, math or engineering programs. This variable assumes knowledge exists of societal demand for science and technology personnel.

5.4 Phase I

Based upon theoretical claims, this research proposes the following expectations in response to the associated questions. The expectations are geared more toward an understanding of relationships than proof of causality.

Q1: What are the characteristics of HBCUs that explain higher productivity levels in science and technology indicators?

Based upon research conducted by Graham and Diamond measuring productivity by federal R&D dollars and journal publications in science, sociology and arts and humanities, four year private institutions were found to be initially more productive than public for-profit and non-profit colleges and universities. Despite a significant narrowing of the gap between public and private universities, the latter still enjoys a higher ranking than public universities in science and technology criteria (Graham & Diamond, 1997). Inferences from these findings are used in support of the following expectations.[14]

E1: Four year private HBCUs will average a higher rating on science and technology productivity indicators than four year public HBCUs

E2: Four year private HBCUs will average a higher rating on science and technology productivity indicators than four year landgrant HBCUs

[14] E1, E2, and E3 stand for Expectations 1, 2, and 3.

E3: Four year private HBCUs will average a higher rating on science and technology productivity indicators than 2 year HBCU associate colleges.

Doctoral level and master's level universities are categorized according to the number of students that graduate at a post secondary level. These students are expected to contribute to the knowledge base through theses, dissertations, research, and teaching (Carnegie Foundation for the Advancement of Teaching, 2001). Thus, it's expected that research output will be higher at institutions that produce a greater output of post-secondary students.

E4: Research HBCUs categorized as Doctoral Extensive and Intensive and Master's I and II according to the Carnegie classification will average a higher rating on science and technology productivity indicators than all other HBCUs (except HBCU medical schools).

5.4.1 Phase I: Methodology

The research will proceed in two phases. To determine which universities are more productive, a composite science and technology index is constructed with a rating assigned for each university. Each phase uses different techniques in examining different subject populations.

Phase 1: Ranking of all HBCUs in science and technology related fields

Goal: To assess the characteristics of higher performing HBCUs

Population: 103 HBCUs

Methods: Development of a science and technology index through the use of standardized scores, regression analysis on the resultant index

For the science and technology indicators, the population is all 103 HBCUs. Regression analysis is used to understand what characteristics account for universities with higher science and technology scores. The science and technology index is the independent variable and the characteristics are the independent variables.

5.5 Phase II

The primary question addressed by this phase (and of the dissertation overall) is what theory(ies) (termed strategies when implemented) account for the development of science and technology at research-oriented HBCUs. Phase II, the qualitative approach of the research design, hypothesizes that linkages are the primary factor influencing the development of science and technology at HBCUs. This will be explored by assessing which strategies are utilized by the most productive research universities.

5.5.1 Phase II: Methodology

The 35 research-oriented HBCUs (Doctoral and Master's universities according to the Carnegie classification) are ranked and classified into high, middle and low ratings according to their composite science and technology index. One HBCU is selected from each category for more in-depth study.

Phase II: Assessing the effects of linkages and other rival theories

Goal: To determine a) whether linkages are the primary factor in influencing science and technology productivity and b) if linkages are not the primary factor, then what is/are the most influential theory(ies)?

Sample Population: 3 HBCUs

Methods: Interviews, archival analysis, pattern matching, rival explanations, triangulation, and chronology of events

The central hypothesis of this dissertation study asserts that linkages are the primary factor influencing science and technology development at HBCUs. This hypothesis will be proven false if a) no evidence of linkages exists or b) evidence of linkages is found to exist but there is no evidence linking it to the development of science and technology; or c) evidence of linkages is found to exist but a rival explanation is found to have more influence on the development of science and technology at the university (i.e., the rival explanation occurs more frequently or the rival explanation precedes linkages in a time chronology). This dissertation's earlier chapters established the logical consistency of each theory. Deductions were made based upon the logic presented in each theory. Replicability and generalizability resulted from comparing the same *theory* in different environments. These case studies, therefore, achieve the standards set by science and qualitative research practice through its design. It establishes rigor by having several case studies, introducing several rival theories, and establishing predictions for each theory.

5.6 Design

A qualitative approach design was chosen for two reasons. First, there are a small number of HBCUs relative to the population of colleges and universities and their characteristics are skewed. Statistical analyses could be completed but the results might be biased. Second, questions that seek to uncover explanations that may be complex in nature or have more than one factor involved lend themselves more to a qualitative than quantitative approach.

The selection of the three research HBCUs is explained further in Section 5.7. Once the HBCU was selected, its website was reviewed for university characteristics,

Mission Statement, Strategic Plan, structure, goals and objectives, departments, key personnel, Fact Book, President's report, annual report, report of External Funding, partner organizations, and any other relevant information. Science and technology departments, schools, and notable (featured as successful on the website) programs were identified.

Original interview plans included administrators, faculty and students. A pilot interview was conducted with a student to determine whether he/she had sufficient knowledge to respond to interview questions. The student was unable to provide any information regarding the development or conduct of a program; therefore, they were removed from the list of people to interview.

Letters requesting approval to interview faculty were sent to the President requesting interviews with the Vice President of Sponsored Research (or similar position) and the number of faculty that represented the number of Colleges/Departments associated with science and technology. A limited number of interviews were requested in order to secure approval. When appointments were arranged with the department, a request was sometimes made to interview faculty within significant programs if such were found on the website. Attempts were not made to speak with staff because it was believed that interviewees might be inhibited in their responses if they were aware that their boss was responding to similar questions.

Chairs of the department were sought when possible because they often had longer tenures, more information about the history of the department, more understanding of the goals and objectives, and insights as to what direction the department was taking.

Questions were constructed based upon a) understanding how science and technology programs are created and expand, b) understanding how linkages affect s&t development, and c) uncovering which of the rival theories deserves credit for creation and expansion of s&t programs. Assistance with question formation and placement was sought from questionnaires on the Internet, previous surveys by Georgia Institute of Technology and Georgia State University, and qualitative research manuals.

Ethical considerations were considered minimal. The primary dissertation question is not of a personal nature so potential harm to humans is low. HBCUs have been maligned in the past and labeled as inferior and sub-standard. The image portrayed could have hurt the university by inhibiting students from attending the institutions. The major concern was in maintaining an appropriate balance of objective yet critical inquiry into the subject matter. By developing a standardized method of ranking the HBCUs, ranking in only one subject area, and not making any judgements about the HBCU, the researcher believes objectivity was maintained. Further explanation of the process is explained in section 5.8 - Process and Appendix D – Case Study protocol.

5.7 Selection of Universities

Methods for selection of HBCUs were taken from the United States Accounting Office on Case Study evaluations. Using a purposive representative sample scheme, three research-oriented HBCUs are selected as case studies. A representative scheme is defined as a sample that has approximately the same distribution of characteristics as the population from which it is drawn. The universities that are selected are typical or representative of important variations in HBCUs (U.S. General Accounting Office, 1990). The 35 research HBCUs were ranked and divided into three equally proportioned

sections representing high, medium and low science and technology productivity based upon the ratings obtained from the science and technology index produced in Phase I. An HBCU was selected from each section. In selecting the three universities, an attempt was made to include a cross section of factors such as location, Carnegie classification, size and control. Selecting more than one case study, choosing congruent universities while including variation in the samples chosen strengthens the rigorousness of the case, methods, and results (Lee, 1989).

5.8 Process

The first step after selection of the three research HBCUs was to obtain descriptive, background information. In addition to contextual information obtained on each institution, data was collected on factors relating to science and technology development. The second step was to seek official university documentation presenting the university's position regarding science and technology. Documents such as the Mission Statement, the Strategic Plan, the President's message/report, goals/mission statements of science and technology related departments, department annual reports, lists of companies that contracted with those departments, and descriptions of projects on which the departments were working, were obtained from the universities and their websites (or as much of the above as could be obtained). The purpose of obtaining these documents was to determine whether the University had a policy towards science and technology, whether the University was interested in increasing its production or productivity, and whether any progress had been made towards those goals (if they

existed)[15] The results of the first and second step can be found in Chapter 7 – The Three Research Universities.

The third step was to formulate a set of standard questions for each of the three universities regarding their development in science and technology. These questions were to be presented to the Deans or Chairs of the primary departments associated with science and technology. Prior to the questions being addressed to the HBCUs, a pilot test was conducted with Spelman University[16] (an HBCU that was ineligible since it was not a research university). The pilot test facilitated validation of the survey tool. The amended survey tool was sent to the Vice President of Research at the Georgia Tech Research Center, Dr. Jilda Garton, to obtain the perspective of a research university not part of the study. Comments from both sources were incorporated into the final survey tool.

Once the basic questions were finalized, the information obtained from the databases and the websites were incorporated into the standard set of questions so the department/university could respond according to its unique development. Approval to conduct the research according to university procedures was obtained from the Georgia Institute of Technology Institutional Review Board. The Dean, Chair or Director of the largest colleges/departments/institutes or programs were interviewed. Eighteen HBCU administrators were interviewed (two of the interviews had the present and past Chair present). In addition, interviews were conducted with 6 administrators at external agencies that partnered or worked with HBCUs including non-profit organizations,

[15] As stated in Chapter 7, Hampton University would not provide any strategic documents.
[16] Spelman University is a single-sex (females only) HBCU which presents a potential bias in the pilot. However, sex has not been identified as a source of potential bias in the development of science and technology at universities. Thus, the use of Spelman as a pilot is not expected to have adverse effects. Additionally, Spelman was not the only test subject.

government, and corporations. They were given an amended version of the survey for the purpose of corroborating or countering responses or providing additional insights about HBCUs. As an individual organization, each could provide insight and additional explanation to information provided by the HBCU. However, an external agency is not in a position to explain what initiates programs at HBCUs. Thus, their answers were used to support or constrain responses provided by the HBCU respondents. Their responses were coded in the section addressing the expansion of science and technology.

5.9 Data Sources

Research and development expenditures data is publicly available information obtained from the National Science Foundation. Limited information on graduates in selected fields is available from the National Center for Education Statistics (NCES). Associates at NCES supplied additional information for graduates from HBCUs. Data on the number of publications, notes and abstracts was obtained through bibliometric software[17] that tabulated and summed results from the Web of Science, a service that provides Internet access to research literature through various access points.

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[17] The bibliometric software was obtained by using Vantage software, a trademark technology produced at Georgia Institute of Technology. Vantage is innovative software that enables researchers to capture citation data across a wide spectrum of data. It is limited only by the constraints of the databases themselves (e.g., whether foreign publications are included, whether English only publications are included, etc.).

Data	Source	Date
Publications, notes and abstracts	Web of Science database from ISI (Science Citation Index, Social Sciences Citation Index, Arts and Humanities Index	1987-2002
Bachelors and Master's degrees conferred in science and engineering related fields of study by race and institution	National Center for Education Statistics (NCES) IPEDS data system http://nces.ed.gov/ipeds/	1987-2000
Research and Development Expenditures at Universities and Colleges	National Science Foundation (NSF) Web Caspar database (Integrated Science and Engineering Resources Data System)	1987-2001
Documents - Mission Statement, Strategic Plan, Department descriptions	Individual University websites	
Interview data	HBCU campus visits	2003-2004

Figure 5.3 Data Sources

Access to non-public data was not easily obtained. The two public HBCUs (Fort Valley State University and Florida Agricultural and Mechanical University) had mission statements, strategic plans, and goals and objectives on their websites. Hampton University, a private institution did not have their strategic plan, annual report, or the goals and objectives of some of their programs on their website. Neither would they make such documents available.

Approval to interview faculty at HBCUs was bureaucratic and difficult to obtain. Howard University had been included in the original set of universities to interview. After repeated attempts over a period of months to obtain permission to interview faculty, the university responded in the affirmative but required that the researcher obtain approval from their institutional review board. At the time notification was given, even with an expedited process the approval would have taken too long. Due to time constraints, the university had to be removed from consideration.

Attempts to obtain information apart from the interviews were often unsuccessful due to bureaucracy and the time required to obtain permission. For example, when it was discovered a science park existed on FAMU's campus, attempts were made to approach businesses and/or administrators of the science park. Information on businesses, related personnel from FAMU or University of Florida, and science park staff associated with the park was not obtainable during the visit. Attempts to interview faculty not on the itinerary were unsuccessful.

5.10 Data Analysis Plan

For the qualitative data, four techniques have been chosen to analyze the data. Four techniques – pattern matching (did the theories match their prediction), validity against rival explanations (did one explanation offer more explanatory value than another), chronology of events (did one theory precede another and therefore become more causal than another theory), and investigator triangulation (was more than one process used) strengthened the internal validity and reliability of the research (Garson, 2001; Yin, 1989).

Pattern matching compares the prediction derived from the theory to the evidence collected. Thus, under the proximity theory, the prediction that proximity to a science center leads to the development of science and technology would have to be supported from evidence or documentation.

Rival explanations/theories, another form of pattern matching searches for variations in the independent variables (rival theories) given the same dependent variable (science and technology productivity). Again, the concern is with the pattern of results.

Internal validity is strengthened when rival hypotheses can be ruled out and the leading hypothesis confirmed by a preponderance of the evidence.

Chronology of events over time attempts to create a temporal sequence of events. Observations assist in the determination of causality from different variables. One event must precede another to establish causality. For example, using a chronology of events analysis, actions taken at a university after the introduction of a new Chair may be causally linked to leadership, whereas, actions in support of science and technology before the Chair came aboard cannot be causally attributed to leadership[18].

Of the four basic types of triangulation (data, method, investigator and theory), this dissertation study uses three – data (time, space and persons), theory (using more than one theory in analyzing the phenomenon) and methodological (using more than one method). Data triangulation is achieved by gathering and comparing data from three sources – statistical data from NSF, NCES and ISI Web of Knowledge; archival/historical documents; and interviews with internal representatives and external liaisons. Theory triangulation is achieved through rival explanations. Using both quantitative and qualitative methods represents the methodological triangulation.

There are vulnerabilities to this design. In Phase I, the descriptive characteristics used are mostly demographic variables. While important and insightful, other characteristics addressing capability such as infrastructure, library resources, lab equipment, and other contextual/cultural features would have added further insight into what characteristics describe "successful" HBCUs. In addition, the design would be improved by comparing HBCUs to majority universities. The assumption is that HBCUs

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[18] Causality cannot be established because results followed the leader but causality can be eliminated if action occurs prior to the leader.

are a unique subset of universities. Without comparing HBCUs to other colleges and universities in science and technology related criteria, HBCUs' uniqueness remains an assumption rather than an observed fact.

In Phase II, the selection of three universities is a small sample from which to draw conclusions that may relate to the HBCU population. However, this is an issue that confronts all case studies. There is a trade off between the time and resources required to do in-depth research and the generalizability of the findings to the entire population.

The methodology outlined in this research design should enable the analysis of Linkages as the strategy most adopted by HBCUs for developing science and technology productivity. Due to constraints of resources and funding, vulnerabilities will remain to some degree. However, the rigorousness of the design should strengthen the validity of the findings.

CHAPTER 6
Quantitative Analysis

This Chapter presents the findings from Phase I, the configuration of the science and technology index. Several questions are answered in this section. Which HBCUs exhibit high levels of production and productivity in science and technology indicators? What are the characteristics of productive HBCUs? Do the findings support the expectations?

Based on the methods described in Chapter 5, results of the Science and Technology (S&T) Index are presented for the 103 HBCUs. The index is analyzed to determine whether there is support for the expectations; it is then regressed on descriptive characteristics to identify which characteristics, if any, show a relationship to successful HBCUs. Finally, the index is used to select three research HBCUs for further in-depth study of strategies utilized for the development of science and technology.

Findings from this section of the dissertation study support the expectation that research universities have higher levels of productivity. Further analysis indicates that the higher the Carnegie classification, the higher the level of productivity. It does not support the expectations that four-year private HBCUs exhibit higher levels of science and technology productivity than four-year public or land-grant HBCUs.

6.1 HBCU S&T Index

The methodology for construction of the science and technology index follows the method used by Rogers & Yin in their development of a technology transfer effectiveness index. The methodology is explained in Chapter 5. In brief, the independent variables are university characteristics (Carnegie classification, control,

region, size and years). The dependent variable is composed of six normalized variables representing a knowledge component, a human capital component and a research and development investment component (normalized by full-time faculty).[19] The six variables, with various units of measurement, are converted to standardized Z scores. The variables are considered equally important components of science and technology development at universities.[20] The composite index measure is obtained by averaging each university's z-scores for the six variables, rank-ordering the universities based on their resultant average z-scores for science and technology development, and assigning rank scores from 1 (highest science and technology index score) to 90. (Although there are 103 HBCUs, the lowest rank is 90 because the 14 lowest ranked HBCUs have identical scores). The scores represent a productivity measure normalized by full-time faculty. Table 6.1 displays the results of the HBCU science and technology index.

[19] The six variables are federal R&D expenditures, industry R&D expenditures, state and local R&D expenditures, institutional R&D expenditures 1985-2001 at colleges and universities (the research and development indicator); b) bachelors and master's degrees awarded in science and technology fields from 1987-2000 (the workforce indicator); and, c) publications, notes and abstracts from 1986-2002 (the knowledge component).

[20] Although each variable is equally weighted, the use of four variables representing expenditures at colleges and universities versus one each of publications and graduates represents a weight. It is the opinion of this author that the importance of funding justifies the use of four variables. This is true also in the other science and technology indexes.

Table 6.1 HBCU SCIENCE AND TECHNOLOGY INDEX 1986-2000*

Institution	Average Z Score	Rank	Institution	Average Z Score	Rank
Jackson State Univ	5.14846	1	LeMoyne-Owen College	-0.23038	53
Lincoln Univ (Jefferson City, MO)	2.22640	2	Dillard Univ	-0.23143	54
Prairie View A&M Univ	2.02021	3	Mississippi Valley State Univ	-0.23542	55
Tennessee State Univ	1.49061	4	Saint Augustine's College	-0.23571	56
Tuskegee Univ	1.37305	5	Claflin College	-0.24046	57
Spelman College	1.29851	6	Morris Brown College	-0.24091	58
Texas Southern Univ	1.18968	7	Savannah State Univ	-0.24339	59
South Carolina State Univ	0.92253	8	Barber-Scotia College	-0.25073	60
Southern Univ/New Orleans	0.81999	9	Wilberforce Univ	-0.25448	61
Univ of the Virgin Islands	0.79734	10	Morris College	-0.26187	62
Howard Univ	0.69304	11	Stillman College	-0.26453	63
Central State Univ	0.49873	12	Oakwood College	-0.28023	64
Florida A&M Univ	0.44547	13	Florida Memorial College	-0.28815	65
Clark Atlanta Univ	0.44170	14	Alabama State Univ	-0.29200	66
Univ of the District of Columbia	0.34058	15	Bennett College	-0.29323	67
Southern Univ/Baton Rouge	0.32664	16	Philander Smith College	-0.29843	68
Meharry Medical College	0.32494	17	Bethune Cookman College	-0.31108	69
Alabama A&M Univ	0.31644	18	Virginia Union Univ	-0.31991	70
Albany State Univ	0.24796	19	Cheyney Univ of Pennsylvania	-0.32200	71
North Carolina A&T State Univ	0.23955	20	Saint Paul's College	-0.32395	72
Langston Univ	0.20631	21	Livingstone College	-0.32579	73
Virginia State Univ	0.20467	22	Huston-Tillotson College	-0.33162	74
Winston-Salem State Univ	0.12853	23	Lane College	-0.34169	75
Morehouse School of Medicine	0.11230	24	Paul Quinn College	-0.34178	76
Norfolk State Univ	0.09524	25	Edward Waters College	-0.34440	77
Bowie State Univ	0.09516	26	Miles College	-0.35225	78
Fisk Univ	0.08476	27	Paine College	-0.36910	79
Grambling State Univ	0.05280	28	Wiley College	-0.37363	80
Xavier Univ of Louisiana	0.04791	29	Jarvis Christian College	-0.38425	81
Univ of Maryland Eastern Shore	0.03230	30	Texas College	-0.41197	82
Hampton Univ	0.00209	31	Knoxville College	-0.41455	83
Johnson C Smith Univ	-0.04912	32	Allen Univ	-0.42210	84
Morehouse College	-0.07409	33	Arkansas Baptist College	-0.45258	85
Coppin State College	-0.09515	34	Selma Univ	-0.47650	86
Morgan State Univ	-0.10840	35	Harris-Stowe State College	-0.48647	87
Shaw Univ	-0.11173	36	Lewis College of Business	-0.48648	88
Elizabeth City State Univ	-0.11561	37	Trenholm State Technical College	-0.48772	89
North Carolina Central Univ	-0.11916	38	Bishop State Community College	-0.49111	90
Fort Valley State Univ	-0.12009	39	Clinton Junior College	-0.49111	90
Univ of Arkansas at Pine Bluff	-0.12938	40	Coahoma Community College	-0.49111	90
Tougaloo College	-0.13084	41	Concordia College	-0.49111	90
Alcorn State Univ	-0.13566	42	Denmark Technical College	-0.49111	90
Lincoln Univ (Lincoln Univ, PA)	-0.14068	43	Hinds Community College	-0.49111	90
Delaware State Univ	-0.16938	44	Interdenominational Theological C	-0.49111	90
Kentucky State Univ	-0.17943	45	J F Drake State Technical College	-0.49111	90
Talladega College	-0.18564	46	Lawson State Community College	-0.49111	90
West Virginia State College	-0.20434	47	Mary Holmes College	-0.49111	90
Rust College	-0.21505	48	Saint Philip's College	-0.49111	90
Fayetteville State Univ	-0.21776	49	Shelton State Community College	-0.49111	90
Bluefield State College	-0.21863	50	Shorter College	-0.49111	90
Voorhees College	-0.22306	51	Southwestern Christian College	-0.49111	90
Benedict College	-0.22903	52			

*The lowest rank is 90 because the bottom 14 HBCUs have identical scores.

6.2 Results of the S&T Index

Jackson State University, a public Doctoral-Intensive university with a large student population (6,360) in Mississippi had the highest average science and technology z-score rating of all the HBCUs. Its average z-score (5.15) is more than 3 standard deviations from the norm and more than twice the second highest-ranking HBCU. Therefore, it is considered an outlier. It had the highest score in four of the six categories – Federal R&D expenditures, Industry R&D expenditures, Institutional R&D expenditures and Publications. That Jackson State University achieved this despite its large size is notable. Larger organizations encounter more of a challenge achieving productivity since the law of diminishing returns often starts to take effect. Increasing the number of faculty or some other independent measure given the same level of governmental, industry or societal resources usually means the output (number of grants, publications, graduates and so forth) drops. This result can be mitigated if growth occurs in other areas as well.

It is interesting to view the results of the universities that have the highest production versus the universities that have the highest productivity (see Table 6.2). The big three in terms of overall output are Howard University, Clark Atlanta, and Florida Agricultural and Mechanical University (FAMU). Each is within the top five in output for five of the six variables. In productivity, five different universities stand out. Jackson State University is within the top 5 in five of the six variables, Lincoln University (Missouri) in four of the variables, and Tennessee State, Spelman and Texas Southern are within the top five in three of the variables. Further research would be necessary to

understand what combination of variables permits Jackson State University to overcome the productivity challenges inherent in its size.

The difference between HBCUs with the highest production versus the highest productivity is not unusual because diminishing returns start to take effect. However, effectiveness ratings (high productivity) often point to up and coming (or solidly performing) “stars.” In corporations, it is usually a sign of good management; in universities, it may indicate the same. Thus, those universities that have high productivity today may be the ones that will have the highest production a number of years from now.

