ABSTRACT

Title of Dissertation: EXAMINING UNDERGRADUATE STEM DEGREE PRODUCTION ACROSS STATES: A PANEL DATA ANALYSIS

Erin Denise Knepler,
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Dissertation directed by: Dr. Marvin A. Titus
Department of Counseling, Higher Education, and Special Education

The United States is not producing enough college graduates in science, technology, engineering, and mathematics (STEM) fields (Kuenzi, Matthews, & Mangan, 2006; Chen & Weko, 2009). By 2025, there will be over three million STEM jobs to be filled in the United States and more than two million may remain unoccupied (Giffi et al., 2018). This study explores how undergraduate STEM degree production is influenced by state higher education STEM policies, and uses a microeconomic conceptual model rooted in two theories derived from economics and political science: principal agent theory and production function theory. Panel data over a 17-year time period from all 50 states were analyzed to address two questions:

1) How is undergraduate STEM degree production within a state related to state

economic and higher education finance variables?

2) Controlling for state economic and higher education finance variables, how are states' undergraduate STEM degree production influenced by state higher education STEM policies?

The study found that state undergraduate enrollment per full-time equivalent (FTE) and state expenditures for need-based aid per undergraduate FTE influence state STEM degree production. Different time lag models were used to analyze the effect of state STEM policies.

Two variables representing state STEM policies, incentives for STEM and articulation agreements in STEM influence STEM bachelor's degree production in a state when no time lag is applied. Three variables representing state STEM policies (i.e., incentives, articulation agreements, and scholarships), however, influence STEM degree production in a state when lagged by five years.

Results from this study contribute to both literature and policy. The conceptual model combines two theories to higher education literature providing a useful framework for analyzing the effects of various state actions on STEM degree production. Potential policy implications also emerged: 1) policy-focused research can inform stakeholders and the public of what are the influencers of STEM degree production and the impact of policy on STEM degree production; 2) data can be used to drive policy development focused on meeting state completion objectives and economic goals; and 3) understanding what drives policy adoption is useful context for states looking to affect STEM policy development.

EXAMINING UNDERGRADUATE STEM DEGREE PRODUCTION ACROSS STATES:A PANEL DATA ANALYSIS

by

Erin Denise Knepler

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Advisory Committee:
Associate Professor Marvin A. Titus, Chair
Professor Alberto Cabrera
Professor Sharon Fries-Britt
Professor Steven Klees
Dean and Professor Jennifer Rice
Associate Vice Chancellor and Research Professor Nancy Shapiro

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Table of Contents

Examining How Undergraduate STEM Degree Production is Influenced by State Higher Education STEM Policies Across States: A Panel Data Analysis

Chapter One: Introduction

The United States needs significant investment in the country's educational infrastructure in order to meet the economic demands related to growing science, technology, engineering, and mathematics (STEM) fields (Cromley, Perez, & Kaplan, 2016). The National Association of Manufacturing and Deloitte (2018) report that by 2025, there will be over three million STEM jobs to be filled in the United States and it is estimated that more than two million will remain unoccupied (Giffi et al., 2018). According to a report from the President's Council of Advisors on Science and Technology (PCAST) (2012), without such educational investments (e.g., similar funding investments like those made possible by the National Defense Education Act of 1958), the United States' future economic prosperity and world standing are at risk. The production of STEM degrees, as a proportion of all degrees produced in the United States, has decreased (U.S. Department of Education, National Center for Education Statistics, 2009) in recent years. The percentage of bachelor's degrees conferred in science, technology, engineering, and mathematics fields in the United States was lower in 2008–09 (24.2%) than it was in 1998–99 (25.6%) (U.S. Department of Education, National Center for Education Statistics, 2009). More recently, a 2016 report from the Nation Center for Education Statistics found that 18% all of the bachelor's degrees awarded in 2015-2016 were in STEM fields.

As the United States economy transitions from heavy manufacturing, more STEM degrees are needed than ever before (President's Council of Advisors on Science and Technology, 2012; National Science Board, 2015; Cromley et al., 2016). The production of STEM degrees has fallen in the past decade; without action “it is likely that this proportion will continue to drop as groups that have historically earned fewer STEM degrees on average than white men become a larger majority of college students” (President's Council of Advisors on Science and Technology, 2012, p. 1). The United States has enjoyed prosperity and achieved many scientific and technological successes, in part, because of a long history of federal government educational investment. Examples include the creation of land grant colleges and universities, the GI Bill, the National Defense Education Act, and the Post-911 GI Bill. Like past investments by the federal government, investments made by states through the creation of state STEM policies could potentially answer the call to produce more qualified individuals in STEM fields. At the same time, such investments may transform and reinvigorate a state’s economy.

State leaders are increasingly aware of the important role of STEM (National Governor’s Association, 2011; President's Council of Advisors on Science and Technology, 2012). Budgetary and policy levers can be used to highlight and improve a state’s STEM education pipeline as well as build the necessary political will to make meaningful changes across education systems (National Governor’s Association, 2011). Furthermore, the National Governor’s Association (2011) Center for Best Practices notes that state governors “are in a unique position to advance comprehensive STEM education policy agendas aligned with workforce expectations that will ultimately aid state economic growth” (p.1). States have started to evaluate their own education systems and are considering what strategies (i.e., STEM policies) have the power to improve the overall quality of education in order to prepare students for jobs in a 21st century workforce. Some states have legislated policies that could increase the rigor of high school courses, address the problem of losing students who were college-bound, and improve the quality of the teaching and leadership within a school (STEM Education Coalition, 2013; STEM Education Coalition, 2016; STEM Education Coalition, 2017).

More specifically, state legislators are focusing on STEM policies, which range from increasing high school graduation requirements in computer science, math, and science, providing incentives for teachers in STEM areas, specific STEM related articulation agreements, and providing incentives for students who pursue STEM fields at the post-secondary level (STEM Education Coalition, 2013; STEM Education Coalition, 2016; STEM Education Coalition, 2017).

Purpose of the Study

Some state policymakers are understandability concerned with the rate of STEM degree production in their states, as the production of STEM degrees can play a role in any state's long-term economic vitality (STEM Education Coalition, 2013; STEM Education Coalition, 2016; STEM Education Coalition, 2017). This study explores how state higher education STEM policies influence undergraduate STEM degree production. While prior research (e.g., Eagan, Hurtado, & Chang, 2010) explored the role institutions play in STEM degree production (from an economic and human capital perspective) and other studies examined the impact of state financial policies on baccalaureate completion levels across states over time (e.g., Titus 2006, 2009), no published research to date was found that examined how state higher education STEM policies influence the production of STEM degrees.

Background of the Problem

Educators and policymakers have increasingly expressed concern that the United States is not producing a sufficient number of college graduates in STEM fields required to grow the economy and fill open STEM jobs requiring at least a bachelor's degree (Chen & Weko, 2009; Cromley et al., 2016; Kuenzi, Matthews, & Mangan, 2006; National Science Board, 2015; PCAST, 2012). Two levels of government are working to address this concern: 1) the federal and 2) the state. While this study focuses on a state perspectives, a brief background of both levels is provided below for context. The two levels are intricately related as work done by one affects the other.

Federal. The United States once led other nations in the production of STEM degrees (National Science Board, 2015; NCES, 2007). The National Center for Education Statistics (NCES) (2007) found, however, that other countries are now producing STEM graduates at a high rate, including Korea (38%), the United Kingdom (31%), Czech Republic (30%), Mexico (28%), Austria (27%), Finland 27%, Ireland (27 %), Italy (26%), Belgium (25%), Spain (25%), Australia (24%), Switzerland (22%), and Turkey (22%). By contrast, only 18% of all degrees awarded in the U.S. are to STEM majors (NCES, 2016). Despite recent efforts (e.g., increased postsecondary federal funding and state financial aid for students majoring in STEM) and a national desire to improve STEM education, the United States still compares poorly to other industrialized nations (National Science Board, 2016). The United States is not producing enough STEM degrees to fill all of the available STEM job openings (PCAST, 2012). Several researchers (e.g., Lacey and Wright, 2009; Langdon, McKittrick, Beede, Khan, and Doms, 2011) estimated that one million more STEM professionals need to be added to the workforce over current rates. In order to meet this growth demand, approximately one million more STEM degrees are required or an additional 100,000 per year (Radford, Berkner, Wheeless, & Shepher, 2010).