Table 6.2 TOP 5 HBCUS IN INDIVIDUAL COMPONENTS OF S&T INDEX 1985-2002*

PRODUCTION

Federal $		State&Local		Industry		Institutional		Publications		Graduates	
Howard	$293,045	FAMU	$ 36,588	Howard	$ 24,608	Howard	$ 26,855	Howard	582	Howard	8065
FAMU	$266,585	U of Virgin Isl	$ 13,268	Morehouse Med	$ 6,289	Clark Atlanta	$ 25,191	Jackson St	245	FAMU	5258
Clark Atlanta	$200,990	Clark Atlanta	$ 10,847	Clark Atlanta	$ 6,043	Southern A&M	$ 21,466	FAMU	234	Southern A&M	5135
N.C. A&T	$153,889	U of D.C.	$ 9,348	FAMU	$ 5,853	Alabama A&M	$ 20,762	Hampton	167	N.C. A&T	4208
Meharry Medical	$133,727	Priaire View	$ 7,848	Jackson St	$ 4,354	Albany St	$ 17,844	Clark Atlanta	160	Grambling	4068

PRODUCTIVITY (PER FULL-TIME FACULTY)

Federal $		State&Local		Industry		Institutional		Publications		Graduates	
Jackson St	$ 5,030	Prairie View	$ 183	Jackson St.	$ 242	Jackson St.	$ 319	Jackson St.	13.6	Southern/N.O.	48.46
Lincoln (MO)	$ 4,934	U of Virgin Isl	$ 110	Howard	$ 65	Lincoln (MO)	$ 284	Tuskegee	3.45	Bowie State	19.98
Tuskegee	$ 4,000	Texas Southern	$ 105	Spelman	$ 53	Tennessee St	$ 269	Lincoln (MO)	2.71	Grambling	17.92
Tennessee St	$ 2,372	Jackson St	$ 79	Lincoln (MO)	$ 48	Spelman	$ 202	Spelman	2.1	Texas Southern	17.52
Meharry Med	$ 2,157	U of D.C.	$ 72	Texas Southern	$ 46	U of Virgin Isl	$ 145	Tennessee St	2.05	Alabama A&M	16.56

* Years vary according to the variable.

6.3 Results and Findings

What are the characteristics of universities that display higher levels of science and technology development? According to expectations E1, E2 and E3, four-year private HBCUs should perform better (receive an average higher rating) on the science and technology index than all other universities. The three associated expectations are restated here:

E1: Four year private HBCUs will average a higher rating on science and technology productivity indicators than four-year public HBCUs.

E2: Four year private HBCUs will average a higher rating on science and technology productivity indicators than four-year land-grant HBCUs.

E3: Four year private HBCUs will average a higher rating on science and technology productivity indicators than 2-year HBCU associate colleges.

6.4 Results

The results of the index indicate that four-year private universities do not perform better than four-year public or four-year land-grant universities (see Table 6.3). Private HBCUs have the lowest rank of the four-year colleges and universities and only perform better than the two-year institutions, thus, providing support only for the third expectation, E3. Following are the averages for each category.

Table 6.3 HBCU Z-score by University Control and Year

Category	Mean Z score
Landgrant 4-year	0.50859
Public 4-year	0.27106
Private 4-year	-0.16015
Private 2-year	-0.48299
Public 2-year	-0.49043

It is noteworthy that not only is there no support for E1 and E2, but the mean z-score of private HBCUs is below the average. The results are somewhat surprising given that the performance of their peer group, majority four-year private universities, exceeds that of majority four-year public universities. At the Doctoral level, private universities have only a slight edge but at the Master's level, the discrepancy between privates and public is larger with privates usually displaying higher ranking or scores (Graham & Diamond, 1997).

There could be several reasons that explain why private HBCUs do not have productivity levels comparable to public and land-grant HBCUs in science and technology indicators. The average student population size at the four-year private HBCU is considerably smaller than the average size at the four-year public and land-grant HBCUs (see Figure 6.1). A look at Figure 6.2 shows that private HBCUs are skewed toward smaller size colleges and universities. Just as great size can adversely affect productivity, threshold effects (very small sizes) can challenge productivity in small colleges. Smaller institutions often have difficulty obtaining adequate resources such as facilities, equipment, and high quality faculty (Roach, 1998). Many private HBCUs, therefore, face quality and threshold issues. In addition, private HBCUs face greater funding challenges having less operating support than their public counterparts (Jones & Weathersby, 1978). Over a period of years, federal support in funding has favored public HBCUs. Resources that could have gone into maintaining quality infrastructure and faculty at private universities have been diverted to maintaining operating funds. A steady flow of government funds has enabled public universities to

avoid the issue of basic survival. A third explanation could be the inability of most private HBCUs to accumulate a sizeable endowment, which has made them more vulnerable to funding changes. Other reasons could include factors intrinsic to lower-performing private HBCUs (i.e., failure to stay current with the changes in higher education, inability to keep costs down, and so forth).

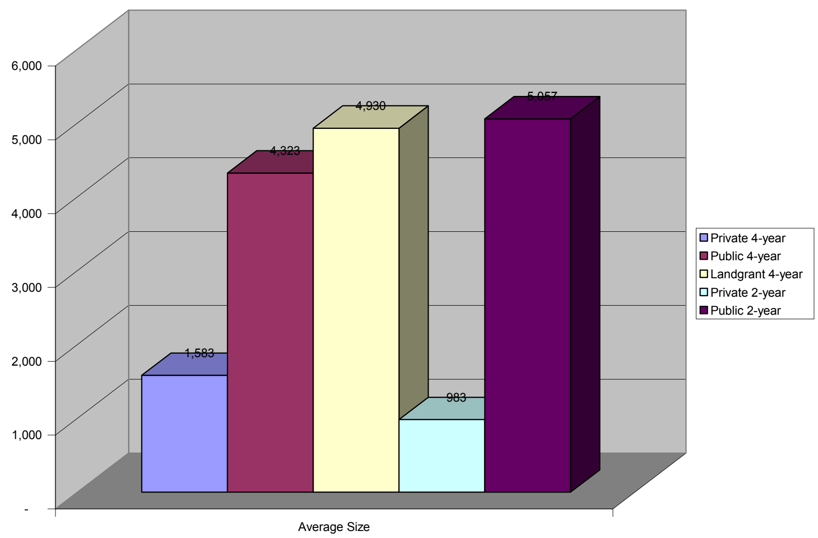

Figure 6.1 HBCU Average Size by Control: 2002

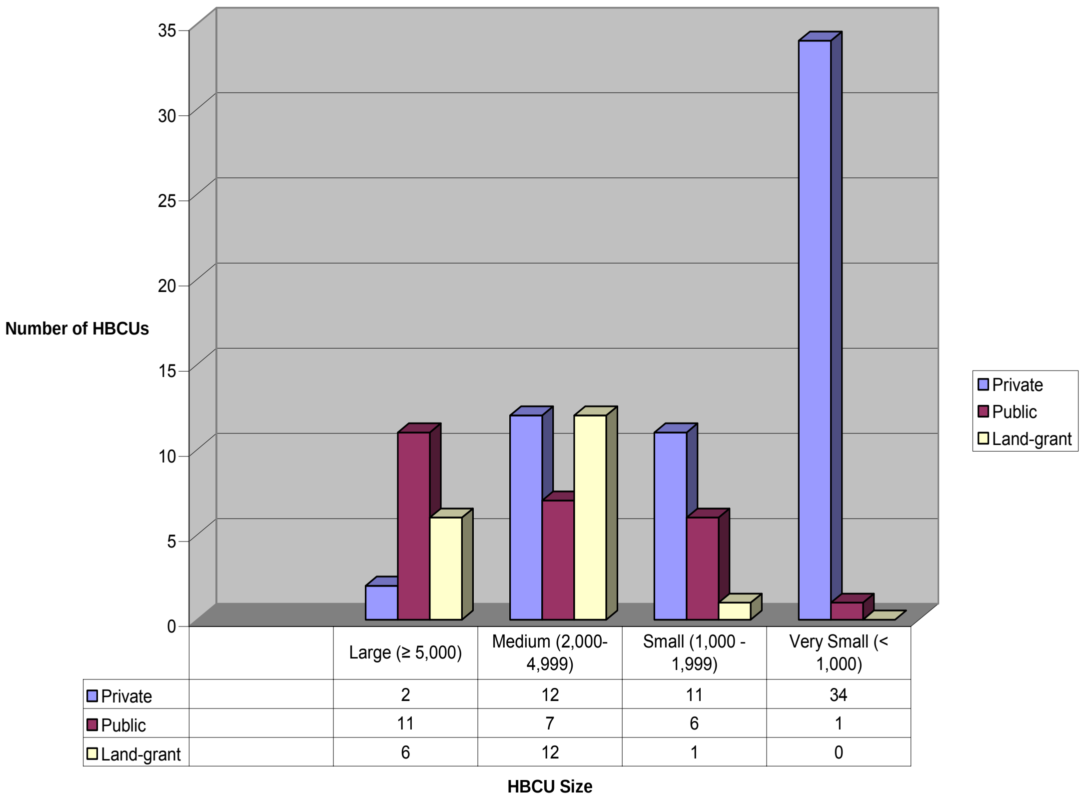

Figure 6.2 NUMBER OF HBCUS BY SIZE AND CONTROL - 2002

Why do land-grants achieve a higher average science and technology index rating than public universities? Land-grant universities are public universities with one major difference. They are imbued by an act of Congress with a special mission – to teach agriculture, military tactics, and mechanical arts so that each state can be assured of at least one educational institution that provides practical training via training and service extensions. Congress provides funding in support of this mission via a federal formula. Due to their mission, land-grant universities are more applied in their educational endeavors than public universities. They provide services through field extension offices and continuing education classes. Therefore, they do not conduct as much basic research.

Their lower levels of research should disadvantage land-grant universities on the science and technology index. Instead, land-grant universities are the highest performing

HBCUs. Stable, predictable and significant funding appear to be the most prominent explanation. The struggle of HBCUs to survive has been heavily reliant on funding. As explained in Chapter 3-Literature Review, funding has been an important factor in the growth of universities, particularly in their ability to conduct research, hire faculty, and improve their infrastructure. Thus, the additional funding received by land-grant HBCUs as part of the federal government formula funding may be the edge that enables land-grant universities to achieve more in science and technology indicators than public universities. It could also be that government requirements have forced land-grant HBCUs to be more accountable operationally in response to grants or contracts earned. Another hypothesis is that applied universities are more in synchrony with related industry interested in research that has an application (as per the Mode 2, entrepreneurial university explanation in Chapter 3). At this point, it is not clear why land-grant universities on the average have a higher productivity level in science and technology indicators. The answer to that question lies in further research.

The next expectation, E4, is restated as follows:

E4: Research HBCUs categorized as Doctoral Extensive and Intensive and Master's I and II according to the Carnegie classification will average a higher rating on science and technology productivity indicators than all other HBCUs (except HBCU medical schools).

A research university is "a university whose primary mission emphasizes 1) the conduct of research, and 2) the training of graduate students in how to conduct research" (Rogers et al., 2000, 49). Based on the definition used by the Carnegie Foundation typology of universities, Doctoral (at least 10 doctoral degrees across 3 or more

disciplines) and Master's universities (at least 20 or more Master's degrees) are defined as institutions that are committed to graduate education through the Master's degree (Carnegie Foundation for the Advancement of Teaching, 2001). Thus, this study considers institutions that have been classified as Doctoral Level-Extensive, Doctoral Level-Intensive, Master's I and Master's II as Research universities. It is expected that research output will be higher at institutions with such a mission.

The findings support the fourth expectation, E4 (see Table 6.4). Research universities average a substantially higher rating on the science and technology index than all other HBCUs. Master's and doctoral degrees require a research component as part of the criteria for completing the program. Thus, it is expected that research universities, defined as graduating research-oriented students, will conduct more research, apply for more research and development funds, and publish more papers. As variables that constitute the index, research universities should average higher index scores.

Table 6.4 HBCU Z-ratings by Carnegie Classification

Category	Mean Z score
Research HBCUs	0.50486
Baccalaureate HBCUs	-0.20189
Associate & Other HBCUs	-0.41171

6.5 Selection of Three HBCUs

While a science and technology index score was constructed for all 103 HBCUs, the focus of this dissertation is on HBCUs that aspire to develop their research, science

and technology capability. These universities are categorized as research universities. Within the 103 HBCUs, there are 35 research universities.[21]

The 35 research HBCUs were put into rank order based on their average z-scores for science and technology development. A rank score was assigned from 1 (highest score) to 35 (see Table 6.8). The universities were then partitioned into three equal groups. The top third percentile was classified as high science and technology productivity HBCUs, the second percentile as middle productivity, and the third percentile as lower productivity HBCUs.

In order to fulfill the requirements for a purposive representative sample scheme, one university was selected from each group. Using this method enables the sample to represent the distribution of characteristics in the population from which it came. The selection of one particular HBCU from within each of the groups was based on the desire to retain variation in the characteristics, to have access and availability to the faculty and administration, and to stay within the researcher's financial resources.

In selecting the three universities, an attempt was made to include a cross section of characteristics such as location, Carnegie classification, size and control. FAMU was selected from the High Productivity group, Hampton from the Middle Productivity and FVSU from the Lower Productivity group. These universities were studied further using qualitative methods. Selecting more than one case study and choosing congruent universities while including variation in the sample, strengthens the rigorousness of the case, methods, and results (Lee, 1989).

[21] Research universities do not include medical or professional schools.

Table 6.5 RESEARCH HBCUS SCIENCE AND TECHNOLOGY INDEX 1986-2000

Institution	Z score	Rank	Groupings	Carnegie Classification
Jackson State Univ	5.15	1	Highest	Doctoral-Intensive
Lincoln Univ (Jefferson City, MO)	2.23	2	Highest	Master's II
Prairie View A&M Univ	2.02	3	Highest	Master's I
Tennessee State Univ	1.49	4	Highest	Doctoral-Intensive
Tuskegee Univ	1.37	5	Highest	Master's I
Texas Southern Univ	1.19	7	Highest	Doctoral-Intensive
South Carolina State Univ	0.92	8	Highest	Doctoral-Intensive
Southern Univ/New Orleans	0.82	9	Highest	Master's II
Univ of the Virgin Islands	0.80	10	Highest	Master's II
Howard Univ	0.69	11	Highest	Doctoral-Extensive
Florida A&M Univ	0.45	13	Highest	Master's I
Clark Atlanta Univ	0.44	14	Highest	Doctoral-Intensive
Univ of the District of Columbia	0.34	15	Middle	Master's I
Southern Univ A&M College/B.Rouge	0.33	16	Middle	Master's I
Alabama A&M Univ	0.32	18	Middle	Doctoral-Intensive
Albany State Univ	0.25	19	Middle	Master's I
North Carolina A&T State Univ	0.24	20	Middle	Master's I
Virginia State Univ	0.20	22	Middle	Master's I
Norfolk State Univ	0.10	25	Middle	Master's I
Bowie State Univ	0.10	26	Middle	Master's I
Grambling State Univ	0.05	28	Middle	Master's I
Xavier Univ of Louisiana	0.05	29	Middle	Master's I
Univ of Maryland Eastern Shore	0.03	30	Middle	Master's I
Hampton Univ	0.00	31	Middle	Master's I
Coppin State College	-0.10	34	Lowest	Master's I
Morgan State Univ	-0.11	35	Lowest	Master's I
North Carolina Central Univ	-0.12	38	Lowest	Master's I
Fort Valley State Univ	-0.12	39	Lowest	Master's I
Alcorn State Univ	-0.14	42	Lowest	Master's I
Lincoln Univ (Lincoln Univ, PA)	-0.14	43	Lowest	Master's II
Delaware State Univ	-0.17	44	Lowest	Master's I
Kentucky State Univ	-0.18	45	Lowest	Master's II
Fayetteville State Univ	-0.22	49	Lowest	Master's I
Alabama State Univ	-0.29	66	Lowest	Master's I
Cheyney Univ of Pennsylvania	-0.32	71	Lowest	Master's I

6.6 Summary

In summary, the findings from the science and technology index produced Jackson State University in Mississippi as the HBCU with the highest science and technology productivity rating. As a large, Doctoral-Intensive university, Jackson State University continues to have high growth in several areas. Jackson State University has both high production as well as high productivity. The university is a model for developing and maintaining science and technology capability.

The findings do not support expectations 1 or 2 which state that private 4-year HBCUs will outperform public and land-grant HBCUs. This stands in contrast to TWIs where private universities have a slight edge. Federal, state and local funding received by public universities could be an explanation as to why private HBCUs do not perform at the same level as public HBCUs. Private, four-year HBCUs receive a higher average science and technology rating than 2-year private and 2-year public HBCUs thus supporting the third expectation, E3. The latter are not eligible for certain funding which could be one explanation for their lower ratings.

Based upon these findings, three research-oriented HBCUs were selected from each category of high, medium and lower level of science and technology rankings. These universities were chosen to include a cross section of characteristics present in the population. Results from in-depth research conducted at these universities will be used to determine what strategies HBCUs should adopt to develop their science and technology productivity.

CHAPTER 7
FORT VALLEY STATE UNIVERSITY

7.1 Fort Valley State University (Low productivity)

7.1.1. Characteristics

Fort Valley State University (FVSU) is located in the state of Georgia, the southern region of the United States. It is a public, land-grant, 4-year university. Opening its doors in the late 1800's, Fort Valley State University is now classified as a Master's I Research University. It is a medium-sized university (2,660 students in 2002) serving a population that is 92% Black. On the science and technology index developed in this dissertation study, this university was ranked in the bottom third percentile of the 35 research universities. It is relatively recent (1996) that FVSU received its Master's I designation in the Carnegie classification typology and its designation as a Level IV university by the Southern Association of Colleges and Schools (SACS) (1995). FVSU's science and technology program can be categorized as "emerging."

7.1.2 History

Fort Valley State has come a long way from its industrial origins as a junior college. Originally named Fort Valley High and Industrial School in 1895, it emerged out of a joint venture between several small towns that attempted to establish a school system in rural Georgia but failed because of farming demands. In 1901, the Board of Trustees, overseen by the Episcopal Church, hired the second president, Henry Hunt, under whose leadership the university would become an accredited 4-year college. Hunt inherited a run-down, disorganized school of 145 students running on a budget of $840 a year (Neyland, 1990; Range, 1951). The grounds were described as "water standing

around the house…the old laundry shack right alongside the principal's home…and so forth" (Range, 1951). By the mid-1920s, the grounds and buildings of the university grew in value to nearly half a million dollars while the $840 budget rose to $80,000 per year.

The school philosophy was the Hampton-Tuskegee ideal – industrial education as opposed to a classic liberal arts education. But progress led to change and by 1939 a merger occurred with the State Teachers and Agricultural College of Forsyth to form the 4-year Fort Valley State College (FVSC). In 1945, the Board of Regents authorized FVSC to initiate a 4-year program to train, place and follow-up with all students interested in training in Agriculture.

Fort Valley State was not the original designee of the Negro land-grant institution for the state of Georgia. Clark Atlanta, a more wealthy and stable institution which seemed the automatic choice, was considered too progressive. Georgia State Industrial College for Colored Youths (known today as Savannah State) won the bid to receive the award. (Range, 1951). The Strayer Committee, named by the University of Georgia, recommended the establishment of a four year school of agriculture in Fort Valley. Feeling that FVSC was "in a position to develop a sound program in the field of general agriculture as a basis for the preparation of teachers of Vocational Agriculture," the committee recommended that "FVSC be developed distinctly as the State College for Negroes in the fields of agriculture and home economics." The state agreed and in 1949, the land-grant award status was transferred to FVSC. Through the 1940s and 1950s FVSC continued to train teachers in agriculture. This emphasis was largely due to the

scarcity of employment opportunities except for those in vocational agriculture. It was also consistent with the mission of the college.

The Southern Association of Colleges and Schools admitted FVSC entry in 1957. According to Fort Valley State's website, FVSC achieved university status in 1996. It also achieved Master's I Carnegie classification in the mid-1990's (Fort Valley State University, 2005). So it is relatively recent that FVSU has emerged as a research university.

7.1.3 Structure

FVSU is located in a rural environment, one hour away from Atlanta, Georgia. It currently has two colleges affiliated with science or technology - the College of Arts, Science and Education and the College of Agriculture, Home Economics and Allied Programs. In addition, it has the Cooperative Developmental Energy Program (CDEP), an innovative energy education program that focuses on increasing the number of minorities and women working in the private and government sectors of the energy industry (Fort Valley State University, 2005).

7.1.4 S&T Statistics

One of Fort Valley's strengths (and one of HBCUs' strengths in general) is the graduation of students in science, engineering and technology fields. From 1987-1996, Fort Valley State more than doubled its number of students in science and technology related fields (from 99 to 201). It averaged an increase of 20% per year during those years. Since 1996, the numbers have begun to decline (National Center for Education Statistics, 2001).

The funding picture provides some insight into the college's growth. Fort Valley State received no federal funds for research and development until 1989 according to the National Science Foundation's data on Research and Development Expenditures (National Science Foundation, 2004a)]. Despite being a land-grant university with a mandated mission to do basic and applied research in agriculture by and for the state, Fort Valley State received no state and local funds for research and development until 1996. Around the same time, Fort Valley began to receive a small amount of industry funds for research and development. Thus, it is not until the last fifteen years that Fort Valley obtained research funding.

The university receives the bulk of its federal funding from the U.S. Department of Agriculture (USDA). Of the $6,019,000 Fort Valley received in federal funds for science and engineering in 2002, $5,227,000 (86%) came from the USDA. Most if not all of this went to the College of Agriculture, Home Economics and Allied Programs (National Science Foundation, 2000b).

No data could be gathered on publications indicating either no research has been published or they could not be found.[22]

7.1.5 Unique Achievements

The CDEP program at Fort Valley claims to be the only "program of its kind" in that it is an industry-university-government partnership providing students with internships leading to careers in the field of science, energy and ecology. The program solicits talented individuals and provides them with internships at selected energy companies. CDEP prepares students for technology-oriented employment and facilitates

[22] The VantagePoint bibliometric software using the database Web of Science by ISI Web of Knowledge uncovered no articles from Fort Valley State University despite using several variations of the name (i.e., Fort Valley, FVSU, Fort Valley State University).

this through its dual degree program (one degree from FVSU and one from the other institution). Dual degree programs have been established with the Georgia Institute of Technology, the University of Nevada, the University of Oklahoma and the University of Texas-Austin. The federal government assists this effort through matching funds for the student interns.

FVSU also distinguishes itself in other ways. The Biology program produces a higher number of minority students enrolling in medical or dental schools than any other state university in Georgia.[23] The Georgia Goat Research and Extension Center is the largest facility of its kind east of the Mississippi.

7.1.6 Analysis

Fort Valley State presents a picture of a university that has evolved considerably from its educational roots of applied industrial education. Sixty years ago (1945) Fort Valley State University became a 4-year institution. Less than ten years ago (in 1996) it achieved university and Master's I Institution (Carnegie Classification) status. Fort Valley's strategic plan commits to a research agenda. Its mission statement includes "research and public and extension services…a commitment to a basic and applied research program and a full range of degree programs in the food and agricultural sciences…consistent with its land-grant….tradition." Its strategic initiatives include fostering collaborations, developing international links, and accelerating the full development of its basic and applied research program. Consistent with that plan, it has increased its level of federal, state and local funding as well as its production of graduates in science and engineering fields from 1987 to 2001.

[23] This fact is stated on their website. It could not be verified otherwise.

But there are some areas of weakness as well. Its funding base is not diversified. As a land-grant institution, the university receives the bulk of its research (86%) and development funds from the U.S. Department of Agriculture. This compares to an average of 12.4% in funding received from the U.S. Department of Agriculture by the total population of land-grants (National Science Foundation, 2000a).[24] The USDA funds benefit predominantly one college at FVSU – the College of Agriculture. This could mean that other departments receive insufficient attention from university administration. Alternatively, other departments may not display sufficient initiative to obtain grants from other sources. In addition, the increase of funding since 1987 is not accompanied by evidence of research. The inability to obtain publication data does not indicate there is no research, but it does indicate that if research is being done, the results are not as readily available as they should be.

Overall, Fort Valley State University continues to make progress as can be seen by its recent elevation to Level IV status by the Southern Association of Colleges and Schools (SACS) in 1995. The strategic initiative represents a plan that commits the university towards a goal of research, scholarship and collaboration. The next few years will indicate whether the implementation process matches the written commitment. FVSU's president from 2001-2005 (the time period during which the strategic initiatives were developed), Dr. Kofi Lomotey, is no longer with the university. It remains to be seen whether his departure will disrupt implementation plans. His departure is also an

[24] A list of 75 land-grant universities was extrapolated from Table B-17 from the NSF Survey of Federal obligations for science and engineering research and development (R&D) to universities and colleges, by State, institution, and agency: fiscal year 2000. A calculation was made of the average percent received by all land-grant universities (including HBCUs) from each agency.

interesting litmus test for the importance of leadership in science and technology productivity.

7.2 Interviews

The material that follows presents summaries of interviews conducted at FVSU. Each summary begins with a description of the current status of the program. Following that is data obtained in response to the first data analysis tool – chronology of events. Each interviewee was asked to explain the origins of a typical program. In the concluding paragraph, the response is analyzed for pattern matching – evidence matching the predictions for linkages and rival theories (predictions can be found in the case study protocol – Appendix E).

Based upon chronology of events, two questions emerged regarding development of science and technology programs. The first question was, "Did this theory lead to initiation of the program?" The second question was, "Did this theory cause the program to expand?" For a theory to be credited, it must be critical to initiation or expansion of the program (depending on the question that is being asked) and must meet the requirements of the prediction.

The chapter concludes with the findings - a table summarizing the interviews and coding for each question. Each theory is coded affirmatively if there is a match between the prediction of the theory and the evidence presented in the interview. More than one theory may be supported by the evidence.

7.2.1 A Science program

FVSU-1 is Chair of a science department at FVSU. Currently, the department joint ventures on summer programs (medical, dental, pharmaceutical and chiropractic)

with several nearby universities that provide graduate education. The programs often act as entryways to those universities for FVSU students interested in pursuing further education in those fields. The programs benefit FVSU and the graduate institutions. FVSU is able to advertise graduate opportunities to potential applicants and the graduate institutions have a minority pool of talent from which to draw that are already interested in their fields. FVSU-1 has been at the University since 1963 and has headed this program since its inception.

When asked how the program began, FVSU-1 recounted that in 1965, laws came into effect that mandated integration. Until that point, the surrounding colleges and universities had refused to admit Black students despite applications from FVSU. In 1965, in order to comply with integration laws, the Medical College of Georgia accepted its first Black student from FVSU. No relationships existed when the Medical College reached out to FVSU. The University of Georgia School of Pharmacy initiated a similar program. Over time, the graduate institutions saw the advantages of having an additional pool of qualified students. They now eagerly support the program. Summer programs were set up with nearby institutions (within and eventually outside the state of Georgia) so students could be exposed to work in the field. In addition, the graduate schools offer additional course preparation if needed.

Based on the integration policy, the information obtained by the chronology of events analysis indicated **Policy** was the strategy that initiated this program. FVSU was aware of the policy. It worked with surrounding institutions within the year to enact programs that would facilitate the policy and expand science and technology

development. Based on the institutions that reached out to FVSU for student applications and summer programs, the theory of **Proximity** was also found to be a critical factor.

The summer programs have not changed in a significant manner since their inception. Growth has been in the form of more institutions and more students participating. Thus, **Proximity** and **Demand** were strategies that expanded the program.

7.2.2 CDEP (Cooperative Developmental Energy Program)

FVSU-2 is the Director of the CDEP program. The CDEP program is a thriving program for students interested in energy careers. It is a collaborative effort between FVSU, energy-oriented corporations, the federal Department of Energy, and various other universities. Dual degree programs exist in engineering with Georgia Institute of Technology, in engineering and health physics with University of Nevada-Las Vegas, and in geo-sciences and petroleum engineering with the University of Oklahoma.

How did the program begin? FVSU-2 had conducted a previous project with the U.S. Department of Energy (DOE) prior to employment at FVSU. In November 1982, the Office of Minority Impact at DOE contacted him regarding a Request for Proposal (RFP) for initiatives that would increase the number of minorities in energy. A less important goal within the RFP was to expose students to careers in energy. FVSU-2 recognized early on that focusing on minority businesses would create a temporary program. The real money in the industry was in heavy equipment. Minority energy-related businesses were too small – they could do only 2-3% of energy company operations. FVSU-2 decided to infiltrate the industry with students. Three other universities were awarded the grant in 1983; by 1986 only FVSU had a viable program still in operation. In the response to the RFP, FVSU-2 asked DOE for 50% of minimum

wage for each student in the internship program; corporations would pay the rest. He selected only science students. He referred to them as his “Special Forces” – military terminology for the highly trained special forces units that penetrate the target area (corporations) and prepare it for subsequent troops. Cold calls were made to all the utilities and energy-related companies in the area. Georgia Power, Atlanta Gas & Light, Oglethorpe Power, MEAG and Flint responded. FVSU-2’s effort was assisted by a key figure at Georgia Power who promoted the program and influenced the other energy companies to support the program. Employees from each company, usually a minority, would make presentations to the students and encourage them to consider careers in the field. The program was a success. FVSU-2 could have stopped there but he was interested in expanding the program.

The next phase was to expand beyond the state of Georgia and get other energy companies to hire FVSU students. Additional cold calls were made to energy companies. Contacts were made at the Hoover Dam, Portland (Oregon), San Francisco, and the Nevada Test Site. The need for personnel skilled in these areas led national companies to support summer internships. FVSU did not have the faculty, infrastructure or skills to offer training in these areas. FVSU-2 recognized that relationships had to be formed with other universities so students could receive the needed training. Plant Vogel in Georgia, an internship site for FVSU students, needed plant physicists. Georgia Institute of Technology eventually agreed to a dual-degree engineering program.

The Department of Energy in Las Vegas contacted FVSU-2. FVSU students were interning at the Nevada Test Site. DOE in Las Vegas and FVSU reached an agreement to fund an initial program at the University of Las Vegas-Nevada provided FVSU recruit

students from Las Vegas. A dual-degree program in engineering began that later expanded to include Health Physics. A third dual-degree program was initiated based on a friendship that started from a cold call. Mr. Hofstedler, President of Cities Service Oil and Gas, had accepted several students from the CDEP program. At the time, there was no geo-science program that existed to measure seismic movements. He proposed a dual-degree program. An alumni of the University of Oklahoma and a geo-scientist, he facilitated discussions between University of Oklahoma and FVSU. The dual degree program in geo-sciences and later, petroleum engineering, was initiated.

As noted earlier, three of the programs that received funding at the same time as the CDEP program were no longer in existence after three years. Three strategies combined to make FVSU successful. The RFP, a **Policy** from the Department of Energy led to the creation and support of the program. The initiative and **Leadership** of FVSU-2 brought on other companies that supported the program. And, the **Demand** for students who could become qualified personnel was necessary for initial support of the program.

Linkages did not exist initially but the cold calls resulted in friendships and relationships. As a result of the urging, participation and facilitation of one of these friends, a dual-degree program emerged in a different state. The N**etwork** of companies built by FVSU-2's initiative produced benefits that were not the result of direct efforts by FVSU. This was also one of the few instances where **Policy** remained important. The DOE in Las Vegas contacted FVSU to increase the number of minorities in energy. **Leadership** and initiative by FVSU-2 continued to be critical to the growth of the program as did demand for skilled personnel in energy. The CDEP program is the only instance at FVSU where **Linkages** operated on the level of Networks/Clusters. There

were a number of relationships that existed, various types of participants (government, corporations and other universities), and actions being taken on behalf of the university by members in the Network. The actions resulted in formal agreements that are characteristic of Networks.

7.2.3 Middle Georgia Regional Council

In 1995, FVSU was asked by Governor Zel Miller to act as fiscal agent for the Middle Georgia P16 Regional Council. The goal of the Commission is to improve educational standards and opportunities in that area. The Commission does not concentrate solely on science and technology; however, it is a part of their overall educational focus. FVSU-3 was the Director of the initiative. FVSU-3 spoke about the goal to reach out to K-12 regarding educational quality and science programs but no specific projects for science and technology were in effect. FVSU-3 described the Council as sustaining itself but not growing. This program supported the theory of **Policy** as it would not have been created without a request by Governor Zel Miller. The program has not expanded beyond its original creation.

7.2.4 Bio-Technology Program

FVSU-4, a member of the faculty, has been at FVSU for the shortest period of the FVSU interviewees – seven years. Of foreign born descent, FVSU-4 came to the university with a research interest in agricultural biotechnology. He currently has two grants totaling $600,000 from the USDA to expose students to agricultural biotechnology. FVSU-4 is responsible for FVSU's first grant from the National Science Foundation (NSF). The grant, $2.5 million, was awarded from the NSF bio-technology program to strengthen undergraduate preparation in SMET (science, math, engineering

and technology). FVSU is the only HBCU and the only land-grant institution to be funded under this grant.

When asked about the origins of the program, FVSU-4 stated that when he came to the university there was no program in bio-technology at all. However, that was his research interest. He searched on the NSF website for potential funding opportunities. He found an RFP and made a cold call to NSF to ask for information. NSF made a site visit and provided technical assistance. He is now pursuing a second grant from NSF. The first grant from NSF has produced a collaborative effort between 20 universities that provides internships for FVSU and other universities' students. Several activities are coalescing around FVSU-4's efforts. Another researcher, who has similar academic interests, recently received a patent for producing a transgenic strawberry. FVSU-4 has plans to start a bio-technology major at FVSU within a couple of years.

There appears to be only one strategy critical to the initiation of a bio-technology initiative at FVSU that also meets the requirements of the prediction **– Leadership**. FVSU-4 appears dedicated to his research interests and the students at FVSU. Without his efforts, no program would exist. He used previous contacts (at his graduate institution and his post-doctoral organization) to establish collaborations for the internships but they are not responsible for initiating or expanding the program. FVSU-4's efforts created the program and they sustain the program. Further follow-up is required to determine whether continued growth can be attributed to other factors or strategies.

7.2.5 Administrator

FVSU-5 is a member of the Administration. He cited the efforts of the new President, Dr. Kofi Lomotey, as significant in the support for a research agenda at FVSU.

As an example, he cited the new Science Building built in 2001. Dr. Lomotey (who was President at the time of the interviews) had not been at the university long enough to be responsible for creating new science and technology endeavors; however, he is credited by FVSU-5 with sustaining on-going efforts. No coding was given.

7.3 Summary

Table 7.1 Strategy Responses from HBCU Interviews

"Did Strategy Initiate the Program"

	Did Networks/Clusters lead to initial S&T development	Did Policy lead to initial S&T development?	Did Univ Leadership lead to initial S&T development?	Did proximity lead to initial S&T development?	Did Demand lead to initial S&T development?
Respondents	**Linkages**	**Policy**	**Leadership**	**Proximity**	**Demand**
FVSU-1	0	1	0	1	1
FVSU-2	0	1	1	0	1
FVSU-3	0	1	0	0	0
FVSU-4	0	0	1	0	0
FVSU-5	0	0	0	0	0

Science and technology programs at FVSU are at a beginning or emerging phase of development. Policy at the federal level was responsible for several of the programs with Leadership being a significant element that facilitated policy (see Table 8.1). Most of the programs are geared toward student development rather than research agendas. Demand for qualified students in the hope of filling future personnel needs is important in science and technology program development at FVSU.

Table 7.2 Strategy Responses from HBCU Interviews

"Did Strategy Expand the Program"

	Did Networks / Clusters expand the program?	Did Policy expand the program?	Did univ leadership expand the program?	Did proximity expand the program?	Did Demand for S&T grads expand the program?
Respondent	**Linkages**	**Policy**	**Leadership**	**Proximity**	**Demand**
FVSU-1	0	0	0	1	1
FVSU-2	1	1	1	0	1
FVSU-3	0	0	0	0	0
FVSU-4	0	0	1	0	0
FVSU-5	0	0	1	0	0

The above table summarizes the interviews in response to the second question of "what strategies expanded the program." Linkages at the Network/Cluster level are present in only one instance and that is the result of years of continued and sustained leadership and communication with corporations and government interested in talented and qualified students. Contributions by the Network are significant. The creation of a dual-degree program and training in specialized areas represent a higher level of development than summer programs or exposing students to science fields. The dual-degree programs are significant offerings that contributed to FVSU being ranked as a Master's I institution. Policy dropped out as a sustaining factor once the program was initiated. Demand remained important. It contributed to the expansion of two of FVSU's programs.

CHAPTER 8
HAMPTON UNIVERSITY

8.1 Hampton University (Mid-level productivity)

8.1.1 Introduction and Characteristics

Hampton University, commonly referred to as Hampton, is located in the state of Virginia, in the Mid-Atlantic region of the United States. It is a private, 4-year, Master's I research university. Hampton is considered large with over 5,000 students and a 96% Black population. It was ranked in the middle third on the science and technology index. As a private university, it is not subject to the same reporting requirements as public universities. Hence, documents like the strategic plan and funding from industry and other sources are not publicly available. Hampton exhibits a sophisticated and mature level of linkages operating on the Networking and Clustering level.

8.1.2 History

Brigadier General Samuel Chapman Armstrong founded the Hampton Normal and Agricultural Institute in 1868 with a mission to train common school teachers to lead and teach newly-freed Negroes. His philosophy became known as the "Hampton Idea" – the education of Negroes to do the honest work of menial labor without aspiring to a liberal arts/classical education. The philosophy of industrial education was to have enormous influence on almost all public Negro colleges, as funding typically depended on its adoption (Anderson, 1988; Drewry & Doermann, 2001).

Hampton and its philosophical peer, Tuskegee, exemplified the white southern and northern industrialist philosophical beliefs. This caused them to be the recipients of the lion's share of the philanthropic funding for Negro colleges making them the two

most well endowed and well-known Negro colleges of that time. In 1891 Hampton was designated the Negro land-grant college by the state of Virginia. By 1916, only 2 Negro colleges had substantial endowments - Hampton ($2,700,000) and Tuskegee ($1,900,000). In the 1920s, Hampton and Tuskegee accounted for 75% of endowment funds held by HBCUs (Anderson, 1988).

Despite its relative financial security, the weaknesses and failures in Hampton became evident by 1915 when Hampton admitted it could not find one of its own graduates sufficiently qualified to fill a teaching position at the Whittier Elementary Lab School located on Hampton's campus because they were insufficiently trained to provide any further knowledge to the children. The routine labor in unskilled and semi-skilled agricultural and industrial training, the discouraging of college or even high-quality secondary work, and the heavy emphasis on moral development and ideological training made it difficult for the graduates to meet state and local academic requirements for teacher certification. One example of this is that students worked 60 hours per week for the first three years in simple mechanical arts earning .07 cents an hour. As a further example, one prominent graduate testified that he took gymnastics, nothing else, for two or three summers. As a result, in 1920, the land-grant designation was transferred to Virginia State University at Petersburg. Hampton retained its status as a private institution and shifted to emphasizing a liberal arts curriculum and teacher training (Holmes, 1934; Neyland, 1990).

By 1932, Hampton enrolled 889 students and had caught up to its institutional peers. The Black private colleges maintained a reputation for more demanding academic

programs but by the 1950’s they had lost their dominance in enrollment. Public HBCUs had enhanced the quality of their programs while offering lower tuition costs.

Hampton was now in the higher education market without any particular advantage. It had to compete against other black private schools with better academic reputations such as Fisk and Howard. In addition, black public institutions by the 1960s were able to offer better faculty salaries as did private and public white colleges and universities that had more resources (Drewry & Doermann, 2001).

In the 1960s and 1970s Hampton strengthened its financial position placing it first in endowment among Black colleges. By the 1970s, however, the level of financial remuneration had dropped and was not a major attraction in drawing and retaining faculty. Drewry notes one change that occurred in the 1960s and 1970s.

> The stronger private black colleges came to more closely resemble one another and to separate themselves from the more slowly developing private black colleges…They were by and large, urban schools at a moment when the city was becoming a powerful draw for prospective students. Their growth generally outpaced that of other schools. Their endowments tended to be healthier and their facilities remained more intact. Naturally, then, they were best able to give serious consideration to and plan coherently for a future unlike any that private black colleges had faced in their previous hundred years. Thus, they were in a position to strengthen their situation in the years to come (Drewry & Doermann, 2001, 126).

In 1978, Dr. William Harvey was named President of Hampton University, a position he still holds. A businessman with 100% ownership of a Pepsi Cola franchise, Dr. Harvey brought his business and entrepreneurial philosophy and applied them to Hampton. During his 27-year tenure as President, the student enrollment at Hampton University increased from approximately 2,700 students to over 6,000, and the SAT scores of entering freshmen increased approximately 300 points (Hampton University,

2005). Among his many achievements, Dr. Harvey initiated a University-owned commercial development named Hampton Harbor consisting of a shopping center and 246 two-bedroom apartments. Profits from the Hampton Harbor Project are primarily utilized for student scholarships.

8.1.3 Structure

Hampton has 7 schools at the undergraduate level of which the School of Engineering and Technology, the School of Science, and the School of Liberal Arts and Education offer courses related to science and technology. There are three divisions within the School of Science – the Division of Biological, Chemical and Environmental Sciences, the Division of Health Sciences, and the Division of Mathematical and Physical Sciences. Master's degrees programs are offered in Applied Mathematics, Biology, Chemistry, Communicative Sciences and Disorders, Computer Science, Mathematics, Physics and Environmental Science. The doctor of philosophy (Ph. D.) degree is offered in physics. Under the School of Liberal Arts and Education resides the Division of Social and Behavioral Sciences.

Since 1978, President Harvey has been responsible for 64 new academic programs, 17 new buildings and $50 million spent on the renovation of existing facilities (Hampton University, 2005).

8.1.4 S&T Statistics

Hampton has significantly increased its output of publications from 1987-2002 and the number of students graduating in science and technology fields (from 369 students in 1987 to 602 students in 2001, a 63% increase) (Appendix C).

One strength Hampton displays is in the level of funds it receives from the federal government. Federal research and development funding went from $2,168,000 in 1989 to $8,337,000 in 2001 (287% increase) greatly outpacing the 113% growth rate of all U.S. universities (National Science Foundation, 2004b). President Harvey has also increased the university endowment from $20 million in 1987 to $140 million in 2004. However, this strength is offset by the weakness of not raising any state or local funding since its loss of land-grant status in 1920. Likewise, Hampton appears to have little success with receiving research and development funds from industry. Hampton's numbers may be misleading. As a private university, it is not required to divulge as much financial or other information as public universities. With its reputation as a physics center, there may be more partnerships with industry and government than what is known or reported.

8.1.5 Unique Achievements

Hampton has the 4th highest endowment of all HBCUs - $140 million (Cooke, 2002). Hampton's physics department has an international reputation. The Center for the study of the Origin and Structure of Matter (COSM) is one of four Physics Frontier Centers established in 2001 by the National Science Foundation and the only one to be located at a historically black university [Hampton, 2004 #540].

8.1.6 Analysis

As a private institution, Hampton University would not yield any documents such as the Strategic Plan, Mission Statement or Report of External Funding. The university's website did not contain any of these documents. In the absence of such documents,

information was obtained from interviews or gleaned from external sources such as books, magazines, or journals.

From the time it was created in 1868, Hampton has had a long distinguished history as one of the top Negro colleges in the United States. However, its early reputation was based on industrial education even as it eschewed a classic, liberal arts education. Its educational stagnancy and lack of competitiveness forced the university to enhance the quality of its curriculum around 1930.

Hampton was like many HBCUs in size and wealth until the 1970's when Dr. William Harvey took over as President. As a businessman, Dr. Harvey brought an entrepreneurial attitude to the university. He created and implemented a financial and marketing plan. Not only did he forge relationships with government and business, he started profit-making institutions which will enable Hampton to be self-sustaining. His efforts have paid off with Hampton having the fourth largest endowment of all HBCUs (Ebony, 1997).

While Dr. Harvey and Hampton University have been impressive in receiving federal funds and establishing relationships and collaborations with government and business, there are some areas for improvement. Hampton receives no research and development dollars from state and local sources (see Appendix C).[25] According to NSF data, they received no industry dollars until 2001. Given their achievements and prominence in physics (a Ph.D. program in Physics, scientists with international repute, a Physics Frontier Center designation by the National Science Foundation, and so forth), Hampton should receive more research dollars from industry.

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[25] Information obtained from the interview indicates they have applied but state legislators believe public funds should not be directed toward private institutions.

Despite the lack of support from state and local sources, Hampton has built a solid financial foundation, established a science department of international repute, and displayed entrepreneurial creativity in setting a direction for the future that includes a niche in physics and science.

8.2 Interviews

The material that follows presents summaries of interviews conducted at Hampton. Each summary begins with a description of the current status of the program. Following that is data obtained in response to the first data analysis tool – chronology of events. Each interviewee was asked to explain the origins of a typical program. In the concluding paragraph, the response is analyzed for pattern matching – evidence matching the predictions for linkages and rival theories (predictions can be found in the case study protocol – Appendix E).

Based upon chronology of events, two questions emerged regarding development of science and technology programs. The first question was, “Did this theory lead to initiation of the program?” The second question was, “Did this theory cause the program to expand?” For a theory to be credited, it must be critical to initiation or expansion of the program (depending on the question that is being asked) and must meet the requirements of the prediction.

The chapter concludes with the findings - a table summarizing the interviews and coding for each question. Each theory is coded affirmatively if there is a match between the prediction of the theory and the evidence presented in the interview. More than one theory may be supported by the evidence.

8.2.1 The Military Industrial Complex

Hampton-1 is an Administrator whose responsibilities include obtaining money and raising funds for Hampton. He opened his comments by stating,

> Hampton is a private university which means Hampton sees itself as an economic enterprise. Hampton is not supported by public funds, thus, whatever we need we must raise. We get our money through the private sector and research. The strategic plan is designed to increase research – $100 million in 10 years.

Hampton currently receives 80% of its money from government but Hampton-1 believes that government is getting out of sponsored research. He went on to say that Hampton does not label itself as a "Black" university; its goals are to compete against the top universities in the United States. It will compete by building institutions in areas that represent market niches for African Americans. For example, health care disparities have a disproportionate effect on African Americans. "Health and health care is a trillion dollar business. Yet, HBCUs who do research on Blacks and health get only a miniscule amount of that money, perhaps ¼ of 1%. Thus, it's a potential area for Hampton to target."

Hampton-1 was asked how Hampton developed its niche in science and physics in particular. The President, Dr. Harvey, sponsored a market analysis of the region and discovered it was home to the largest military cluster in the United States. The decision was made to target the military complex and focus on developing an excellent, high quality science department that catered to the military's needs. He targeted NASA because it was proximate and represented financial opportunity and stability. Hampton needed to develop the infrastructure to support NASA's needs. Two NASA officers were brought on board at Hampton. In addition, Dr. Harvey raised funds to support endowed professorships so he could bring on the level of talent needed by NASA and its projects.

Dr. Harvey developed a Vision and a Plan to meet that vision. He targeted a major research sponsor that was within Hampton's reach and then put into place the infrastructure needed to meet that sponsor's needs. The process utilized by Dr. Harvey was as follows:

1) Identify an area of opportunity.
2) Develop a Plan and Vision.
3) Create track records. Get your foot in the door by getting a small project and performing it with excellence. Communicate with the agency. Compare the quality Hampton provides to the requirements of the project and the money received. Prove that Hampton can do the job and do it well.
4) Invest in human capital. Raise money for endowed Chairs and get nationally renowned faculty. Attract high quality students.
5) Repeat with other programs and other subject areas.

Rather than create brick and mortar infrastructure, Hampton strategically decided to build collaborations. An example is the University of Virginia. A partnership has been established between Hampton and the University of Virginia (UVA) for Hampton to utilize UVA's infrastructure and personnel for commercialization, patents, licenses and so forth. Hampton has access to UVA's patent attorneys, license attorneys, patent base, and so forth. In this way, Hampton can leverage UVA's mature structure to get Hampton products in the marketplace. For example, Dr. Keppel, a faculty member at Hampton has 14 patent disclosures. Hampton cannot afford $10,000 per disclosure nor does it have access to the marketplace. So Hampton is making a strategic effort to collaborate with

universities or other entities that can enhance Hampton's growth and commercial prospects.

Dr. Harvey's goals were focused on improving the financial and educational status of Hampton University by exploiting market opportunities. Circumstances were such that science and technology areas represented the best opportunity by which Hampton could achieve its goals. Thus, attention and effort were focused on developing the School of Science. The two strategies critical to initiation of the program was the President's Vision and **Leadership** as well as the **Proximity** of the military complex.

As Hampton completed several initial projects and gained the military's confidence in its abilities and capabilities, it began to develop relationships with other components of the military complex such as Langley Air Force Base, Jefferson Labs, the Naval base, and other agencies. The relationships (social capital) Hampton developed with NASA was used as a means to gain projects from the other organizations. As the School of Science continued to grow, the collaborations between Hampton and the various components of the military complex can be described as **Clustering**. There was no formal agreement to use Hampton, but its **Proximity**, the skills in which it specialized, its established reputation, and its quality work made it easy for the various agencies to choose to work with the institution. Agglomeration effects clearly aided Hampton in growing its School of Science and other departments. In addition, the growth of the program can be attributed to the **Leadership**, continued vision, direction, and support of the President. Thus, **Networking/Clustering**, **Leadership**, and **Proximity** were strategies that expanded the program.

8.2.2 A Breast Cancer program

The School of Science has several established divisions. It currently offers Master's degrees in several programs and a doctor of philosophy in Physics (with a doctor of philosophy in Physical Therapy to be added next year). The physics department cites several accomplishments. One includes their Center for the study of the Origin and Structure of Matter (COSM), one of four Physics Frontier Centers established in 2001 by the National Science Foundation.

When asked about the origins of a relationship between Hampton and another organization that was typical of how relationships began, Hampton-2&3 chose the National Institute of Health (NIH) and the development of the cancer research program. The relationship between Hampton and NIH started 20 years ago but it was only within the last 5-6 years that significant results have been realized.

Twenty years ago, few Hampton faculty were persistent at applying for grants. A previous Chair attempted to initiate interaction by encouraging faculty to serve at NIH by participating on panels to review proposals.   While there, Hampton learned that NIH was concerned about the number of biomedical research dollars going to HBCUs. There were no minorities on decision making boards yet there were certain health disparities that affected Blacks disproportionately such as breast cancer.[26] NIH created an initiative to include HBCUs in biomedical research. Hampton became aware of the policy and its intent but had no biomedical research program and inadequate facilities so they had to "get creative."

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[26] It was not stated at the interview but while White women develop breast cancer at higher rates than African American women, African American women have a higher likelihood of dying from the disease (Gibbs, 2004).

Interested faculty at Hampton applied for and received a three year grant to train faculty. They partnered with the University of Pittsburgh medical department whose staff agreed to provide training to Hampton faculty and students interested in breast cancer research. The University of Pittsburgh already had research capabilities in this area. The training occurs partly through distance learning. Research is done in the summer at the University of Pittsburgh. According to Hampton-2, it is a win-win situation for both schools. "Hampton gets faculty training in breast cancer research, a portion of the funding, and a pipeline to a doctor of philosophy program in research at the University of Pittsburgh. The University of Pittsburgh gets funding, recognition for a breast cancer research program, and facility enhancement." Now there is a core of faculty at Hampton that are interested and trained in breast cancer research.

Based on the above information, it became clear that **Policy** by NIH and **Linkages** was the strategy that initiated the program. A health disparity that disproportionately affected the Black population motivated NIH to set policy that would provide research on the causes of the disparity. However, Hampton, in realizing it did not have the facilities, was forced to establish a relationship with another institution. The formal collaboration between the two universities and the government proved to be more beneficial than each initially realized. Hampton gained access to a Ph.D. program which in turn led to a larger applicant pool for the University of Pittsburgh. **Linkages/Networking** were critical elements that enabled the program to expand.

8.2.3 COSM and the CERN project

Hampton-4 had been working at Jefferson Labs and another university when he was hired by Hampton. He made it clear that he joined Hampton's faculty because of the

presence of such high quality scientists as Dr. Keith Baker, a graduate of Massachusetts Institute of Technology and Stanford University in experimental nuclear physics. They both hold concurrent positions at both Hampton and Jefferson Labs. Hampton-4 is a faculty member and an Administrator in the COSM Center.

When asked about a significant relationship, Hampton-4 chose to focus on relations with CERN in Switzerland. CERN is a joint venture between 20 European countries conducting high-energy physics research. CERN is the world's largest particle physics laboratory and credits itself with creating the World Wide-Web browser. The United States made a policy decision to join the European collaboration. They implemented this decision by putting together U.S. teams composed of scientists from various universities that would make a contribution. Dr. Keith Baker, a faculty member, was identified because of his work in particle physics. He is considered a star scientist.

The flagship project at CERN is the building of the Large Hadron Collider (LHC), an undertaking in which Hampton is participating. Through the COSM center, Hampton is working in the ATLAS experiment using the Large Hadron Collider at the CERN laboratory to explore the basic forces that shape the universe. COSM is constructing the Barrel Transition Radiation Tracker which will measure the momentum of each charged particle during the experiment.

The policy decision by the United States to get involved in a European effort and the selection of Dr. Keith Baker resulted in coding of **Policy** and **Leadership** as strategies that initiated the program. The institutional decision to get involved led to growth in the program. Hampton-4 agreed to join the faculty; he also worked on the CERN project. Hampton's involvement was a likely contributor to the university being

awarded the COSM Center. By joining the network of organizations collaborating in the project, Hampton exhibited linkages at the level of Networks/Clusters. The U.S. policy decision played no part in Hampton's decision to continue its participation in the collaboration. Thus, networking and the continued role of star scientists resulted in coding of **Linkages** and **Leadership** as necessary for expansion of the program.

8.2.4 The School of Engineering

The School of Engineering and Technology (SET) emerged from the School of Science about 15 years ago. Ten years ago it became a department (the terms School and department were used interchangeably). The School is small in numbers and considers itself in its early stages. It has plans to introduce a new program within the department – Mechanical Engineering. The School specializes in a few areas. It focuses on aerospace propulsion as a result of proximity to Langley Air Force Base, the work being conducted by Langley on wind tunnels, and the opportunity for research. For this reason, Hampton-5, who received his Doctor of Science degree from Massachusetts Institute of Technology, was recently hired as an Administrator. The School also targets the development of sensors and nanotechnology because they can partner with the Physics department which is already working in these areas and enjoys a national reputation. A top priority of the School is to build partnerships both internally and externally.

Hampton 5&6 chose Lockheed Martin as a company that typified how relationships began at the Department. They both explained that the School of Engineering had emerged because there were additional needs expressed by elements of the military complex that had grown beyond the domain of the School of Science. (Hampton-5 had been hired a few months prior to the interview.) Lockheed Martin has a history of being

friendly to HBCUs. They provide support to a laboratory on Hampton's campus and they hire students from Hampton to work in their company. Hampton-6, a former Administrator, focused on developing a "marriage" with Lockheed. Lockheed had significant money in defense contracts and a desire to diversify. The Department of Science at Hampton always had a relationship with Lockheed. Hampton-6 fostered and developed a relationship with Lockheed to obtain support for the SET program. Hampton-6 maintained an open door philosophy; he welcomed industry and purposefully cultivated a relationship with the company by inviting them over to the premises and sending them promising students. Hampton-6's philosophy was "If you want it, you better get it yourself." (All the Department Deans seem to understand that whatever you want, you've got to find the funds to get it.) Over time, he built a relationship with Lockheed and now they support SET.

In the example of Lockheed Martin, Hampton-6 relied on several factors. He tapped in to and exploited the network built by the School of Science. For this, the strategy of **Linkages** was coded. Hampton-6 identified an existing client that had expanding interests. He courted and cultivated their support by supplying one of their most important needs – promising students. The strategy of **Demand** was coded. Without these two strategies, the School of Engineering may not have emerged from the School of Science.

Hampton-5 worked at NSF prior to coming to Hampton. He explained that NSF total funding increases every year, however, with the large amounts of funding that go to multi-year contacts and the rate of inflation, there is little real increase in funds. Funding from corporations is low for Hampton because the region is not highly industrialized. It

is a large military complex so there are operational funds available but minimal funding from industry and not much in research. However, with the establishment of SET, there is an entity for corporations to approach so one strategy is to target industry. SET also hopes to joint venture with the Naval Shipyard. The plan is to duplicate the success of the university by starting with a few faculty and getting small contracts which they will perform successfully. They will turn these projects around and get larger and longer contracts.

8.3 Summary

Table 8.1 Strategy Responses from HBCU Interviews

"Did Strategy Initiate the Program"

	Did Networks/Clusters lead to initial S&T development	Did Policy lead to initial S&T development?	Did Univ Leadership lead to initial S&T development?	Did proximity lead to initial S&T development?	Did Demand lead to initial S&T development?
Respondents	**Linkages**	**Policy**	**Leadership**	**Proximity**	**Demand**
Hampton-1	0	0	1	1	0
Hampton-2&3	0	1	0	0	0
Hampton-4	0	1	1	0	0
Hampton-5&6	1	0	0	0	1

Hampton is a university with a mature science program. As a private university, its orientation toward education was markedly different from the two public universities at which interviews were conducted. Every interviewee emphasized the need to raise funds. One interviewee stated that each department has to raise 1/3 of its operating budget. Sixty-six percent weight is given to research activity in faculty evaluations. Bonuses, raises and tenure are attached to research activity. In addition, faculty recognize that Hampton does not have the infrastructure (facilities and equipment) needed for large science projects so there is a necessity for faculty to collaborate and form partnerships in order to form research portfolios. Creative solutions, such as that exercised in the breast cancer research program were needed to realize some of the

university's goals. Policy was an important factor initially. Leadership was important as well, both in the form of an active President and a key scientist of international repute.

Table 8.2 Strategy Responses from HBCU Interviews

"Did Strategy Expand the Program"

	Did Networks / Clusters expand the program?	Did Policy expand the program?	Did univ leadership expand the program?	Did proximity expand the program?	Did Demand for S&T grads expand the program?
Respondent	**Linkages**	**Policy**	**Leadership**	**Proximity**	**Demand**
Hampton-1	1	0	1	1	0
Hampton-2&3	1	0	0	0	0
Hampton-4	1	0	1	0	0
Hampton-5&6	1	0	0	1	0

However, once Linkages reached the level of Networking and Clustering, other members of the Network were integral to Hampton's continued expansion in collaborating with other universities, industry, and other organizations for further support. Every interviewee cited events which indicated that the department relied on networking/clustering as a means of expansion. Hampton has the synergy described by Porter and it is fueling continued expansion of science and technology programs.

CHAPTER 9
FLORIDA AGRICULTURAL AND MECHANICAL (FAMU)

9.1 Florida Agricultural and Mechanical University (High Productivity)

9.1.1 Characteristics

Florida A&M University (FAMU) is located in Tallahassee, Florida, in the southern region of the United States. It is a public, land-grant, 4-year university in an urban environment. Currently classified as a Master's I Research university, it is in the 'very large' size category, catering to more than 12,000 students of whom over 90% are Black. FAMU is in the top third of all research HBCUs on the science and technology index and consistently ranks in the top 10% of all HBCUs on most other indicators.

9.1.2 History

The origins of FAMU are not atypical of other Negro land-grant colleges. In April 1887, the state legislature of Florida approved two schools – one white and one black - to teach illiterate or poorly educated students in the state. The school for Negro students was called the State Normal College for Colored Students. Florida appropriated $4,000 for each school for the next two years. Upon passage of the Morrill Act of 1890 which gave scrip (land) to each of the 17 southern states so it could establish revenue to pay for the establishment of Negro land-grant colleges, the State Normal College for Colored Students was designated the Negro land-grant college for Florida. By 1909, the legislature changed the name to Florida Agricultural and Mechanical College (FAMC) for Negroes and recognized it as a 4-year college level institution.

The land-grant designation required that FAMC establish an industrial education curriculum (applied agricultural, mechanical and military sciences) which, at that time,

was looked upon by southern blacks as an inferior education. Despite this emphasis, the first two presidents, Thomas Tucker and Nathan Young, advocated a liberal arts education to accompany the industrial arts education. Each President was fired from his position for advocating that Negroes should receive an elevated education (Neyland, 1990). However, their labor and commitment yielded some results. In 1910, FAMC awarded its first post-secondary degree, a Bachelor of Science. By 1916, according to the survey by the U.S. Department of Education, FAMC had 16 students studying at the collegiate level, the only Negro land-grant institution to be offering college level courses (Anderson, 1988; Hill, 1985).

Appropriations from the state decreased as Morrill fund appropriations increased. However, student enrollment increased due to the growth in the number of public schools, thereby increasing revenue from tuition. With the new “college” status firmly established, FAMC received an “A” rating by Southern Association of Colleges and Schools (SACS) in 1935 (Holmes, 1934). In 1953, the college’s name was changed by legislative action from FAMC to FAMU. When SACS finally opened its membership to include black schools in 1957, FAMU was the first to be admitted (Drewry & Doermann, 2001; Neyland, 2001).

As with most colleges, FAMU benefited from the return of the veterans of WWII through an increase in enrollment and associated military benefits subsidizing education. Student enrollment grew from 812 in 1944 to 2000 by 1949. In 1971, the state of Florida recognized FAMU by installing the institution as a full partner in the 9 university state, public higher education system. And, in 1984, the University granted its first Doctor of Philosophy degree - in Pharmacology. In less than 100 years, FAMU had gone from

teaching illiterate students at the elementary and secondary level to offering both a liberal arts and engineering, industrial and technical curricula as a recognized, accredited institution.

In 1985, Frederick Humphries, a chemist by training, became the 10th president of FAMU. His 16-year stint represented a phase of remarkable leadership.

When Humphries took over, enrollment, morale and facilities were declining. He is credited with the academic equivalent of a corporate turnaround. Under his motto of "Excellence with Caring," Humphries doubled enrollment from 1985 to 2000; surpassed or tied the Ivy League schools in attracting the highest number of National Achievement scholars in 1992, 1995, 1997 and 2000; increased the number of science and engineering students tenfold over the same period of time; increased contracts and grants by the Division of Sponsored Research from \$8.5 million in 1985 to \$46 million in 2000 (441%); and increased funds from the private sector through the FAMU Industry Cluster from \$6.2 million in 1986 to \$62.5 million in 2000 (908%) (Neyland, 2001). Under Humphries leadership, the state went from appropriating \$0 research and development dollars to an average of \$2.3 million dollars annually. Humphries was able to accomplish much of this by raising the level of corporate dollars and establishing a University Industry Cluster.[27] He fought to have a law school approved but the Florida legislature denied the request despite a nationwide controversy.[28]

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[27] The University Industry Cluster is a group of companies that donated funds, joint ventured in summer intern programs, provided strategic advice on university planning and otherwise supported the university.

[28] The controversy ensued because the State of Florida had designated FAMU to be only a comprehensive level university. Approval of a law program would potentially elevate FAMU's status. The application was denied.

9.1.3 Structure

Today, FAMU has 131 buildings situated on 416 acres. Its student population consists primarily of undergraduates. The University has 13 schools and colleges that offer 62 bachelor's degrees in 103 majors/tracks, 36 master's degrees with 56 majors, two professional degrees and eleven Ph.D. programs.

In 1982, FAMU/Florida State initiated their joint College of Engineering. The legislature initially debated the request for an engineering school and almost refused it, but after intense lobbying decided instead to approve a joint College of Engineering between FAMU and Florida State University. From a standing start in 1982, it grew to more than 2,000 students by 2002. The college now offers doctoral programs in all its engineering disciplines. The college graduates six of every 10 Black engineering students in Florida. It is one of the top five universities in the nation in the number of minorities graduating in engineering.

A science park, geographically designed to take advantage of the university setting, is located adjacent to the FAMU and Florida State University campuses.

9.1.4 S&T Statistics

From 1987-2002, FAMU had an average growth of 10% in publications. Its strengths include its growth not only in the number of science and technology graduates (an average of 26% from 1989-1996) but also in federal research and development funding (yearly increases averaging 20% from 1989-1992). FAMU receives more state dollars than any other HBCU, sometimes accounting for more than 50% of state funds allotted to HBCUs in a single year (see Appendix D).

The latest data showing federal obligations for science and engineering for 2000 by agency shows FAMU with a well-diversified portfolio. Health and Human Services (HHS), USDA and NASA are the largest contributors with relatively comparable amounts near $5 million each year. The Department of Commerce and Defense also provide significant sources of over $1 million each year.

9.1.5 Unique Achievements

The institution's tremendous growth and accomplishments during President Frederick Humphries tenure is one of the reasons that Time magazine chose FAMU as its College of the Year in 1998. The awarding of 129 bachelor's degrees in 1998-99 made FAMU America's second-highest producer of Black engineers (Neyland, 2001).

The development of the University's Industry Cluster was a creative means of garnering industry dollars and support for FAMU initiatives. Only 48% of HBCUs receive funds from industry for R&D. Of those, FAMU is the second highest receiving 9.17 million dollars (National Science Foundation, 2005).

9.1.6 Analysis

Florida Agricultural and Mechanical (FAMU) benefited from the philosophical beliefs of its first two presidents. They believed in higher education's inherent value and set a curriculum based on a classical education. FAMU began its education of Negro students in 1887, the post-Reconstruction era. It offered higher quality courses earlier than any other public HBCU becoming a 4-year institution by 1909. Despite this strong beginning, in 1968 FAMU was still a medium-sized institution facing many of the same obstacles and challenges other HBCUs face today.

In 1985, the Board of Trustees hired an exceptional leader in President Frederick Humphries. As a chemist, he recognized the importance of science and technology. As part of a strategic planning process he made a research agenda, collaboration and partnership integral priorities of a strategic plan for the University. Humphries devised a creative tool – the Industry Cluster - to partner with industry to fund his plans for educational excellence.

There are few weaknesses to point to for FAMU except that it remains to be seen whether Humphries' plans for excellence were institutionalized or whether the research agenda and partnerships with Industry instituted during his tenure were a result of great leadership. Since Humphries departure in 2001, there have been 3 Presidents. Dr. Castell Bryant is the current Interim President. Cluster corporate participation and funds declined in 2003 but that has been attributed to a downturn in the economy.[29]

9.2 Interviews

The material that follows presents summaries of interviews conducted at FAMU. Each summary begins with a description of the current status of the program. Following that is data obtained in response to the first data analysis tool – chronology of events. Each interviewee was asked to explain the origins of a typical program. In the concluding paragraph, the response is analyzed for pattern matching – evidence matching the predictions for linkages and rival theories (predictions can be found in the case study protocol – Appendix E).

Based upon chronology of events, two questions emerged regarding development of science and technology programs. The first question was, "Did this theory lead to initiation of the program?" The second question was, "Did this theory cause the program

[29] This information was provided by FAMU-4.

to expand?" For a theory to be credited, it must be critical to initiation or expansion of the program (depending on the question that is being asked) and must meet the requirements of the prediction.

The chapter concludes with the findings - a table summarizing the interviews and coding for each question. Each theory is coded affirmatively if there is a match between the prediction of the theory and the evidence presented in the interview. More than one theory may be supported by the evidence.

9.2.1 The Viticultural Center

The Center for Viticulture and Small Fruit Research (Viticulture Center) was chosen because the Center presented itself (on its website) as a partnership between FAMU and grape growers. It emphasizes technical transfer of knowledge. The Center for Viticulture and Small Fruit Research is part of the College of Engineering Sciences, Technology and Agriculture (CESTA) at FAMU. It is located several miles away from the main campus. It has its own building that has a tropical feel to it with a courtyard in the front and acres of vines with some other small fruit in the back. The Center expects to have several patents on grapes and seedless muscadines within the next few years. They have already developed new strains but several years ago the University of Florida announced new strains of grapes. The new grapes were so vulnerable to disease that they were not considered quality grapes. The Center wants to avoid that problem so it is doing extensive testing and re-testing of the grapes to ensure quality. FAMU-1 believes the Viticulture Center is one of the flagships of the University because the quality of the work and research has given FAMU nationwide exposure.

Grape growing is a new and emerging industry in Florida where climatic conditions favor the industry. The industry is new and small compared to the wine industry in California, Oregon, and New York. For example, there are 1 million acres dedicated to grapes in California; Florida has 1,200 acres of grapes. Ten years ago (1994), 50,000 gallons of wine was made from 4-5 wineries in Florida; today, over 250,000 gallons of wine are made every year from about 50 wineries. The Viticulture Center is the only one in the Southeast dedicated exclusively to the grape industry.

FAMU-1 described the growth of the relationship between FAMU and the grape growers association. The grape and wine industry represent a cluster in the mid to north-Florida area. The state passed the Florida Viticulture Policy Act in 1978 to support the fledgling industry by providing funds to farmers ($1,000 per acre if they devoted at least 5 acres to growing grapes) and to the universities (University of Florida and FAMU) for research. FAMU's Center for Viticulture and Small Fruit Research was established in 1978 to a) help grape growers become better and more efficient growers through transfer of technical knowledge, b) promote interest and consumption of Florida grapes and wines, c) strengthen and promote understanding between grape growers, processors and the scientific community, and d) contribute to the development and growth of Florida's grape and wine industry (these goals are listed in their brochure). Later, the State established a Florida Viticultural Advisory Council composed of FAMU, the University of Florida, the Department of Agriculture, the Grape Growers' Association, and several wineries, nurseries, process product companies and fresh fruit companies. They have annual meetings and regular workshops. They talk about 25-30 times a year. The council not only keeps the participants informed of new developments, it makes them

participants in policy affecting the grape industry. Every two years the Advisory Council develops a new plan that details the needs of the industry, goals, and so forth. FAMU's Viticulture Center formulates its strategies, program areas, and objectives around the Council's plan.

About 13 years ago, the University of Florida decided to terminate its involvement in research on grapes. FAMU maintained its involvement. The progress made by the industry and FAMU made University of Florida reconsider its position and re-enter the field. University of Florida suffered a temporary setback when its newly patented grapes did not perform well. FAMU-1 considers its work to be cutting edge and nationally competitive despite the lack of facilities, staff and equipment. The consortium of organizations represented in the Council interacts to further the industry's growth. The State continues to be a significant supporter of the Viticulture Center by contributing to the payment of salaries.

There are several necessary ingredients that contributed to the growth and success of FAMU's Viticulture Center. **Policy** decisions were made at the state and local level to nurture a fledging industry with considerable economic development potential. State policy continues to be important as it provides salaries for continued research. **Proximity** to grape growers and other components of the cluster is critical for knowledge transfer which occurs on a daily basis with either grape growers or various members of the Council. The formation of the Council led to **Linkages** at the Clustering/Networking level. The networking that resulted from the Council was critical to maintaining a level of knowledge that enabled FAMU to conduct meaningful research and expand the program.

9.2.2 Research programs

FAMU-2 is an Administrator in the College for Engineering Sciences, Technology and Agriculture (CESTA). He has been at the university for 27 years. CESTA is an established college at the university.

Prior to describing the evolution of a program at CESTA, FAMU-2 recounted that in his early years at FAMU, few faculty submitted applications for research funding. During Dr. Humphries tenure, the President insisted that each faculty develop a plan of work. Faculty would be held accountable by evaluation on publications, grants, and student advisements. (No specific targets were mentioned by the interviewee.) As a means of support, FAMU-2 sends RFPs and communicates regularly with faculty. In response to a question on policies that affect the department, FAMU-2 informed the interviewer that two policies had great impact on FAMU.

> A piece of legislation called the Evans-Allen Funds authorized funding for 1890 colleges (Black land-grant colleges). There was also an Executive Order from the White House mandating agencies to work with 1890s. Without these pieces of legislation, FAMU wouldn't be on federal agencies' radar. Reagan started federal support in 1980. The State never matched federal funding until the past 5 years. (*The interview was conducted in 2004.*) Currently, the University of Florida gets $120 million for research and extension from the State. FAMU used to get $0, now it gets $1 million from the State.

When asked about the evolution of a particular program, FAMU-2 chose two examples. The first example concerned the U.S. Department of Agriculture Cooperative State Research Extension and Education Services (CSREES). FAMU-2 communicates with CSREES almost every day. The relationship began as a result of a Congressional mandate that began in 1972 to provide funding to FAMU. The funds appropriated by Congress are apportioned to 18-20 agencies within the U.S. Department of Agriculture.

FAMU obtains funding from CSREES, one of the Department's agencies. Funding is disbursed according to the percentage of the rural population in the State.

Another example is the ARS (Agricultural Research Services) which has laboratories across the U.S. on anything related to agriculture (food, fiber, corn, weeds, strawberries, food, fiber, etc.). FAMU is currently conducting research on biological control in vegetable crops. FAMU was interested in expanding the program. ARS was interested in a program that didn't use chemicals to control crops. There was a mutual interest in developing a program for crop research so ARS told FAMU to develop a concept paper/proposal. FAMU sent it in and ARS sent site visitors to FAMU. The proposal was strengthened and sent to Congress for appropriation. Congress approved the program in their budget.

FAMU-2 attributed the growth in his College to internal **Leadership** provided by former President Humphries and key faculty within the department. The President of the university was important because he emphasized research as a priority. He implemented the priority by holding the faculty accountable via the evaluation process. Other faculty were also considered important because they supported the President and shifted from a teaching agenda to include the work of establishing a research agenda. Yet his explanation of the origination of the programs reveals federal **Policy** as an integral component in the initiation of various projects. The programs that start as a result of policy may not be sustained by policy; however, the department sustains continued growth by continuous application to bids. Thus, **Policy** is seen as causing the program to sustain and expand.

9.2.3 A Joint College of Engineering

FAMU and the University of Florida joint ventured to form a Joint College of Engineering. The College is an impressive building located at the edge of both campuses and within easy walking distance of a science park. The school has one dean, one staff and one faculty (taken from both schools); however, the school answers to two boards of trustees. As the budget entity, funds are directed to FAMU. Each school can give additional funding. The School is considered a success. According to FAMU-3, the University is the third largest producer of minority engineers in the United States. She claimed that if graduates of the Computer Science program were included (they're in CESTA), they would be the largest producer in the United States.

FAMU-3 explained how the Joint College of Engineering was created. Both universities applied for a College of Engineering at the same time 22 years ago (1982). FAMU's application for a law school prior to the application for the College of Engineering had been denied because the university had been designated by the State as a comprehensive university. This meant FAMU was limited to offering Master's level courses not doctoral level coursework. The rationale was that funding could be most efficiently allocated by allowing only a select few institutions at the highest level. FAMU and others saw this as a discriminatory policy because there were no Black institutions approved at the highest level statewide, FAMU and others had no input in this policy decision, and FAMU had demonstrated the capability to offer doctoral programs but had been denied (these insights were provided by another interviewee – FAMU-6). Thus, they were being penalized for a condition which had been denied by those who were judging. A college of engineering was needed; there were five or six in the state but

none in the Panhandle area. Therefore, the legislature, in trying to figure out how to make a politically correct decision, decided to grant a joint college to both schools.

FAMU-3 did not believe there was a "typical" organization that represented how science and technology programs/projects evolve at the School of Engineering. For example, one relationship with the ICURC in the Southeast came about because of the strength of the contacts of the Department Chair who had many contacts in industry and government. Another example of how relationships developed can be seen in the Florida Highway Safety Patrol program. The College of Engineering received a request from Highway Safety for research assistance from faculty to analyze crash data. They were so happy with the results that the school now gets $3 million per year. Another example is a printing company that wanted a work flow analysis. That opportunity was great for faculty but it also gave students a real life problem to solve. Programs come many different ways. Many times faculty will initiate a partnership as well.

Several factors were responsible for growth at the Joint College of Engineering. A **Policy** decision by the legislature to create the joint College was critical to the initiation of the School. Without **Proximity** of the two universities the College could not have been created. Additionally, **Leadership** was critical because the President of FAMU had to wage a national campaign to overcome an existing policy and garner sufficient support to force the state of Florida to allow FAMU to offer doctoral degrees. Once established, the **Demand** for students became another key factor. A tool used by President Humphries to attract corporations was the base of quality students at the College of Engineering.

9.2.4 Industry Cluster

The Industry Cluster was initiated by former President Humphries as a creative and innovative means of paying for the upgrade of FAMU. He solicited corporations and then gave them a meaningful role in improving FAMU's infrastructure. Corporations invested in FAMU by offering internships, engaging in strategic planning, and providing funds to the university. It is not a cluster in the traditional economic definition of the term. It is instead an example of networking at the university level. In this case, it is a collaboration and informal agreement between FAMU and a number of different corporations. Some of the corporations participate only by offering internship programs; others operate on an Advisory level offering strategic planning advice. The latter also usually provide significant funding to the university. It is a win-win situation for all who participate. FAMU benefits from internship programs, corporate sponsorship and investment, and corporate strategic planning. Corporations benefit by having access to a pool of quality students.

Leadership via personal salesmanship by the President of the university was responsible for the initiation and expansion of the Industry Cluster.

9.2.5 Environmental Sciences Institute

The Environmental Sciences Institute (ESI) is relatively young. Established in 1995, the Institute has been in existence for 10 years. In that short time, it has become the largest producer of Black doctorates in the environmental sciences in the United States. The Institute has a strong emphasis on research. All undergraduates are required to produce and present a senior thesis based on a research project. FAMU-5, a former Director of ESI, served (and still continues to serve) on many organizations enabling

FAMU to interact with state, federal and international agencies. Some of these organizations include the Center for Environmental Studies, Florida Sea Grant, Florida Institute of Oceanography, statewide committees, the Board of Regents (which he chaired at one point). One of his roles on the Board of Regents was to determine which courses (in environmental science) based on their content should be assigned to which category. He has also staffed the former Florida governor's commission on environment science.

FAMU-5's tenure at FAMU began as an Instructor for the first classes taught by the Institute in 1996. FAMU-5 had worked at the Oak Ridge National Laboratory in Knoxville, Tennessee as a Radiation Safety Officer. He was highly respected at Oak Ridge such so that he could be categorized as a "key scientist." The DOE (Department of Energy) provided funds to Lockheed to run Oak Ridge. Various federal agencies were interested in supporting programs where there was a critical need for personnel. FAMU-5 was interested in promoting minorities in science. A mutual interest was held by FAMU. The university was aware of the high correlation between environmental hazardous areas (toxic waste sites, brownfields, etc.) in poor and minority neighborhoods and the low number of African American professionals in the environmental sciences field. DOE was also aware of this underrepresentation and sought African American expertise. The participation of FAMU-5 gave all members of the collaboration a sense of assurance that the program would be taught in a quality manner. When FAMU applied for the degree to the Board of Regents, it stressed the collaborative efforts between FAMU, DOE and Oak Ridge.

The first class of the Institute began in Fall, 1996. FAMU-5 worked at the Institute as a Professor and commuted from Tennessee to teach at FAMU. Oak Ridge

provided FAMU-5 “flex” time to teach the classes. He also had wide experience in supervising Ph.D. candidates as well as an excellent record in securing grants from the federal government and other agencies. Eventually he agreed to leave Oak Ridge and was selected as the Director of the Environmental Science Institute.

Under FAMU-5’s leadership, the program grew. Faculty were required to have a research portfolio. ESI fostered a culture to support a high quality educational program. This included 1) a right mix of academic programs, 2) offering a Ph.D. research level program, 3) supporting an environment for applying for funds. When FAMU-5 first came to ESI, there were a total of 3-4 applications for funding. When he left the department as a result of being promoted to Vice-President at FAMU, there was an average of 3-4 applications per professor.

In summary, it was federal **Policy**, motivated by a desire to increase diversity that led to the initiation of the Environmental Sciences Institute at FAMU. DOE’s goal of increasing the number of minorities in the field was supported by a network of agencies with similar objectives albeit different motives. In addition to federal policy, the creation of the Institute could not have occurred without the **Linkages** that existed at the Networking level between the Department of Energy, Oakridge Laboratories, and FAMU. A formal agreement rose between the three entities that was used to encourage the Florida legislature to support the program and enact Policy. Finally, the stature of the key scientist, FAMU-5 encouraged the three entities to agree to the program. This falls under the theory or strategy of **Leadership**.

9.2.6 Administrator

FAMU-6 is a high level Administrator at FAMU who is phasing out of active duty. He spoke of development at the university overall as well as the development of the Environmental Sciences Institute. FAMU-6 stated that you need to have a fairly specific relationship over a period of years. He is concerned about a lack of long term commitment that prevents true development of a college program and expertise in the field. The College of Pharmacy program at FAMU is an example of a program that was nurtured and is now very productive with several Ph.D. specialties. Over time, the College of Pharmacy was able to recruit outstanding faculty which led to a high quality program.

As an example of how a relationship typically forms, FAMU-6 used the NOAA (National Oceanic and Atmospheric Administration). In December 1997, the former Administrator for NOAA invited HBCUs to Washington DC to help build their capacity so that NOAA could, in turn, diversify its agency. An African-American Under Secretary of Commerce and a graduate of an HBCU, supported this policy. The NOAA Consortium comprised of HBCUs was formed. In 1998, a request was put in the federal budget for $5 million to fund environmental centers. It was not approved. In 1999 the request was submitted again with the same outcome. An administrator at the Education Partnership program suggested a dramatic increase in the request for funding with the understanding that HBCUs would compete for the funds. In 2000, the federal legislature approved $50 million for environmental centers with a competitive request for bid open to all universities. Four centers were approved and three of the four had HBCUs involved. The four centers covered Remote Sensing, Atmospheric, Marine Science and

Environmental Science. It was in the last category that funding was awarded to the Environmental Sciences Institute at FAMU. **Policy** or approval by the legislature was needed for the funding. **Leadership** was a critical component because it provided the persistence to enable the funding to become a reality.

9.3 Summary

Table 9.1 Strategy Responses from HBCU Interviews

"Did Strategy Initiate the Program"

	Did Networks/Clusters lead to initial S&T development	Did Policy lead to initial S&T development?	Did Univ Leadership lead to initial S&T development?	Did proximity lead to initial S&T development?	Did Demand lead to initial S&T development?
Respondents	**Linkages**	**Policy**	**Leadership**	**Proximity**	**Demand**
FAMU-1	0	1	0	1	0
FAMU-2	0	1	1	0	0
FAMU-3	0	1	1	1	1
FAMU-4	0	0	1	0	0
FAMU-5	1	1	0	0	1
FAMU-6	0	1	1	0	0

FAMU is a large university with a developed and mature science program. It benefited from leadership with vision and initiative. Fortunately, many of the former President's initatives were institutionalized such as evaluating faculty on research portfolios. FAMU is a public university but it displayed entrepreneurial goals and actions towards fulfilling its goals. The concept and existence of the Industry Cluster is indicative of private sector thinking. The inclusion of corporate involvement on a planning level also speaks to innovative action.

Policy was critical to the creation of many programs at FAMU. The motivation behind the policy varied from the desire to increase personnel in environmental sciences to the desire for diverse representation to the simple need for more research in certain areas. Leadership was also critical not only in the form of the President who used his

power to fight for programs and their development but also in the form of key scientists whose involvement created and/or expanded programs.

Table 9.2 Strategy Responses from HBCU Interviews

"Did Strategy Expand the Program"

	Did Networks / Clusters expand the program?	Did Policy expand the program?	Did univ leadership expand the program?	Did proximity expand the program?	Did Demand for S&T grads expand the program?
Respondent	**Linkages**	**Policy**	**Leadership**	**Proximity**	**Demand**
FAMU-1	1	1	0	0	0
FAMU-2	0	1	0	0	0
FAMU-3	0	0	1	0	1
FAMU-4	1	0	1	0	0
FAMU-5	1	0	1	0	0
FAMU-6	1	0	1	0	0

However, once programs were started the policy that created the programs often dropped out. Linkages developed over time and were critical to causing the program to expand. Councils formed to create networks, agencies found benefits from continuing to work together and the synergy from industry-university-corporate partnerships led to continued growth. Perhaps the most enduring legacy of President Humphries was that he had a platform of growth and he institutionalized growth measures in various departments. The outreach required to do research led to linkages on a networking/clustering level. The demand for students was used by the President to entice corporate involvement but it was not an integral component for growth; it was merely a tool to achieve university growth.

CHAPTER 10
ANALYSIS OF LINKAGES AND RIVAL THEORIES AT HBCUS

This chapter presents the findings from the interviews. The primary question asked in this dissertation is what theories (when implemented they are termed strategies) account for the development of science and technology at HBCUs. Relying on the theories of higher education in universities, national systems of innovation, and competitive advantage, this study posits the hypothesis that linkages in the form of networks and clusters are the strategy that HBCUs should adopt to enhance their development of science and technology. Several theories were offered as rivals including the effects of policy, leadership, and proximity to centers of science and technology, and demand for skilled personnel. Qualitative research methods were conducted including interviews with key participants and liaisons, review of university policy documents, and analysis of public data on HBCUs. Data analysis tools included pattern matching, rival explanations and chronology of events. This chapter reviews the evidence and judges the effectiveness of linkages as a strategy for science and technology development.

The findings from this research do not support the use of linkages as the best strategy for HBCUs to initiate the development of science and technology. Rather, policy emerges as the strategy that seems most responsible for the initiation of science and technology at HBCUs. However, linkages and leadership emerge as the most important factors once the initial stages of development have passed and greater productivity is the goal.

The following presents information collected through interviews and documents. It summarizes the findings from the analysis of the primary hypothesis and rival theories.

10.1 Analysis

Results were analyzed for reliability through pattern matching (did the theories match their prediction), for validity against rival explanations (did one explanation offer more explanatory value than another), and for chronology of events (did one theory precede another and therefore become more causal than another theory). It is possible for more than one theory to be causal for a particular respondent. For example, if a program is located near a science park and a prominent faculty member initiates a research project with a corporation at the science park, then two theories could potentially be coded – proximity and leadership. If the project would not or could not have occurred without the geographical location and that particular scientist then the two theories would be credited. Each theory offers a different perspective.

Three qualitative methods - pattern matching, rival theories, and chronology of events were used. The format for pattern matching can be found in Appendix E. It contains several sections: 1) a brief explanation of the theory, 2) a description of the questions on the survey instrument from which evidence is derived, 3) the prediction, and 4) the evidence necessary to fulfill the prediction. Each of the rival theories follows the same format, thus, fulfilling the requirements of exploring rival explanations.

Finally, the third methodology, chronology of events is fulfilled by answering the question, "Does this theory lead to initial science and technology development?" This question seeks the root causes of development; i.e., what factors came first in causing the development of science and technology. A summary concludes each theory tying together the evidence found (results), offering support for (or against) the theory, and suggesting its implications (findings).

Each of the rival explanations had supporting evidence. This is not unusual for theories derived from logic and/or evidentiary studies. It is possible for more than one theory to be responsible for the development of science and technology at each College/program/department.[30] However, the validity of the theory is gained by examining which theory is supported by a preponderance of the evidence, and whether the theory is contravened by existing evidence. The theory must have been a necessary and critical factor for it to be credited for being causal (i.e., did the theory lead to the program). The theory that occurs with the most frequency should logically be deemed the theory with the most validity. See Table 10.1 for a complete analysis of each theory at the three universities. In the table, each theory is coded either 0 as not leading to program development or 1 for being necessary and integral for the program to occur at the university.

Respondents from the HBCUs included Vice-Presidents, Deans, Chairs and Directors. The average employment term for the respondents was 13 years. Universities that exhibited higher levels of science and technology development (as per the index) typically had more complex structures that included more colleges, institutes, departments and programs. It was impossible to cover all the science and technology related programs or departments at each of the three HBCUs; therefore, in general, larger or more successful programs at each HBCU were selected for interviews. The following table summarizes the results discussed on the following pages (see Table 10.1).

[30] Questions were not asked about the creation of the department as many of them existed since the school began or by the mid-1900s. Rather, the questions addressed the cause behind the development of a typical program or partner at the university. The lone exception is the engineering department at Hampton University created within the past 15 years.

Table 10.1 SUMMARY OF STRATEGY RESPONSES FROM HBCU INTERVIEWS

“Did Strategy Initiate the Program?”

	Did Networks/Clusters lead to initial S&T development	Did Policy lead to initial S&T development?	Did Univ Leadership lead to initial S&T development?	Did proximity lead to initial S&T development?	Did Demand lead to initial S&T development?
Respondents	**Linkages**	**Policy**	**Leadership**	**Proximity**	**Demand**
FVSU-1	0	1	0	1	1
FVSU-2	0	1	1	0	1
FVSU-3	0	1	0	0	0
FVSU-4	0	0	1	0	0
FVSU-5	0	0	0	0	0
Hampton-1	0	0	1	1	0
Hampton-2	0	1	0	0	0
Hampton-3&4	0	1	0	0	0
Hampton-5	0	1	1	1	0
Hampton-6&7	1	0	0	0	1
FAMU-1	0	0	1	1	0
FAMU-2	0	1	1	0	0
FAMU-3	0	1	0	1	1
FAMU-4	0	0	0	0	0
FAMU-5	1	1	0	0	1
FAMU-6	0	0	1	0	0
Sub-total	**2**	**9**	**7**	**5**	**5**

FVSU-5 and FAMU-4 were both new to the university. They contributed insight into what expanded the programs. At the interviews with Hampton-3&4 and Hampton-6&7, one was a current and the other was a previous Department head.

10.2 Linkages

Theories on Linkages as Networks and Clusters state that formal partnerships (implicit or explicit) between HBCUs and external organizations in which there are mutually exchanged benefits positively affect science and technology productivity at HBCUs.

Evidence supporting Linkages was gathered from three questions on the survey instrument. The first question asked the Respondent to select an organization with whom the University interacts a great deal that might be typical of how relationships are developed at the department and to explain how a relationship began and developed. The second question asks the Respondent whether there were policies to collaborate with other institutions. The third question asks what benefits were received from university partners. Evidence was also pulled from relevant responses to other questions.

Predictions:

1. Networks or Clusters exist (as defined earlier in this study).
2. The network/cluster formed in order to stimulate the HBCU's development of science and technology.
3. The network/cluster was the reason for the initiation of the s&t program/department/college

Linkages received a "Yes" in response to the question, "Did linkages lead to initial s&t development?" if evidence was found to support all three criteria.

10.2.1 Results and Findings

Some form of linkages exists at all the universities, although only two of the three HBCUs had linkages at the level of Networks/Clusters that initiated development. Networks and clusters, by definition, evolve out of social capital, which takes time to

develop. Twenty years ago, when the seeds of many of these programs were being planted or just starting to grow, social capital was just beginning to emerge. A lack of trust was the norm and issues of equity were dominant in the discourse between HBCUs, the federal government and other universities.

Currently, there are more plentiful examples of Linkages. The strategic plans of FAMU and FVSU both state a priority to develop partnerships, including global ones. However, there is little to indicate that Linkages were the ***cause*** of science and technology development at these universities. The example of the engineering department at Hampton is a recent and novel development.

Other factors appear responsible for stimulating initial science and technology development. For example, FAMU fostered the creation of a University-Industry cluster – a group of corporations brought together to be a source of revenue, strategic planning, internship opportunities, executive assistance and so forth – for the College of Engineering Sciences, Technology and Agriculture. However, while this Cluster was and is instrumental in facilitating the growth of science and technology at the university, it was Leadership that conceived the idea of the cluster and put emphasis on its growth.

Responses from external agencies corroborate other factors as critical to initiation of programs and projects. All the respondents stated that partnerships were important, however, they pointed to other factors as initiators. One example is AMIE (Advancement of Minorities in Engineering), a non-profit organization that acts as a catalyst to forge Government-Industry-HBCU partnerships. AMIE points to demand of science personnel as a motivating factor. As the AMIE respondent stated, "HBCUs' biggest draw is their students."

In summation, networks and clusters represent a sophisticated level of collaboration and interaction that support science and technology capacity building. Networks and clusters do not appear to be the strategy that typically initiates science and technology at HBCUs. However, they appear to be an effective and necessary strategy for sustainability and growth of science and technology programs.

10.3 Policy

The Policy theory states that external formal or informal policies (laws, guidelines, and initiatives) developed by federal, state and local governments and their related agencies have assisted and enabled the growth of science and technology productivity at HBCUs. Evidence supporting the theory of Policy was gathered primarily from the question on the survey instrument that asked, "What policies external to the University at the government level (federal, state or local) are you aware of that have had an impact on your university's involvement in science and technology?" Evidence was also pulled from relevant responses to other questions.

Predictions:

1. A policy exists which enables HBCUs to develop science and technology.
2. HBCUs become aware of these policies and initiate action to take advantage of the policy within a year.
3. HBCU policy regarding science and technology is initiated for the purpose of increasing the university's role in science and technology.

Policy received a "Yes" in response to the question, "Did government policy lead to initial science and technology development?" if evidence was found to support all three criteria.

10.3.1 Results and Findings

It is important to note that none of the respondents mentioned policy as the initiating factor for the program. Many of them attributed the development of the program to leadership from the President, a Dean or a faculty-scientist. However, their description of how the program evolved and what served as the catalyst for action to begin was the point of importance for this author. Policy was a causal factor in many of the science and technology programs at the selected three HBCUs.

The motivation behind instituting the policy varies; however, a few things stand out. Respondents most frequently cited the influence of federal policy on HBCUs. The Civil Rights Act, Title IX, the White House initiative and subsequent policies afforded HBCU's economic and social capital. Second, a frequent motivation has been the desire to increase minority participation in agency decision making. Such diversity is seen as a valued element. Third, this desire often stems from the impact of issues, illnesses or problems that disproportionately affect minority areas. These policies strengthen HBCUs by providing them with not only more resources, programs, and opportunities, but also better equipment in science and technology areas. The government benefits from having educated minority participants that provide a voice for affected parties. HBCUs benefit from federal support for a university program.

10.4 Leadership

Theories emphasizing the role of Leadership in science and technology development state that key individuals, whether they be administrators (President, Dean, S&T Department Chair) or "star" scientists, are responsible for the growth of science and technology productivity at HBCUs. Whereas Policy represents external influences on the

university, Leadership represents internal actions initiated within the HBCU to effect change. Evidence supporting Leadership was gathered primarily from the question on the survey instrument that asked the respondent whether there were any administrators (faculty, Deans or Chairs) or key scientists responsible for promoting science and technology at the university. Evidence was also pulled from relevant responses to other questions.

Predictions:
1. A new or newly promoted leader/star scientist joins the program.
2. Advocacy or influence in the form of promoting S&T or increasing S&T productivity rates are visible within 1 year after the introduction of the new or newly promoted leader/star (within 1 year).

Leadership received a “Yes” in response to the question, “Did Leadership lead to initial science and technology development?” if evidence was found to support both criteria.

10.4.1 Results and Findings

Leadership has been a critical element in increasing science and technology programs at the three universities. Two of the universities have been beneficiaries of exceptional leadership at the Presidential level. The benefit of leadership at the Presidential level is that it creates a systemic approach to growth which over time often results in a network or cluster effect. This occurs in several ways. First, university policies such as expecting a specific number of grant applications and evaluating faculty on the effort results in institutionalization of production. University personnel gain training in grant preparation, education on becoming aware of what is available, release time to write and submit applications, and experience in receiving and responding to feedback. Second, such policies require consistent contact with agencies that provide

funding, which cultivates and nurtures relationships. Third, the systemic approach created by policy at the university level fosters the interactive relationship described in Mode 2 theory where universities become more entrepreneurial. The agency, the university and other contractors work so closely together that it is hard to tell where boundaries end and who works for what organization. For example, at Hampton, a key scientist works at the University and is also a staff member at a government lab. Strong presidential leadership at places like FAMU and Hampton creates a systemic approach to growth that results in networks.

While leadership is important, there is a logical inconsistency in stating that it leads to science and technology development. There is a history of strong presidential leadership at HBCUs both individually and as an organization. As an example, Black land-grant colleges formed an organization known as the Association of Negro Land-Grant Colleges on January 15-16, 1923. For 32 years, the organization, composed of Presidents of the Black land-grant colleges, fought to improve the quality of their institution and gain equity in funding, mostly without success. The university presidents met with President Truman in 1946, produced reports revealing the inequities, and tried unsuccessfully to meet and work with the comparable majority organization, Association of Land-Grant Colleges and Universities [ALGCU] (Neyland, 1990). The United Negro College Fund in its early days also had difficulty meeting with success. Despite these efforts, the disparities and inequities in funding to HBCUs continue until today. Assuming an equal and consistent level of leadership over time, yet with different outcomes, one must conclude that intervening factors are also responsible.

External respondents also cite HBCU leadership as one of the hurdles to the development of science and technology. One of the federal government respondents, one non-profit respondent, and a couple of university respondents cited the 'traditional' thinking of HBCU leadership as an obstacle. Some HBCU leaders do not place an emphasis or priority on science and technology. Others continue to emphasize a teaching mission. And others do not know how to develop a science or engineering program.

In analyzing which of the theories is most valid, Leadership is clearly important; but it appears to need the effects of other factors such as Policy. The circumstances or chronology, which maximizes these strategies, should be addressed in another study.

10.5 Proximity

The Spatial Proximity theory states that locating near centers of innovation (high science and technology activity) creates a feedback loop. It enhances the participants near or within the system. They, in turn, increase science and technology output, which feeds back into the system. (Oinas & Malecki, 2002; Varga, 2000). Evidence supporting Proximity was gathered primarily from the question on the survey instrument that asked, "Has there been any S&T development at your university due to its spatial proximity to a business, another university or science park? If so, how, why and when did development occur?" Evidence was also pulled from relevant responses to other questions.

Predictions:

1. The HBCU must be located near a science park, a technology center or a business/university known for research or technology development.
2. Science and technology activities at the HBCU are attributed to the proximity of the technology center.

3. An increase in science and technology development is seen at the HBCU within one year of being located near the technology center.

Proximity received a “Yes” in response to the question, “Did Proximity lead to initial science and technology development?” if evidence was found to support all the criteria

10.5.1 Results and Findings

Support was found for the theory that proximity to centers of science, engineering and technology instigates a feedback loop that enhances participants near the system. Hampton is a prime example. After exploring potential growth opportunities, the university conceived a strategy to promote contact with one of the most concentrated military complexes in the United States. They did so because of the opportunity presented by being in close quarters.

FAMU represents a good example of the benefits of being in close proximity to industry and research centers. One institute owes its existence to the proximity of the grape growing industry. However, FAMU also reveals that proximity is not sufficient for development of partnerships to occur. A prime opportunity with a technology park resulted in no collaboration occurring after 5 years. Such contradictory evidence undermines the theory. Does one occurrence nullify a theory? Not necessarily. But when one examines several competing theories and evidence emerges to contradict the logic, the argument is weakened. By implication, competing theories are strengthened.

10.6 Demand for Skilled Personnel

The Demand theory, in application to universities, relies on traditional economic theory of supply and demand to explain science and technology development. The science and technological explosion since the 1950s in the United States has caused a significant need and demand for research, innovation, and skilled personnel. There is a limited supply of skilled personnel to conduct research and innovation. The market therefore, adjusts to produce factors at universities (resources, programs, policies, investments) that will increase the supply of scientists and research. Evidence supporting the theory of demand for skilled personnel was gathered primarily from the survey question that asked, “Has your university changed its policies toward student graduation as a result of the demand for skilled personnel?” Evidence was also pulled from relevant responses to other questions.

Predictions:

1. The University is aware of the personnel shortage and research needs.
2. The University creates programs for students to major in S&T or to encourage faculty to get more S&T contracts.
3. The University graduates more students in S&T fields.

Demand for skilled personnel received a “Yes” in response to the question, “Did Demand lead to initial science and technology development?” if evidence was found to support all three criteria.

10.6.1 Results

Table 10.2 Bachelor's and Master's Degrees Conferred by Degree-granting HBCUs 1987-2000

Academic Year*	FVSU		Hampton		FAMU		All HBCUs	
87-88	99		369		415		12,392	
89-90	119	20.2%	444	20.3%	463	11.6%	12,595	1.6%
91-92	131	10.1%	503	13.3%	562	21.4%	14,405	14.4%
93-94	173	32.1%	536	6.6%	775	37.9%	17,141	19.0%
95-96	201	16.2%	593	10.6%	1,022	31.9%	20,262	18.2%
97-98	201	0.0%	590	-0.5%	956	-6.5%	20,945	3.4%
99-00	166	-17.4%	602	2.0%	1,065	11.4%	20,302	-3.1%
Total	1,090		3,637		5,258		118,042	
Percent Increase 1987-2000		67.7%		63.1%		156.6%		63.8%

* As provided by the National Center for Education Statistics

All three universities demonstrated a consistent increase in the number of students graduating in science and technology fields from 1987 to 1996 (see Table 10.2). Thus, evidence exists to suggest that the universities are attempting to meet the need for skilled personnel. Is this purposeful? (All the programs mentioned here are also coded under other theories.)

Demand for skilled personnel has been high and remains high in the United States. Media attention and controversy surrounding jobs leaving the U.S. and wages going to foreigners highlight this issue. At first glance, there appears to be a purposeful strategy at HBCUs to address this need, particularly since the increase in the proportion of graduates in science and technology has been far higher at HBCUs than their majority counterparts. Responses from the interview indicate that new programs emerged as a result of external demand from corporations and universities. When asked, respondents stated that no programs were created to encourage students to major in these areas outside of the summer programs offered to pre-college students. As some respondents stated, it

appears that students themselves, aware of increased opportunities, decided to major in these fields.

HBCUs responded to external interest in skilled personnel; however, it appears that the agencies needing personnel have been more active in encouraging greater number of students to major in the field. Federal agencies have provided incentives, through policies and subsequent funding, for universities to create programs to attract students. Corporations have done likewise, providing incentives such as jobs and internship programs. HBCUs, more so than majority universities, represent growth opportunities for increased supply of skilled science and technology personnel. However, as the numbers indicate, the number of Black students deciding to major in these fields has declined within the last years in which data were available. HBCU respondents did not appear to have a strategy to counteract the decline. The lack of strategy to counteract the decline is an interesting observation as student graduation, and particularly student graduation in the sciences and engineering fields appear to be a competitive niche for HBCUs. The active interest from corporations and government is understandable; it seems that HBCUs should consider creating programs to encourage students to maintain interest in these fields.

10.7 Factors Contributing to Expansion of Program

The preceding analysis sought to determine the factors that initiated science and technology development at the three selected HBCUs. What factors have contributed to expanding the programs once initiated? Expansion would be defined as more students, more revenue, or elevation of a program from major to Institute to college and so forth.

Table 10.3 Summary of Strategy Responses from HBCU Interviews

"Did Strategy Expand the Program?"

	Did Networks / Clusters expand the program?	Did Policy expand the program?	Did Univ Leadership expand the program?	Did Proximity expand the program?	Did Demand for S&T grads expand the program?
Respondent	**Linkages**	**Policy**	**Leadership**	**Proximity**	**Demand**
FVSU-1	0	0	0	1	1
FVSU-2	1	1	1	0	1
FVSU-3	0	0	0	0	0
FVSU-4	0	0	1	0	0
FVSU-5	0	0	1	0	0
FAMU-1	1	1	0	0	0
FAMU-2	1	0	1	0	0
FAMU-3	0	0	1	0	1
FAMU-4	1	0	1	0	1
FAMU-5	1	0	1	0	0
FAMU-6	0	0	1	0	0
Hampton-1	1	0	1	1	0
Hampton-2	1	0	1	0	0
Hampton-3	1	0	0	0	0
Hampton-4	1	0	1	0	0
Hampton-5	1	0	0	1	0
Sub-total	10	2	11	3	4
Army	1	1	1	0	0
NASULGC	1	1	1	0	0
Merck/UNCF	0	0	0	0	1
AMIE	0	0	0	0	1
UNCF	0	0	1	0	0
Armstrong	1	0	0	0	1
TOTALS	**13**	**4**	**14**	**3**	**7**

Table 10.3 reviews each theory for its impact on expanding the program. Three points emerge. The first is that Policy, while it was critical in starting the programs or opening the doors, appears to become inconsequential once the program begins. In only two cases did evidence point to government support leading to program expansion. One

of these instances was state supported policy. Federal policy stops being a factor after initiation. Other factors become responsible for sustaining the program.

The second point is that Leadership emerges as a sustaining factor. Leadership was an important factor in initiating the programs; it remains an important factor in helping the program sustain growth. The third point is that Linkages emerge as being critical for growth. Networks and Clusters, represented by collaborations and partnerships, become vital for growth or sustainability. According to Hampton-1, their growth strategy is based on sustainable collaborations and partnerships. The evidence supports this strategic priority.

10.8 External Agency Responses

The external agencies interviewed – non-profits, corporations and federal government agencies – offered differing viewpoints. There was no unanimity in support of one theory over another whether it was in regards to what initiated the development of the program/partnership or what sustained it. As a matter of fact, each theory found support depending on the agency. But all the external agency respondents agreed that lack of funding was an issue faced by most that prevented them from developing their science and technology capability. Lab equipment, libraries, faculty, research time and so forth are adversely affected by a lack of funding. As one agency said, “It’s not feasible for HBCUs to go after a $200 million contract. That’s one of the reasons they’re starting to collaborate.”

Human capital was the motivation for many of these agencies to work with HBCUs. Whether it was students or faculty needed for research, the desire for sharp,

quality, and skilled personnel leads government, corporations and non-profits to seek out collaborations and liaisons with HBCUs.

There was no agreement on what theory/strategy HBCUs should adopt. The respondent from Merck answered that all the strategies were needed.

> It's like splitting hairs. They're all synergistic. It's imperative that you're close to a center because most HBCUs don't have the resources by themselves. NIH won't give a grant because they [the HBCU] has no track record so they need partnerships. But there must be a person to participate and be able to conduct the research. And the partnership won't happen unless university has upper level buy-in to support. And if there's no national support or effort it won't occur either. The reality is that you need all of them. But if I had to choose one, it would be the research individuals at the department level.

10.9 Conclusion

The feature hypothesis of this dissertation is that linkages, represented by Networks and Clusters, are the primary factor influencing science and technology development at HBCUs. Four rival hypotheses were offered as factors for influencing science and technology development. Three HBUs were selected to obtain facts supporting one or more of the theoretical explanations. Three methodologies for qualitative data analysis were used to determine the validity of each explanation. One of the methodologies, the method of chronology of events, asks, "which theory initiated the project/program?"

Upon initiation of this dissertation study, it was assumed that the factors that initiated the program were the same factors that would sustain it and cause it to expand. When evidence was collected to determine which of the theoretical explanations came first and was therefore, causal, it was discovered that linkages were not the primary factor influencing the initiation of science and technology at the three selected HBCUs. Rather,

government policy which sought to include Blacks in areas where they had been a) excluded or b) where Blacks were disenfranchised from government decision making or c) resident in an area disproportionately affecting Blacks was the primary factor influencing the initiation of science and technology at the three selected HBCUs.

Further analysis of the data indicated that policy was not the primary factor for growth or sustainability. As Hampton-5 stated, “HBCUs are going from one operating mode to another – from a teaching mission to a research mission. That means we must collaborate with other HBCUs, universities and partners.” When linkages begin to result in the development of relationships that lead to contracts, joint ventures, and internship programs, a system evolves that lays the groundwork for continued growth. If leadership maintains its efforts to stimulate growth, then the system keeps evolving until networks or clusters form. Collaborations and multiple partnerships form. Knowledge gets shared. External agencies begin to work on behalf of the university and benefits accrue that are greater than the efforts of the individual university.

This is the essence of the cluster effect of which Michael Porter writes. Linkages and their resulting synergy, enable “the whole to be greater than the sum of its parts.” Respondents at each University mentioned the desire and need to partner and collaborate with other universities, industry and government in order to grow. From the data collected, it appears that policy, leadership and linkages are critical to creation and expansion of science and technology at HBCUs. The choice of strategy is dependent on the stage of science and technology development.

CHAPTER 11
CONCLUSION

As HBCUs enter the 21st century, how should they respond to an increasingly science- and technology-oriented society? What strategies should they adopt to maximize science and technology development? What is the productivity of HBCUs in science and technology indices? These are the questions addressed in this dissertation. This chapter assesses what has been learned.

Various literature bases covering HBCUs, higher education, systems of innovation and competitive advantage were examined to uncover theories and strategies on science and technology development. Five theories emerged **–** linkages, policy, leadership, proximity, and demand for personnel. Of these theories, previous studies pointed to linkages as the most prominent explanation for achieving science and technology productivity. This study adopted the theory that linkages was the strategy HBCUs should adopt for development of science and technology.

To test this theory, a two-phase research design was implemented. The first phase, the construction of a science and technology index, revealed the HBCUs that had the highest productivity. The measure also enabled testing of hypotheses regarding the characteristics of "successful" or high performing HBCUs. The second phase assessed the effects of linkages and the four rival theories at research HBCUs. The results and findings from these two phases are summarized below. Following the summary of the results and findings, the limitations to this dissertation will be discussed. Recommendations to the findings will also be presented.

11.1 Phase I – Results and Findings

This study used a mixed-methods approach composed of two phases. Phase I was a nested approach to acquire and analyze information for Phase II. A science and technology index was constructed using standardized scores of various s&t indices. Four expectations were tested using the index to compare s&t productivity across different types of university ownership and classification. Three of the hypotheses predicted that four-year private HBCUs would average a higher s&t index rating than a) four-year public HBCUs, b) four-year land-grant HBCUs and c) two-year HBCUs. This would be in accordance with performance by TWIs where four-year private universities generally hold a slight edge in performance over peer public and land-grant universities.

The results of the index revealed that four-year private HBCUs not only averaged significantly lower s&t scores than four-year public and four-year land-grant HBCUs, but their average s&t score was below the mean. This represents a significant difference from their peer group of TWIs. Land-grant HBCUs dominated the top 20 HBCUs index. Based on the literature on HBCUs, it is understandable that public HBCUs fare better. Cost is an important factor since a larger percentage of the HBCU student population is low-income than at TWIs. However, that does not explain why land-grant HBCUs (a sub-set of public HBCUs) received a higher average index score than public HBCUs. Further research is required to better understand the dynamics behind the performance of the three control structures. However, the results indicate that land-grant HBCUs, on the average, have acquired a greater level of s&t efficiency than their HBCU peers.

The data on four-year private HBCUs shows that 77% have student populations under 2,000. Given their small size, their below average performance is not surprising.

Size does not dictate performance but the very small size of many HBCUs (58% have population under 1,000) causes threshold issues to arise. Very small colleges and universities find it difficult to garner enough resources to compete for faculty, funding, students and so forth. Hence, organizations like the United Negro College Fund, whose efforts provide small private HBCUs with additional funding, are crucial support mechanisms. Land-grant institutions sustain an advantage based on the financial security afforded by consistent federal and state funding. Having long benefited from being able to offer a lower cost education, land-grants and public universities average larger student bodies than private HBCUs. Among other benefits, this results in more tuition, a significant source of operating funds for HBCUs. Previous studies show that funding plays a critical role in the operational capability of many HBCUs.

11.2 Phase II - Results and Findings

Phase II addressed the primary question of the dissertation – What strategy should HBCUs adopt to maximize science and technology development? Using the science and technology index from Phase I, 3 of the 35 research HBCUs were selected representing high, medium and low performance on the s&t index score (FAMU, Hampton and FVSU respectively). The selection of methodology was critical. Pattern matching, rival explanations, and chronology of events combined to bring out results that would not have been obtained with a survey process. Based on responses to the chronology of events methods (i.e., did one theory precede another and therefore, become more causal than another theory), two questions had to be asked – “what led to the initiation of this s&t program?” and “what caused the program to expand?” University respondents would often attribute the achievements of the program to a “leader”; however, when pressed

about the origins of the program, another answer would emerge that pointed to a rival explanation. Without rival theories, the author would not have picked up on the significance of other explanations for s&t program initiation (which is why the respondents mistakenly attributed its cause to leadership).

Based on results obtained from interviews and archival data, policy had the highest number of occurrences (9 of 16) in response to the question of initiation of the program. Leadership was a close second with 7 occurrences. When seeking to answer the question of what led to expansion of the program, the results were markedly different. Policy almost completely dropped out of consideration (2 out of the 16 HBCU respondents). Linkages emerged as a very close second to Leadership (13 occurrences versus 14 for Leadership). Several findings can be extrapolated from the results based on evidence from the interviews, archival data, published statistics, and so forth.

11.3 Strategy Selection

The first and most significant finding to emerge is that strategy selection varies according to the context of the university environment. Why was policy so significant as an initiator? Most of the programs discussed had their seeds planted in the 1970s and 1980s, during the civil rights era. Policy was shifting from being exclusive to inclusive for minorities. Funds were set-aside in a number of areas to counter the effects of previous discrimination. Federal government, reacting to policy and the change in societal attitudes, began to see a greater need for minority representation on decision-making boards and for minority input in areas that were disproportionately affecting minorities. As technology became more important, they sought more skilled personnel, regardless of color. Doors began to open. Funding that had been previously closed to

HBCUs was now offered, and HBCUs responded with new programs. Land-grant universities received the beginning of federal funding for land-grant services in 1972.

A policy opportunity existed during the 1970s and 1980s for HBCUs to develop science and technology related programs. This is analogous to the policy opportunity that existed for TWIs during the Golden Era of the 1960s, when the federal government dramatically increased science and research funding to TWIs. Federal involvement with HBCUs occurred later. Many of the programs that were discussed during the HBCU interviews evolved during the 1970s and 1980s. However, government funding does not generally continue for one program over a number of years. Thus, while policy could be credited with initiating the program, it was rarely responsible for maintaining or sustaining the program. Policy's influence in the equation waned.

For programs to be sustainable, HBCUs had to engage in development activities. As an example, FVSU-2 received initial funding from DOE to provide training to minority businesses and, as an aside, a small portion went to students. FVSU-2 used the funds for students to start a student program. In order to maintain the program, however, he made cold calls to local corporations for financial assistance and job opportunities. In reaching out to these companies, he developed contacts and relationships. In the process, he built social capital. After a period of time, the program was able to offer scholarship money and a summer internship. Both the program and the scholarships attracted quality students. The corporations with whom he developed relationships, spoke on behalf of FVSU to other companies. Further contacts developed, and from those, a dual degree program emerged in another state on the other side of the country at the University of Nevada at Las Vegas. Thus, three levels of program achievement occurred from the

initial program.   The first level was the incidental money from DOE for students (initiation based on policy). The second level was the scholarship and summer intern program (impetus provided from leadership). The third level was the dual degree program (higher level benefits resulting from linkages and networks).

This ‘science and technology development’ occurred in many different ways at the various universities. Social capital grew from the networking and clustering that enabled HBCUs to sustain their programs. Linkages through social capital caused further programs not only to evolve but also to eventually build an infrastructure that became sustainable. This is how linkages emerged as a vital and critical strategy for science and technology development.

Linkages was not just significant when looking at expansion. The evidence for linkages came primarily from two universities – the medium productivity HBCU (Hampton) and the high productivity HBCU (FAMU). We infer from this that linkages are more likely to exist at HBCUs that have already achieved a level of development. This inference is supported by the science and technology index’s analysis. This author, from the results of this study, finds that, at HBCUs, there is likely not only a correlation between policy and early science and technology development, but also a correlation between linkages and more sophisticated science and technology development.

These findings can be summarized by stating that the selection of strategy must consider the maturity of the HBCU’s science and technology endeavors. An HBCU that is seeking to initiate a science and technology strategy should look to federal or state policy supportive of programs at HBCUs or they can find issues that disproportionately affect minorities and seek government support or offerings in those areas. An HBCU that

has a foundation (meaning they've already exploited some policy opportunities and have some programs and infrastructure in place), and is seeking growth strategies in science and technology areas, should look toward collaborations and partnerships for the purposes of forming networks and clusters.

Why wouldn't the HBCUs starting a program seek to form partnerships and collaborations as well as relying on policy? Lower-performing HBCUs have not yet developed the social capital to make collaborations and partnerships possible or fruitful. Trust, a critical component of social capital, takes time to develop. It is trust that leads an individual or organization to work on behalf of a university. Synergy among individuals or organizations that use their contacts to bring benefits to the HBCU explains how "the sum is greater than its individual parts." For HBCUs initiating a science and technology program, greater productivity will result from energy expended toward exploiting policy initiatives rather than expending time and energy toward forming collaborations and partnerships.

11.4 Rival Explanations

A second finding concerns the role leadership plays in the development of science and technology. Leadership scored high in explaining both the initiation of science and technology development and its expansion. Leadership is usually an important variable; however, archival and historical data was important in showing that leadership was an insufficient explanation by itself. Although FAMU and Hampton had impressive, outstanding leaders, past history indicates outstanding individuals at the helms of HBCUs in the past. Yet, past leaders and key scientists at HBCUs did not achieve equitable funding for their programs, they were prevented from participating in peer associations,

and they did not establish the linkages and networks that exist today between HBCUs and other universities, federal agencies, and corporations. Past leaders of HBCUs did not achieve the same advances that HBCUs have made in recent years (Neyland, 1990). Given the same input (leadership), but a different output (greater s&t development) logic dictates that other variables must be involved. One of those variables is policy, which opened the door and mitigated the racial barriers and the distrust that abounded. A second variable is Linkages. Leadership is dynamic and can foment change, but it cannot operate by itself. Funding from the government requires acquiescence by government officials. Internship programs require cooperation by the corporate sponsor. Dual degree programs require partnerships with another university. Thus, leadership is a vital ingredient as the results show, but it is an intervening variable. Leadership is necessary for policy and linkages to work but it cannot operate by itself. Thus, this author suggests the following mix of context and strategy:

Introductory science and technology development – Policy

Mid-level science and technology development – Leadership

Upper-level science and technology development - Linkages

What can be said about the two other competing theories in this study – proximity and demand? The theory of spatial proximity was undermined by one situation where no signs of science and technology development occurred despite the proximity of a science park and the intent to exploit the advantages of proximity. The weakness lies in the implementation of the theory. Proximity can promote development, but geographical proximity alone does not necessarily lead to development unless other facilitating factors like leadership or linkages exist.

The theory of demand for skilled personnel yielded interesting results. Information gleaned from external liaisons was influential in highlighting the importance of HBCU graduates. It was clear from them, the literature, and the HBCU respondents, that there was strong demand from government, corporations and other universities for HBCU graduates in science and technology areas. HBCUs responded to the demand by creating new programs, Institutes and departments. However, while HBCUs responded to demand, they were not as active in cultivating supply. HBCUs experienced large increases of students majoring in science, engineering and technology fields over the past 15 years without university intervention. As a result, they may have believed there was no need to encourage students. However, while the numbers of Black graduates in S&E fields has increased from 1994-2001, HBCU's percentage has decreased. TWIs are graduating more Black students (National Science Foundation, 2004c). HBCU respondents seemed to have no strategy to counteract their declining percentages. Demand for students led to some development of science and technology at HBCUs but it was not a dominant strategy.

In conclusion, HBCUs have a choice of several strategies to pursue to develop their science and technology capacity. This study has highlighted which ones may be more productive and efficient for them to pursue and why that is so. To maximize productivity, the choice of strategy should be predicated upon the maturity of their science and technology endeavors.

11.5 Limitations

Various methodologies were used in this study to eliminate weaknesses in the design. Triangulation was achieved through multiple methods (utilizing both quantitative

and qualitative methodologies); multiple data sources (using data from public, archival, interview, and website sources), and multiple theories (introducing and testing rival theories). However, certain vulnerabilities still exist.

Due to the type of information that was needed, only a small number of people at HBCUs could be interviewed. The interviewees were all administrators, and most had been at their individual university for a long period of time. While their length of service provided them with critical information, it may also have produced a bias in their response. For example, respondents at FAMU were reluctant to discuss the technology park located nearby. Although they had no ownership in the park, they were supposed to be participants. Their lack of productivity from the park revealed a weakness (from their perspective). It was difficult to obtain information as to why the park had not worked the way it was intended. Attempts were made to speak to officials external to FAMU – administrators at the park, Florida State personnel, or businesses at the park. However, the attempts were unsuccessful and did not yield any further revealing information. Thus, the limited number of interviewees and the homogeneity of their position may have biased the results. Interviewing a larger number of government and corporate partners familiar with the university would strengthen potential counterpoints and offset subject's potential bias.

Another vulnerability (inherent in many case studies) is a potential bias in the sample selection. In this case, for example, two of the three universities had presidents that had long tenures and were outstanding leaders. It is not known whether this is typical of research HBCUs but good leadership is not common. Therefore, a possibility exists that although the cases were not purposefully selected, a bias may exist in the

chosen sample. This always exists as a possibility in the absence of the best known process to obtain a representative sample, random selection. A limited solution to this issue for future research would be to expand the number of HBCUs where interviews are conducted.

An additional issue came from lack of access to critical documents and information. Hampton University, as a private institution is not forced to make public financial reports, annual reports, budgets, strategic plans and so forth. Despite persistent requests, they refused to produce documentation that could be used to corroborate information gleaned from interviews or public data.

Although not considered a vulnerability, the author would have liked to include TWIs in the sample of case studies. Available resources and time prevented that option. The inclusion of TWIs in the study would have enabled further understanding into the differences between HBCUs and TWIs. Is policy as important in the initiation of science and technology programs at TWIs or do they initiate programs through networking/clustering, internal fundraising efforts or industry funds? Do TWIs have a broader base of financial support? In terms of expansion, is industry a significant component (after you get past the top universities)? Are there differences between the two populations that would act as insight or best practices for the other? Further research would have enabled comparisons between a selected sample (HBCUs) and the general population (all universities). HBCUs are only 3% of a larger population. Are they typical? How different are they? Including TWIs in a similar study would answer these questions. Such a study presents a potential future research topic.

The results uncovered areas where further research was required. In Phase I, it was learned that four-year private HBCUs ran counter to expectations by averaging lower s&t scores than their four-year public and land-grant counterparts. Although part of the answer can be found in the threshold issues they face, there is also a question of why they haven't developed more strategies to address the problems and weaknesses that come with being very small. For example, why are there not more examples of collaboration? Do they share resources such as libraries, equipment, faculty, and so forth? Are more organizations like the United Negro College Fund needed? Conversely, the superior performance of land-grant HBCUs invites further research. While consistent government funding appears to be a significant factor in their achieving the highest average science and technology index rating, more research is required to determine whether funding, size, collaboration, efficiency, accountability, etc. are sufficient explanations.

Although vulnerabilities to this design exist and further research would provide explanations for some of the results that emerged, the design and methodologies used proved sufficient to produce results and findings that contribute to the literature.

11.6 Policy Implications and Recommendations

This study was designed to provide guidance to HBCU leadership, HBCU science and technology departments, and federal and state agencies that are interested in identifying potential niches for support of science and technology development. These recommendations are made with them in mind. Many of the comments made by the external liaisons are relevant to this section.

11.6.1 Recommendations for Policy Personnel

One of the key points emerging from this dissertation is that policy supporting science and technology is critical, not just for HBCUs, but for America as well. The significance of policy supporting science and technology endeavors goes back to the 1960s when significant sums of federal funds led to fundamental scientific discoveries that changed the balance of power in the world. The Bayh-Dole policy has led to an increase in university commercialization. Graham and Diamond's research revealed the impact of state policy decisions in elevating University of California's eight campuses, SUNY (State University of New York) at Albany and Buffalo, and the University of Alabama at Birmingham to research prominence. This dissertation adds to these studies by pointing out the importance of policy in assisting HBCUs in starting their science and technology programs. The performance by HBCUs contributes to American performance; conversely, the lack of performance by HBCUs detracts from America's ability to compete (Jackson, 2004). How does this translate into policy recommendations?

(a) Policy personnel at all government levels should support a two-pronged approach – a policy driven approach at an introductory level to initiate s&t programs and a linkages approach for more sophisticated programs to support collaborations, partnerships and networks among HBCUs and other universities government and industry. Policy personnel should understand that policy opens doors and overcomes previous distrust and racial attitudes. As the NASULGC representative stated, "Public policy provides the framework by which opportunity develops." Linkages are the meat and flesh on the policy framework.

(b) The federal government should be more aggressive in promoting student participation in science and technology endeavors. The Newsweek article of May 5, 2005 discussed participation in Intel's worldwide science competition. The U.S. had 65,000 students participate in the competition versus China's 6,000,000 potential scientists (Fareed et al., 2005). These numbers can be put into context by examining the population of the two countries. The ratio of China's youth to America's youth (15 and under) in mid-2005 was 4.6 to 1; however, the participation in the science fair was 92.3 to 1 respectively (Population Reference Bureau, 2005). At the pace in which China is investing, the U.S. will be left behind. It is important to be pro-active in encouraging students at a young age to engage in science or technology fields. The companion piece to the National Science Board's Science and Engineering Indicators 2004 report states, "students entering the science and engineering workforce in 2004 with advanced degrees decided to take the necessary math courses to enable this career path when they were in middle school, up to 14 years ago" (National Science Board, 2004a). Policy personnel, administrators in higher education institutions, and corporations that need the workforce must invest in strategies that will encourage young people to engage in science, engineering and technology fields at a young age.

(c) The U.S. should focus on capacity-building of minority workforce. The competitive advantage the United States has enjoyed in science and technology is being threatened by advances and investment in other countries and by the lack of preparation to maintain its own workforce within its borders. The U.S. scientific and engineering workforce is aging. Over 50% of the science and engineering

workforce is age 40 or over; the number reaching retirement within the next decade may triple (National Science Board, 2004b). Yet there are fewer American students choosing to study science. The number of foreign nationals that were once relied upon to fill the workforce gap is decreasing. Since September 11, 2001, the number of visa applications has declined dramatically and the number of foreign students attending American universities has declined. Some American universities have reported a drop of as much as 40% in foreign graduate student applications (Jackson, 2004).

The demographic changes in the national population point to the need for minorities to make up some of the shortfall in the science and engineering workforce. The non-Hispanic White population grew only 3.4% in the last decade while the Hispanic population grew by 58%, the Asian American population by 50%, and the African American population by 16%. Therefore, as per the recommendation of the organization, Building Engineering and Science Talent (BEST), an initiative of the Council on Competitiveness formed at the recommendation of the Congressional Commission on the Advancement of Women in Science, Engineering and Technology, federal policy has to reframe the issue of diversity (BEST, 2004). Instead of denying minorities and women admittance to science fields on the grounds of securing competitive advantage, administrators of higher education should recognize the importance of building a quality workforce. The focus should be on capacity-building.

(d) There should be equitable treatment for HBCUs. The NASULGC representative pointed out, “HBCU land-grants just started getting state money 5 years ago

(2000). TWI's get $7 state dollars for every $1 federal dollar. HBCUs are lucky if they get $1 for every federal $1. We cannot afford to have regressive attitudes. We need to invest in our students and be progressive." The aforementioned statistics support the need to treat minority institutions in an equitable manner. Even if there was no need to rely on minority workforce in science and engineering fields, all universities of the same status (accreditation and control) should receive equitable treatment for America to be more competitive. A free, competitive educational arena will most likely heighten the standard and quality of the education. Given that the supply of foreign labor the economy has traditionally relied on is decreasing and minority replacement is the most likely and viable alternative, then policy personnel should support the institutions that are disproportionately successful in supplying potential minority workforce. Federal agencies should also take diversity into account when awarding education and research grants to institutions of higher education.

(e) Federal agencies and other universities should study and understand the factors that make HBCUs successful in graduating at-risk students. HBCUs have higher proportions of at-risk students yet higher rates of matriculation of African American students than TWIs. A National Assessment of Educational Progress study shows underperformance by most minorities. A study of high school seniors found that 74% of white students and 80% of Asian/ Pacific Islander students scored at or above a level deemed basic by a national panel of experts. Only 31% of black, 44% of Hispanic, and 57% of American Indian/Alaskan Native students attained that level (National Science Board, 2004a). A number of

factors have been advanced to explain minorities' substandard performance (e.g., low teacher expectations, lack of interest in schooling, lack of role models, insufficient institutional support, isolation, insufficient parental support, outmoded curricula, peer pressure, and even claims of genetic inferiority),but no explanation has received widespread acceptance (Armstrong & Thompson, 2003; Lewis, 2003). Further research would provide insights in to the causes for disparity and the solutions to address it.

(f) This dissertation study, the BEST report, the Standing our Ground report, and other publications seek to research best methods and practices for producing quality science and engineering programs and workforce (Committee on Equal Opportunities in Science and Engineering, 2004; Malcom, Chubin, & Jesse, 2004). However, much more needs to be done. It is not only quantity of personnel that are needed but quality of personnel that are skilled in state-of-the-art equipment, techniques and practices. Policy personnel should, therefore, continue the study of successful research programs and best practices and use the insights gained to improve research and development programs overall.

11.6.2 Recommendations for HBCU Administrators

Administrators at HBCUs who are interested in either establishing a science and technology program or who are interested in growth strategies for their existing program should be interested in the results and findings of this study. The finding that strategy should be tied to context is significant. The study and the index should give them more insight into important variables, strengths and weaknesses in their program, and how to view their particular environment. As this is a relatively new and unexplored area they

will find several of the findings and recommendations to be relevant. Some of the following policy recommendations are directed toward establishing internal initiatives; others are directed toward exploiting external opportunities. Many HBCUs are not fully aware of the opportunities inherent in pursuing a science, engineering and technology program. Or they may be aware of the opportunities but believe that such a program is not within their budget or educational pursuit. The following are recommendations for HBCUs at various stages in their science and technology programs.

11.6.2.1 Internal University Policy

(a) In the 1940s, as U.S. prepared for the war, Black academicians like W.E.B. DuBois, Rufus Clement, Malcolm McLean and Herman Branson encouraged HBCUs to train personnel for the sciences, and other technical fields (Anderson, 1988; Branson, 1942; Clement, 1942; MacLean, 1942). As Branson put it. "If Blacks are 10% of the population they should be producing 10% of America's needs for physics science and technical personnel" (Branson, 1942, 299). HBCUs should adopt this belief today, particularly at this time. America is in need of skilled and trained scientists and technicians for security, defense, medical, and economic reasons. Many HBCUs understand that workforce needs exist in science and engineering. However, they have not aggressively addressed an increase in the supply. Apart from the programs they offer exposing science and engineering to high school students, there are few programs at the college level that encourage students to select s&t fields. The Science and Engineering Indicators 2004 report indicates that "the number of jobs in the U.S. economy that require science and engineering training will grow" while "the number of U.S.

citizens prepared for those jobs will, at best, be level" (National Science Board, 2004a). Responses from the liaisons support the numbers. Demand for students acts as a catalyst for development of linkages, partnerships and joint ventures (or vice-versa). Regardless of the direction of causality, the result is development of science and technology programs. Corporations want access to a talented labor pool. HBCUs enter a win-win proposition if they encourage students to not only major in STEM fields but pursue their education in those fields until they gain a specialized skill.

(b) The same academicians as early as the 1940s suggested that larger HBCUs should act as "mentors" and team up with smaller HBCUs to create a win-win situation or that smaller HBCUs should discontinue operation and merge with larger HBCUs (Branson, 1942; MacLean, 1942). In other words, HBCUs should engage in clustering. Larger HBCUs could win science and technology related contracts based on their infrastructure while utilizing personnel from other schools; smaller HBCUs could get their faculty trained and experienced at participating in contracts. This experience could lead into opportunities for the smaller HBCUs. Both groups share students, history, and culture. In modern culture, this idea can be accommodated through innovative education – virtual education and/or long distance education. As one Dean stated, discussions have already begun around the idea of creating a "virtual center." As he explained, HBCUs lack the infrastructure and resources to compete. But by collaborating and pooling resources, we can create a virtual center in which students can have access to a

larger library, different faculty, and different equipment. The idea of mentoring and collaboration is still viable and a solid recommendation for smaller HBCUs.

(c) HBCUs should consider expanding their mission and looking beyond the traditional boundaries of being teacher colleges or universities. They should consider learning how to start a science program. How do you start such a program? The Army representative said it always starts with a researcher.

> Someone has an idea. Maybe they think they can grease a wheel on a jeep better. They study military requirements and align their interests. The HBCU will contact an Army representative at Research Park and White Papers will exchange. The Army will decide to fund the idea. That idea grows into some students deciding to work on it. Annual solicitations come. The relationship with the Army causes other topics to be offered. The research may have $300,000 assigned to it. A center may evolve. Tuskegee now has $2 million for a 5-year period. In 5 years, Tuskegee will no longer be eligible for the Center but the Army may fund a follow-up in Material Sciences. Then a doctorate program evolves.

(d) HBCUs should invest in research and either develop or hire faculty that have those skills. Perhaps HBCU faculty can be given more release time. FAMU and Hampton have exhibited substantial progress in this area. They have produced research agendas in their department by establishing goals and holding faculty accountable through the evaluation process. A policy recommendation by BEST for all institutions of higher education is especially applicable for HBCUs. “Expanding the base of effective programs will require more rigorous evaluation of outcomes, *support of cutting-edge research on the issues that surround teaching and learning*, and increased participation of underrepresented groups in national research and evaluation efforts” (BEST, 2004). HBCUs should commit to shift from a “teaching” mission to a “teaching and research” mission.

(e) At the other end of the spectrum of encouraging students to choose s&t fields, HBCUs should encourage students to pursue Ph.D.s in science, engineering and technology fields. Since few HBCUs have doctoral programs, there may appear to be little incentive to provide encouragement in this direction. However, if the graduate student earns his/her degree at an HBCU, their presence helps bring in corporate dollars. If the student graduates from an HBCU and earns their Ph.D. at another school that student then represents a potential network contact for the HBCU. One of the liaisons was such an example. He felt some loyalty to his alma mater and thus encouraged and participated in the program his company had with an HBCU. Thus, students should be cultivated on all levels in science and technology fields.

<u>11.6.2.2. External Policy Initiatives</u>

(a) While internal initiatives focus on clustering with other HBCUs and universities, external policy focuses on networking. Just as Hampton found a market niche in the military complex and FAMU found a niche with the grape growers there are industry clusters all around the country. HBCUs should seek opportunities nearby and exploit them.

(b) Land-grants already have a link to industry based on their historical mission. They should determine the needs of industries with whom they are already affiliated so they know what to supply. They are in a natural position to do research on those needs.

(c) HBCUs should apply for all potential funding not just funds set-aside for minorities. As Hampton-1 stated "Those [set-aside] funds are a drop in the

bucket." The competition will make HBCUs improve. Even the failure to receive funding provides lessons for persistent applicants to learn the process and the requirements. This is a lesson learned from the competitive advantage literature.

(d) HBCUs should pool resources to work with and support organizations like NASULGC to lobby on their behalf and keep them informed. Support of organizations like this could result in a greater return to the HBCU. NASULGC sends information on funding opportunities to HBCUs. It is not clear how much interaction occurs regarding policy which affects HBCUs and policy which HBCUs could be initiating.

As the United States enters the 21st century, there is a need for America to remain scientifically competitive for economic, social, and political reasons. The U.S. must take advantage of every opportunity there is to develop science and technological capacity and that includes supporting HBCUs in their science and technology endeavors. As the NASULGC liaison stated, "Public policy provides the framework by which opportunity develops." This dissertation proves that policy does indeed open the doors and provide opportunity. But this dissertation also shows that policy gives way to relationships. Linkages are the key. Getting to the networking and clustering stages will give HBCUs the tools and strategies to forge a new path.

APPENDIX A: LIST OF HBCUS

	HBCU	State	CarnegieCode	Control	Region	Size
1	Alabama A&M Univ	Alabama	Doctoral II	Land-grant	South	Large
2	Alabama State Univ	Alabama	Master's I	Public	South	Large
3	Albany State Univ	Georgia	Master's I	Public	South	Medium
4	Alcorn State Univ	Mississippi	Master's I	Land-grant	South	Medium
5	Allen Univ	South Carolina	Baccalaureate	Private	South	Very Small
6	Arkansas Baptist College	Arkansas	Baccalaureate	Private	South	Very Small
7	Barber-Scotia College	North Carolina	Baccalaureate	Private	South	Very Small
8	Benedict College	South Carolina	Baccalaureate	Private	South	Medium
9	Bennett College	North Carolina	Baccalaureate	Private	South	Very Small
10	Bethune Cookman College	Florida	Baccalaureate	Private	South	Medium
11	Bishop State Community College	Alabama	Associates	Private	South	Medium
12	Bluefield State College	West Virginia	Baccalaureate	Private	Mid-Atlantic	Medium
13	Bowie State Univ	Maryland	Master's I	Public	Mid-Atlantic	Large
14	Central State Univ	Ohio	Baccalaureate	Public	Midwest	Small
15	Cheyney Univ of Pennsylvania	Pennsylvania	Master's I	Public	Mid-Atlantic	Small
16	Claflin College	South Carolina	Baccalaureate	Private	South	Small
17	Clark Atlanta Univ	Georgia	Doctoral II	Private	South	Medium
18	Clinton Junior College	South Carolina	Associates	Private	South	Very Small
19	Coahoma Community College	Mississippi	Associates	Private	South	Small
20	Concordia College	Alabama	Baccalaureate	Private	South	Very Small
21	Coppin State College	Maryland	Master's I	Public	Mid-Atlantic	Medium
22	Delaware State Univ	Delaware	Master's I	Public	Mid-Atlantic	Medium
23	Denmark Technical College	South Carolina	Associates	Public	South	Small
24	Dillard Univ	Louisiana	Baccalaureate	Private	South	Medium
25	Edward Waters College	Florida	Baccalaureate	Private	South	Very Small
26	Elizabeth City State Univ	North Carolina	Baccalaureate	Public	South	Small
27	Fayetteville State Univ	North Carolina	Master's I	Public	South	Medium
28	Fisk Univ	Tennessee	Baccalaureate	Private	South	Very Small
29	Florida A&M Univ	Florida	Master's I	Land-grant	South	Large
30	Florida Memorial College	Florida	Baccalaureate	Private	South	Small
31	Fort Valley State Univ	Georgia	Master's I	Land-grant	South	Medium
32	Grambling State Univ	Louisiana	Master's I	Public	South	Medium
33	Hampton Univ	Virginia	Master's I	Private	Mid-Atlantic	Large
34	Harris-Stowe State College	Missouri	Other	Public	Midwest	Small
35	Hinds Community College	Mississippi	Associates	Public	South	Large
36	Howard Univ	D.C.	Doctoral I	Private	Mid-Atlantic	Large
37	Huston-Tillotson College	Texas	Baccalaureate	Private	Southwest	Very Small
38	Interdenominational Theological Cen	Georgia	Other	Private	South	Very Small
39	J F Drake State Technical College	Alabama	Associates	Private	South	Very Small
40	Jackson State Univ	Mississippi	Master's I	Public	South	Large
41	Jarvis Christian College	Texas	Baccalaureate	Private	Southwest	Very Small
42	Johnson C Smith Univ	North Carolina	Baccalaureate	Private	South	Small
43	Kentucky State Univ	Kentucky	Master's II	Land-grant	South	Medium
44	Knoxville College	Tennessee	Associates	Private	South	Very Small
45	Lane College	Tennessee	Baccalaureate	Private	South	Very Small
46	Langston Univ	Oklahoma	Baccalaureate	Land-grant	Midwest	Medium
47	Lawson State Community College	Alabama	Associates	Private	South	Small
48	LeMoyne-Owen College	Tennessee	Baccalaureate	Private	South	Very Small
49	Lewis College of Business	Michigan	Associates	Private	Midwest	Very Small
50	Lincoln Univ (Jefferson City, MO)	Missouri	Master's II	Land-grant	Midwest	Medium
51	Lincoln Univ (Lincoln Univ, PA)	Pennsylvania	Master's II	Public	Mid-Atlantic	Small
52	Livingstone College	North Carolina	Baccalaureate	Private	South	Very Small

	HBCU	State	CarnegieCode	Control	Region	Size
53	Mary Holmes College	Mississippi	Associates	Private	South	Very Small
54	Meharry Medical College	Tennessee	Other	Private	South	Very Small
55	Miles College	Alabama	Baccalaureate	Private	South	Small
56	Mississippi Valley State Univ	Mississippi	Baccalaureate	Public	South	Medium
57	Morehouse College	Georgia	Baccalaureate	Private	South	Medium
58	Morehouse School of Medicine	Georgia	Other	Private	South	Very Small
59	Morgan State Univ	Maryland	Master's I	Public	Mid-Atlantic	Large
60	Morris Brown College	Georgia	Baccalaureate	Private	South	Medium
61	Morris College	South Carolina	Baccalaureate	Private	South	Very Small
62	Norfolk State Univ	Virginia	Master's I	Public	Mid-Atlantic	Large
63	North Carolina A&T State Univ	North Carolina	Master's I	Land-grant	South	Large
64	North Carolina Central Univ	North Carolina	Master's I	Public	South	Large
65	Oakwood College	Alabama	Baccalaureate	Private	South	Small
66	Paine College	Georgia	Baccalaureate	Private	South	Very Small
67	Paul Quinn College	Texas	Baccalaureate	Private	Southwest	Very Small
68	Philander Smith College	Arkansas	Baccalaureate	Private	South	Small
69	Prairie View A&M Univ	Texas	Master's I	Land-grant	Southwest	Large
70	Rust College	Mississippi	Baccalaureate	Private	South	Very Small
71	Saint Augustine's College	North Carolina	Baccalaureate	Private	South	Small
72	Saint Paul's College	Virginia	Baccalaureate	Private	Mid-Atlantic	Very Small
73	Saint Philip's College	Texas	Associates	Public	Southwest	Large
74	Savannah State Univ	Georgia	Baccalaureate	Public	South	Medium
75	Selma Univ	Alabama	Baccalaureate	Private	South	Very Small
76	Shaw Univ	North Carolina	Baccalaureate	Private	South	Medium
77	Shelton State Community College	Alabama	Associates	Public	South	Large
78	Shorter College	Arkansas	Associates	Private	South	Very Small
79	South Carolina State Univ	South Carolina	Master's I	Land-grant	South	Medium
80	Southern Univ A&M College/Baton R	Louisiana	Master's I	Land-grant	South	Large
81	Southern Univ/New Orleans	Louisiana	Master's II	Private	South	Medium
82	Southwestern Christian College	Texas	Other	Private	Southwest	Very Small
83	Spelman College	Georgia	Baccalaureate	Private	South	Medium
84	Stillman College	Alabama	Baccalaureate	Private	South	Small
85	Talladega College	Alabama	Baccalaureate	Private	South	Very Small
86	Tennessee State Univ	Tennessee	Doctoral II	Private	South	Large
87	Texas College	Texas	Baccalaureate	Private	Southwest	Very Small
88	Texas Southern Univ	Texas	Doctoral II	Public	Southwest	Large
89	Tougaloo College	Mississippi	Baccalaureate	Private	South	Very Small
90	Trenholm State Technical College	Alabama	Associates	Public	South	Very Small
91	Tuskegee Univ	Alabama	Master's I	Land-grant	South	Medium
92	Univ of Arkansas at Pine Bluff	Arkansas	Baccalaureate	Land-grant	South	Medium
93	Univ of Maryland Eastern Shore	Maryland	Master's I	Land-grant	Mid-Atlantic	Medium
94	Univ of the District of Columbia	District of Columb	Master's I	Land-grant	Mid-Atlantic	Large
95	Univ of the Virgin Islands	U.S. Virgin Island	Master's II	Land-grant	Virgin Island	Small
96	Virginia State Univ	Virginia	Master's I	Land-grant	Mid-Atlantic	Medium
97	Virginia Union Univ	Virginia	Baccalaureate	Private	Mid-Atlantic	Small
98	Voorhees College	South Carolina	Baccalaureate	Private	South	Very Small
99	West Virginia State College	West Virginia	Baccalaureate	Land-grant	Mid-Atlantic	Medium
100	Wilberforce Univ	Ohio	Baccalaureate	Private	Midwest	Very Small
101	Wiley College	Texas	Baccalaureate	Private	Southwest	Very Small
102	Winston-Salem State Univ	North Carolina	Baccalaureate	Public	South	Medium
103	Xavier Univ of Louisiana	Louisiana	Master's I	Private	South	Medium

APPENDIX B: DEFINITIONS OF INDEPENDENT VARIABLES

Definitions of characteristics of HBCUs.

A) Years – The term "Years" refers to either a 2-year or 4-year institution.

B) Carnegie code – The Carnegie typology was created by the Carnegie classification. The codes 1-9 follow their classifications respectively.

1 - Doctoral/Research University-Extensive. They award 50 or more doctoral degrees per year across at least 15 disciplines.

2 – Doctoral/Research University-Intensive. They award 10 or more doctoral degrees per year across at least 3 or more disciplines or at least 20 doctoral degrees per year overall.

3 – Master's Colleges and Universities I. They award 40 or more master's degrees per year across three or more disciplines.

4 – Master's Colleges and Universities II. They award 20 or more master's degrees per year.

5 – Baccalaureate Colleges – Liberal Arts. Primarily undergraduate, they award at least half of their baccalaureate degrees in liberal arts fields.

6 – Baccalaureate Colleges – General. Primarily undergraduate, they award less than half of their baccalaureate degrees in liberal arts fields.

7 – Baccalaureate/Associate's Colleges. Primarily undergraduate, the majority of their awards are at the subbaccalaureate level (associate degrees and certificates). During the period studied, bachelor's degrees account for at least 10% but less than half of all undergraduate awards.

8 - Associate's Colleges. These institutions offer associate's degree and certificate programs, but with few exceptions, award no baccalaureate degrees. This group includes institutions where, during the period studied, bachelor's degrees represented less than 10% of all undergraduate awards.

9 - Specialized Institutions. They offer degrees ranging from the bachelor's to the doctorate and typically award a majority of degrees in a single field. For HBCUs, this includes a) theological seminaries and other specialized faith-related institutions and b) medical schools and medical centers.

C) Control – This term was taken from Graham and Diamond's study. Control refers to university ownership. There are 3 categories: Private, Public and Land-grant. Sixteen HBCUs were originally designated as land-grant. There are currently 19 land-grant HBCUs. Howard University is a private HBCU but it is supported by federal funds. Please see list of HBCUs in Appendix A for a complete listing of HBCU ownership.

D) Region – Regional designation was coded as per the Census Bureau.
- 1 – South (Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Kentucky)
- 2 – Mid-Atlantic (District of Columbia, Delaware, Maryland, Pennsylvania, Virginia, West Virginia
- 3 – Southwest (Texas)
- 4 – Midwest (Missouri, Arkansas, Michigan, Ohio, Oklahoma)
- 5 – U.S. territory (Virgin Islands)

E) Size – Size was coded as per Barron's Profile of American Colleges (with the exception of the very small category. Since so many HBCUs had populations of less than 2,000, an additional category was created.
- Very Large – 10,000 or greater
- Large – 5,000 through 9,999
- Medium – 2,000 through 4,999
- Small – 1,000 through 1,999
- Very Small – Lowest through 999

APPENDIX C: STATISTICAL SUMMARY OF FAMU, FVSU AND HAMPTON

All R&D expenditures data were obtained from the National Science Foundation (NSF) Web Caspar database (Integrated Science and Engineering Resources Data System) http://caspar.nsf.gov

Federal R&D Expenditures

	FAMU		FVSU		Hampton		Total HBCUs	
1985	7,266		-		-		57,873	
1986	7,683	5.7%	-	0.0%	-	0.0%	60,910	5.2%
1987	8,100	5.4%	-	0.0%	-	0.0%	61,572	1.1%
1988	8,674	7.1%	-	0.0%	-	0.0%	75,998	23.4%
1989	10,509	21.2%	1,741		2,168		106,759	40.5%
1990	13,110	24.8%	1,938	11.3%	2,307	6.4%	116,827	9.4%
1991	15,592	18.9%	2,047	5.6%	3,345	45.0%	122,682	5.0%
1992	18,698	19.9%	2,384	16.5%	3,272	-2.2%	146,624	19.5%
1993	18,954	1.4%	2,413	1.2%	4,597	40.5%	157,207	7.2%
1994	20,730	9.4%	2,591	7.4%	5,078	10.5%	174,561	11.0%
1995	19,430	-6.3%	2,936	13.3%	6,130	20.7%	199,335	14.2%
1996	20,118	3.5%	2,338	-20.4%	3,854	-37.1%	222,262	11.5%
1997	22,547	12.1%	2,471	5.7%	7,777	101.8%	254,256	14.4%
1998	15,726	-30.3%	2,359	-4.5%	6,801	-12.5%	248,633	-2.2%
1999	20,693	31.6%	2,318	-1.7%	7,168	5.4%	216,513	-12.9%
2000	16,278	-21.3%	2,417	4.3%	8,994	25.5%	228,087	5.3%
2001	22,477	38.1%	2,417	0.0%	8,377	-6.9%	261,903	14.8%
Fed Total	266,585		30,370		69,868		2,712,002	

State and Local R&D Expenditures

	FAMU		FVSU		Hampton		Total HBCUs	
1985	-		-		-		1,150	
1986	-		-		-		1,163	1.1%
1987	874		-		-		2,528	117.4%
1988	2,897	231.5%	-		-		4,475	77.0%
1989	3,063	5.7%	-		-		6,883	53.8%
1990	2,592	-15.4%	-		-		6,902	0.3%
1991	2,818	8.7%	-		-		6,505	-5.8%
1992	2,241	-20.5%	-		-		9,053	39.2%
1993	2,320	3.5%	-		-		8,577	-5.3%
1994	2,360	1.7%	-		-		9,533	11.1%
1995	1,208	-48.8%	-		-		11,162	17.1%
1996	2,356	95.0%	75		-		11,842	6.1%
1997	2,868	21.7%	303	304.0%	-		11,346	-4.2%
1998	3,340	16.5%	415	37.0%	-		12,908	13.8%
1999	929	-72.2%	398	-4.1%	-		6,877	-46.7%
2000	5,334	474.2%	93	-76.6%	-		10,699	55.6%
2001	1,388	-74.0%	93	0.0%	-		8,922	-16.6%
S&L Total	36,588		1,377		-		130,525	

APPENDIX C: STATISTICAL SUMMARY OF FAMU, FVSU AND HAMPTON (cont'd)

Industry R&D Expenditures

	FAMU		FVSU		Hampton		Total HBCUs	
1985	-		-		-		1,377	
1986	253		-		-		1,797	30.5%
1987	-		-		-		1,637	-8.9%
1988	366		-		-		3,292	101.1%
1989	393	7.4%	-		-		3,966	20.5%
1990	145	-63.1%	-		-		5,353	35.0%
1991	142	-2.1%	-		-		3,230	-39.7%
1992	1,291	809.2%	-		-		4,145	28.3%
1993	1,503	16.4%	-		-		4,796	15.7%
1994	1,601	6.5%	-		-		6,724	40.2%
1995	159	-90.1%	-		-		6,481	-3.6%
1996	-		61		-		6,450	-0.5%
1997	-		89	45.9%	-		5,182	-19.7%
1998	-		215	141.6%	-		5,030	-2.9%
1999	-		221	2.8%	-		5,388	7.1%
2000	-		258	16.7%	10		6,084	12.9%
2001	-		258	0.0%	48	380.0%	6,871	12.9%
IndustryTotal	5,853		1,102		58		77,803	

Institutional R&D Funding

	FAMU		FVSU		Hampton		Total HBCUs	
1985	173		-		-		1,867	
1986	349	101.7%	-		-		7,223	286.9%
1987	60	-82.8%	-		-		7,884	9.2%
1988	142	136.7%	-		-		8,392	6.4%
1989	206	45.1%	423		-		12,086	44.0%
1990	-		374	-11.6%	-		11,442	-5.3%
1991	-		323	-13.6%	-		14,062	22.9%
1992	-		327	1.2%	-		14,977	6.5%
1993	-		336	2.8%	-		17,716	18.3%
1994	-		57	-83.0%	264		17,187	-3.0%
1995	-		73	28.1%	214	-18.9%	21,050	22.5%
1996	-		-		-	-100.0%	19,697	-6.4%
1997	-		-		225		13,962	-29.1%
1998	-		-		339	50.7%	10,696	-23.4%
1999	-		-		290	-14.5%	14,681	37.3%
2000	-		-		269	-7.2%	13,163	-10.3%
2001	-		-		643	139.0%	18,837	43.1%
InstTotal	930		1,913		2,244		224,922	

APPENDIX C: STATISTICAL SUMMARY OF FAMU, FVSU AND HAMPTON (cont'd)

Graduation data were obtained from National Center for Education Statistics (NCES) IPEDS data system. http://nces.ed.gov/ipeds/

Graduation Data

Academic Yr	FAMU		FVSU		Hampton		All HBCUs	
87-88	415		99		369		12,392	
89-90	463	11.6%	119	20.2%	444	20.3%	12,595	1.6%
91-92	562	21.4%	131	10.1%	503	13.3%	14,405	14.4%
93-94	775	37.9%	173	32.1%	536	6.6%	17,141	19.0%
95-96	1,022	31.9%	201	16.2%	593	10.6%	20,262	18.2%
97-98	956	-6.5%	201	0.0%	590	-0.5%	20,945	3.4%
99-00	1,065	11.4%	166	-17.4%	602	2.0%	20,302	-3.1%
Total	5,258		1,090		3,637		118,042	
Percent Increase 1987-2000		156.6%		67.7%		63.1%		63.8%

Publication data were obtained from Web of Science database from ISI (Science Citation Index, Social Sciences Citation Index, Arts and Humanities Index)

Publication Data

Academic Institu	FAMU		FVSU		Hampton		TotalHBCUs	
1986	-		N/A		-		1	
1987	-	0.0%			3	400.0%	21	2000.0%
1988	2	200.0%			-	-100.0%	13	-38.1%
1989	1	-50.0%			-	0.0%	17	30.8%
1990	1	0.0%			1	100.0%	29	70.6%
1991	2	100.0%			3	200.0%	59	103.4%
1992	3	50.0%			2	-33.3%	50	-15.3%
1993	4	33.3%			6	200.0%	78	56.0%
1994	8	100.0%			4	-33.3%	90	15.4%
1995	2	-75.0%			2	-50.0%	89	-1.1%
1996	18	800.0%			5	150.0%	179	101.1%
1997	21	16.7%			25	400.0%	277	54.7%
1998	36	71.4%			25	0.0%	373	34.7%
1999	29	-19.4%			29	16.0%	337	-9.7%
2000	34	17.2%			23	-20.7%	367	8.9%
2001	33	-2.9%			23	0.0%	384	4.6%
2002	40	21.2%			16	-30.4%	442	15.1%
PubTotal	234				167		2,806	

APPENDIX D
HBCU CASE STUDY PROTOCOL

I. OVERVIEW

A. Project Description and Objectives

Historically Black Colleges and Universities (HBCUs) face the 21^{st} century with questions about change and adaptation to an increasingly science and technology oriented society. They face the challenge of determining a strategy by which they can utilize current resources and energy to find their science and technology niche. This study conducts a comparative and analytical study of science and technology at HBCUs for the purpose of assisting HBCUs and those interested in supporting potentially capable science and technology institutions in determining productivity levels, characteristics of competitive universities, and effective strategies for science and technology productivity. The primary objective is to determine what theories (when implemented they are termed strategies) account for the development of science and technology at the most successful research-oriented HBCUs. (This is not meant to imply "best strategies" but strategies that appear to be useful and working well.) This will be accomplished through a secondary objective – to assess productivity outputs at HBCUs in various science and technology indices.

This dissertation study posits the theory that development of linkages in the form of networking or clustering between the university and external bodies is a strategy that can be adopted to improve science and technology productivity at HBCUs. Using a qualitative exploratory approach, this study also examines several other theories to determine whether they have more validity for explaining the development of science and technology at HBCUs. These rival theories or strategies have emerged from literature bases on higher education, labor, and innovation. The target audience to which the findings are directed are HBCU leadership involved in policy, HBCU science and technology departments, and federal and state government agencies that are interested in identifying potential niches for support of science and technology development.

B. Case Study Issues

Several substantive issues arise in relation to this research topic.

- The first issue to be addressed is whether HBCUs should be a topic of study in regards to science and technology. They are a small segment of the university population, they cater to a select targeted audience, their student population size is generally small, and few studies have explored the general state of science and technology development at HBCUs outside of issues regarding the digital divide (what computer hardware do students at HBCUs have relative to the general population).

Appendix D - Case Study Protocol (cont'd)

- What criteria and methods should be used to measure science and technology productivity at HBCUs? As a generally disadvantaged population, should traditional measures such as patents, citations, leasing revenue, and so forth be used? Researchers have given considerable discussion to exploring the development of valid, adequate, and useful measures for science and technology and have found many current criteria as wanting in some aspect. Criteria such as patents and licenses often lead to weighting in favor of medical schools, life science departments, and large departments. Small and poor student populations as well as historically discriminatory funding patterns put HBCUs at a financial disadvantage. The selection of appropriate but under-utilized indices is important for entities such as HBCUs that are unique institutions.

- This study puts forward the hypothesis that linkages in the form of networking and clustering is the predominant explanation accounting for science and technology growth at HBCUs. However, several rival hypotheses have also been advanced. At issue is the determination of which theory can gather the preponderance of the evidence to support its claim that it explains science and technology growth at HBCUs. Also, what constitutes "preponderance of evidence."

- How should "linkages" be defined? The term is used in a myriad number of ways. Rarely is the term defined since it encompasses many levels of communication and interaction. Clearly there are differing levels of linkages. How should the more elementary levels of linkages such as attending association or sharing information during meals which are forms of technology diffusion be compared to collaborations and networks that result in dual-degree programs? Should this study use all forms of definitions or should the study select one aspect of linkages? Finally, there is the question of some levels of linkages being embedded in rival explanations. Is communication or linkages involved in universities becoming aware of federal policy? Another example lies in the communication that occurs as a result of proximity. These questions and issues must be addressed in the study.

- Another issue is access to and availability of data. In past articles and studies, HBCUs have been portrayed as poor, inferior institutions that offer substandard education. As a result, they are sensitive to research studies that may make "judgments." Some of the documentation required to support and substantiate the theoretical claims will have to come from the university. A challenge for this research study is whether the data for support of the theory(ies) exists and whether it will be made available for this study.

Appendix D - Case Study Protocol (cont'd)

- Finally, there arise issues associated with case study methodology. Are the results and findings generalizable and applicable to other situations? This study has been structured to meet the same scientific standards required by general scientific experiments. By adopting these standards, this study enables the theory, which leads to the findings to be generalizable and applicable to other similar universities.

C. Relevant Readings

1) Literature on Higher Education
    - [Graham, 1997 #405]
    - [National Science Board, 2004 #556]
    - [Anderson, 1988 #518]
    - [BEST, 2004 #553]
    - [Lucas, 1994 #532]
2) Literature on National Systems of Innovation
    - [Nelson, 1993 #383]
    - [de la Mothe, 2000 #349]
    - [Acs, 2000 #333]
    - [Storper, 1997 #390]
3) Literature on Competitive Advantage
    - [Porter, 1990 #107]
    - [Doeringer, 1995 #106]
    - [Bergman, 1999 #304]
    - [Cooke, 2002 #536]

Further readings on these topics can be found in the References section.

Appendix D - Case Study Protocol (cont'd)

II. FIELD PROCEDURES

A. Presentation of Credentials and Access to the Case study "sites"

Letters requesting access to interview faculty and students were sent to the Presidents of the three targeted HBCUs. A sample of the letter follows:

Dear President X,

I am writing to seek your assistance in conducting a sample of research interviews at your institution as part of my doctoral dissertation. I am a Ph.D. candidate in the Joint Doctoral program in Public Policy at Georgia Institute of Technology and Georgia State University.

My doctoral dissertation, "the Effect of Linkages on Science and Technology at HBCUs" seeks to understand the factors contributing to the growth of science and technology at predominantly Black research universities. My dissertation advisor is Professor Philip Shapira of the Georgia Tech School of Public Policy. Other advisors include a member of my dissertation committee, Dr. Willie Pearson, author of *Blacks in Science*, and Dr. Shirley Malcom who has agreed to assist me as well.

I would like to interview several people at your university – the Vice President of Sponsored Research (or the equivalent position) and two faculty members. The interview will cover topics such as science and technology specialties at your school, partners with whom the university works, and how partners were developed. Each interview should last about 20-30 minutes. Participation is voluntary. All interviews will be conducted in accordance with procedures for research with human subjects established by the Georgia Tech Institutional Review Board.

Your approval will be greatly appreciated. I look forward to hearing from you. If you have any questions please feel free to contact me by mail at the above address or by email at dkttbrice@aol.com or by phone at (770) 490-9657.

Sincerely,

Kathryn T. Brice

Appendix D - Case Study Protocol (cont'd)

B. General Sources of Information

- Vice President of Sponsored Research
- Deans/Chairs/Directors of science, engineering and technology programs
- Websites
- Mission Statements
- Department goals and objectives
- Budgets
- Annual Reports
- External liaisons to the HBCU (corporations, government, and other universities)
- Journal articles
- Reports
- Magazine and newspaper articles
- Books
- Personal observation
- Public databases (CASPAR, IPEDS, ISI Web of Science)

C. Procedural Reminders

1) Get IRB from Georgia Tech.
2) Collect as much research as possible from external sources (associations, federal government policies, state government policies, Black S&T journals, Black S&T magazines, local newspaper articles on S&T at HBCU or majority university) and university internal sources (website, annual report, 5 year plan)
3) Send letter requesting approval to interview subjects to HBCU President
4) Go to website and determine what departments Chairs should be interviewed
5) Make note of the mission statements and goals and objectives for the targeted department
6) Develop itinerary of interviews with contact numbers
7) Prior to the interview, review the NSF Federal obligations for science and engineering by agency for the university
8) Incorporate the NSF data into the questions
9) Incorporate the department's/interviewee's goals and objectives into the questions
10) Print a copy of the tailored questionnaire for each interview prior to site visit
11) Start the interview by getting the Consent Form signed.
12) Conduct the interview
13) While at the university site, go to other departments that may contain relevant information – e.g. obtain budget, strategic plan, university park
14) Type the results of the interview

Appendix D - Case Study Protocol (cont'd)

III. CASE STUDY QUESTIONS

The questions were obtained by checking two sources. The first source was questionnaires for science and technology productivity on the Internet. The second source was a review of the questionnaires used for two survey studies conducted at affiliated institutions – Georgia Institute of Technology and Georgia State University. Questions were drawn and rephrased for the purpose of this study. The first draft of questions was presented to an HBCU that was ineligible for the study (it was not a research HBCU). The questionnaire was revised. The questionnaire was then sent to a research university and further revised. The following represents the final questionnaire.

University ______________________ **Interview Date** ___________
Person __________________________ **Start Date at Univ** ________
Position _________________________

Hello, my name is Kathryn Brice and I am a doctoral student in pubic policy at Georgia Tech and Georgia State University. My dissertation is on science and technology at HBCUs and I'm interviewing you to get your perspective on partnerships and other factors that may contribute to the development of science and technology at your university. FYI, for the purpose of these questions I am defining partners, entities and collaborators as the same thing - organizations (whether they be federal, state, or local agencies, private companies, universities or non profits) with whom you have received a contract, developed a program, supplied students, joint ventured on a program, and so forth.

1. What are the priorities or goals of your department as it relates to S&T.
____
____
____
____

2. What type of organizations that provide benefits/resources to Hampton do you interact with the most – government, industry, other universities, or other organizations? Why – most or best resources or services? What type of resources/services do they provide? Who are the top organizations within the type you chose?
____
____
____
____
____

Appendix D - Case Study Protocol (cont'd)

3. Can you take one of the organizations above that you interact with a great deal that might be typical of how you develop relationships and explain how a relationship began between this organization and your university?
    a. Who is the organization?
    b. When communication was initiated with this organization
    c. the individual/position with whom you communicate,
    d. for what time period,
    e. with what frequency,
    f. and for what purpose?
    g. Is the development of this relationship typical of how relationships with other organizations developed?

____
____
____
____
____
____
____
____

4. Have any of the organizations that you work with or obtain benefits from initiated actions to benefit the university (e.g., found another partner for the university, provided contacts elsewhere or overseas, helped establish a program with another partner, raised funds, and so forth)? Would you say most of the organizations you work with do this, a good number of them, one or two, or none of the organizations you work with. What do the organizations that assist you do?

____
____
____
____
____

5. Does your university have a policy to collaborate with other institutions (federal, state and local agencies as well as firms)? If so, how? Is there any extra effort to collaborate with other universities or HBCUs?

____
____
____
____
____

Appendix D - Case Study Protocol (cont'd)

6. What policies are you aware of that have had an impact on this university's involvement in science and technology (federal, state or local)? the White House initiative on HBCUs? Has the White House policy influenced other policies to be created that foster science and technology at HBCUs? **When** did they occur at the national level? State level?

7. Have there been any administrators at the overall university level, or any Deans or Chairs of S&T departments, or any key faculty/scientists/contractors that have promoted the development of S&T at this university? If so, who are they, **when** did they join the University, and what impact have they had? Have any actions been taken as a result of their support of S&T?

8. Has there been any S&T development at the university due to its spatial proximity to a highly productive S&T center (i.e., another university known for S&T, a science or technology park, a business known for S&T, etc? If so, how and why did development occur at the university based on its spatial proximity?

9. Has S&T development at the university changed due to societal demand for skilled personnel in S&T but scarce national supply? If so, what was the **time** period in which decisions to respond to the demand were made? Have students demanded the development of S&T (i.e., S&T courses)? How has supply and demand impacted the university?

10. Identify the barriers that impede your institution's advancement of research, training of students in S&T fields, obtaining of contracts, or commercialization of any products or research you conduct.

Appendix D - Case Study Protocol (cont'd)

11. Which do you believe best accounts for the development of S&T at your university – a) the development of linkages or relationships, b) public policy that has been enacted, c) leadership from within the university, d) spatial proximity to an entity already productive in S&T, or e) supply and demand conditions for skilled S&T personnel? Why do you believe the one you chose had the most impact?

12. How do HBCUs differ from majority institutions in their S&T development, if at all? Are there other criteria, other than the standard ones of publications, patents, federal R&D dollars, and number of student grads in S&T, that should be used to measure science and technology productivity at HBCUs?

13. Is there anything I haven't asked that you think is important to the development of S&T at HBCUs?

Appendix D - Case Study Protocol (cont'd)

IV. GUIDE FOR THE CASE STUDY REPORT

A. Outline for each Case Study

I. Overview of the University
   - Introduction and Characteristics
   - History
   - Structure
   - S&T Statistics
   - Unique Achievements
   - Analysis

II. Interviews – the evidence (partnerships, policies, location, current leadership in S&T) obtained from the interviews

III. Summary of Interviews– analysis of the evidence to determine support for the theory(ies)

IV. Coding – matrix that depicts results and coding of interviews

B. Format for the Data - Coding Matrix

C. Use and presentation of Other Document – Put information on Liaisons and other corroborating or conflicting information in Chapter following the Case studies

D. **Bibliographical Information** – see References section

APPENDIX E
PATTERN MATCHING PREDICTIONS

How are theories evaluated? Theories cannot be conclusively proved or disproved. One cannot conclusively state that science and technology development results or does not result from linkages or policy or proximity. But the logic underlying theories can be examined and compared to "facts" in the real world. Predictions derived from theory can be tested against observed occurrences. The following represents the predictions for each of the theories presented in this study. The comparison of theory to events is accounted for in the body of the study (Chapters 7, 8, and 9).

Theories and Predictions

Theory 1: Linkages (Interactive factors between the university and other entities)
Statement: Theories on Linkages as Networks and Clusters state that formal partnerships (implicit or explicit) between HBCUs and external organizations in which there are mutually exchanged benefits positively affect science and technology productivity at HBCUs.
Evidence: Evidence supporting Linkages was gathered from three questions on the survey instrument. The first question asked the Respondent to select an organization with whom the University interacts a great deal that might be typical of how relationships are developed at the department and to explain how a relationship began and developed. The second question asks the Respondent whether there were policies to collaborate with other institutions. The third question asks what benefits were received from university partners. Evidence was also pulled from relevant responses to other questions.
Predictions:

1. That Networks or Clusters exist (as defined earlier in this study).
2. The network/cluster formed to stimulate the development of science and technology
3. The network/cluster was the reason for the initiation of the program/department/college

Linkages received a "Yes" in response to the question, "Did linkages lead to initial s&t development?" if evidence was found to support all three criteria.

Theory 2: Policy (factors external to the university)
Statement: The Policy theory states that policies in the form of laws, guidelines, and initiatives developed by governmental agencies such as the White House and the federal and state governments regarding HBCUs and science and technology have assisted and enabled and are responsible for the growth of science and technology productivity at HBCUs [McBay, 1978 #352].

Appendix E – Pattern Matching (cont'd)

Evidence: Evidence supporting the theory of Policy was gathered primarily from the question on the survey instrument that asked, "What policies external to the University at the government level (federal, state or local) are you aware of that have had an impact on your university's involvement in science and technology?" Evidence was also pulled from relevant responses to other questions.

Predictions:
1. That a policy exists which enables HBCUs to develop science and technology
2. That HBCUs become aware of these policies and initiate action to take advantage of the policy
3. That university policy regarding science and technology is initiated within a reasonable time (1 year) of the initiation of the policy

Policy received a "Yes" in response to the question, "Did policy lead to initial s&t development?" if evidence was found to support all three criteria.

Theory 3: Leadership (factors internal to the university)

Statement: The Leadership theory states that key individuals, whether they be administrators (President, Dean, S&T Department Chair) or key scientists at HBCUs, are responsible for the growth of science and technology productivity at HBCUs [Darby, 1996 #430].

Evidence: Evidence supporting Leadership was gathered primarily from the question on the survey instrument that asked the respondent whether there were any administrators (faculty, Deans or Chairs) or key scientists responsible for promoting science and technology at the university. Evidence was also pulled from relevant responses to other questions.

Predictions:
1. The introduction of a new or newly promoted leader/star scientist.
2. Advocacy or influence in the form of promoting S&T or increasing S&T productivity rates after the introduction of the new or newly promoted leader/star (within 1 year).

Leadership received a "Yes" in response to the question, "Did leadership lead to initial s&t development?" if evidence was found to support both criteria.

Theory 4: Spatial Proximity (fixed factors external to the university)

Statement: The Spatial Proximity theory states that having a location near centers of innovation (high science and technology activity) creates a feedback loop that enhances and, therefore, leads to greater science and technology productivity output of participating institutions [Oinas, 2002 #440][Varga, 2000 #385].

Evidence: Evidence supporting Proximity was gathered primarily from the question on the survey instrument that asked, "Has there been any S&T development at your university due to its spatial proximity to a business, another university or science park? If so, how, why and when did development occur?" Evidence was also pulled from relevant responses to other questions.

Appendix E – Pattern Matching (cont'd)

Predictions: 1. Higher S&T productivity rates for HBCUs located near a center of innovation or

2. Creation or expansion of an s&t program

Proximity received a "Yes" in response to the question, "Did proximity lead to initial s&t development?" if evidence was found to support either criteria.

Theory 5: Demand for Research and Skilled Personnel (factors external to the university)

Statement: The Demand theory relies on traditional economic theory of supply and demand to explain that the science and technological explosion since the 1950s in the United States has caused a significant need and demand for research, innovation, and skilled personnel. There is a limited supply of skilled personnel to do research and innovation. The market therefore, is adjusting to produce factors (resources, programs, policies, investments) at universities that will increase the supply of scientists and research.

Evidence: Evidence supporting the theory of demand for skilled personnel was gathered primarily from the survey question that asked, "Has your university changed its policies toward student graduation as a result of the demand for skilled personnel?" Evidence was also pulled from relevant responses to other questions.

Predictions:

1. The University is aware of the personnel shortage and research needs
2. The University creates programs to encourage students to major in S&T or to encourage faculty to get more S&T contracts.
3. The University graduates more students in S&T fields.

Demand received a "Yes" in response to the question, "Did demand for skilled personnel lead to initial s&t development?" if evidence was found to support all three criteria.

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