State. While the federal government has a large stake in the country's education growth and competitiveness, state governments also play an integral role in encouraging STEM development. According to an Education Commission of the States (2006) report, state governments are beginning to respond to this need with a variety of program and policy initiatives. There are three examples of such efforts in Ohio, Texas, and Washington. In Ohio, the Ohio Innovation Partnership (House Bill 119, passed in 2007) aims to strengthen the ability of Ohio citizens to complete degrees in STEM, the medical fields, or STEM education by offering a scholarship (Choose Ohio First Scholarship Program) to support undergraduate and/or graduate education those academic fields (e.g., STEM, medicine, or STEM education) (Education Commission of the States, 2012). In Texas, the Jobs and Education for Texans program (signed into law in 2007) awards grants to public junior colleges and public technical institutes, as well as eligible nonprofit organizations to: (1) develop or support nonprofit organizations' programs that prepare low-income students for careers in high-demand occupations, (2) defray the start-up costs of new career and technical education programs in high-demand occupations, and (3) provide scholarships for students who demonstrate financial need and who are enrolled in training programs for high-demand occupations (Education Commission of the States, 2012). In Washington, Encouraging the Technology Sciences in Education Act (House Bill 2817, passed in 2006), highlights the unique role community colleges play in supporting degree attainment in the fields of science, technology, engineering, and mathematics. That legislation called for the development of transferable curricula and the maintenance of viable articulation agreements with both public and private universities (Education Commission of the States, 2012).

As the above-mentioned examples show, states can build commitments at the highest levels of government, state university systems, and other policy organizations to forge stronger connections between state STEM policies and STEM degree production. Avenues of influence include funding priorities and state STEM policies. For example, through funding priorities, states can influence faculty recognition and rewards, and through state STEM policies, promote greater articulation between two-year and four-year institutions.

Theoretical Frameworks

This study focuses on states' production of STEM degrees. As explained in chapter two, the research is approached using a microeconomic perspective through two theories, principal agent theory and production function theory. Venturing further, this study suggests that when the two theories (principal-agent theory and production function theory) are combined, the conceptual model provides an appropriate lens to examine the relationship between state STEM policies and STEM degree production. The conceptual model uniting both theories is provided at the end of chapter two and the sections below describe the theories being used in the conceptual model.

Principal Agent Theory. Principal agent theory (PAT) is a microeconomic model rooted in political science and economics define by an arrangement where one person or entity (the agent) acts on behalf of another (the principal). According to Braun and Guston (2003), PAT describes a social relationship where two or more actors are involved in an exchange of resources. More specifically, Kassim and Menon (2003) offer a more detailed definition; “Agency relationships are created when one party, the *principal*, enters into a contractual agreement with a second party, the *agent*, and delegates to the latter responsibility for carrying out a function or set of tasks on the principal’s behalf” (p. 122). The principal expends resources to the agent and the agent accepts those resources and agrees to further the interests of the principal (Braun & Guston, 2003).

PAT requires that at least two actors or two organizations work together to meet a goal. Because of this, the principal-agent relationship, at times, can be less than perfect (Braun & Guston, 2003). Williams (1985) describes agents as self-interested actors that seek to maximize their welfare, sometimes engaging in acts like “lying, stealing, and cheating.” This behavior, within the PAT realm, is often referred to as shirking (p. 47). An agent, as a self-interested actor, may hide information from the principal, resulting in less-than-optimal outcomes from what the principal originally wanted (Braun & Guston, 2003). In PAT, it is not imperative for principals and agents to have a hierarchical relationship; this is especially true in higher education (Braun & Guston, 2003). Often times, states (principals) and postsecondary institutions (agents) have a mutually respectful and autonomous relationship (Braun & Guston, 2003). A more detailed discussion of the relationship between principals and agents is provided in chapter two. For present purposes, it is sufficient to note that given PAT’s roots in political science and economics, it can be an appropriate model for analyzing problems in higher education. Additionally, for this study, PAT provides a theoretical lens to understand the relationships between states and institutions of higher education.

Political Science. Over time, PAT's use in the political science realm enabled political scientists to better understand "the role of information asymmetry and incentives in political relationships" (Miller, 2005, p. 203). More specifically, PAT has given political scientists a way to think formally about how power (i.e., a modified incentive) can be used to induce actions in the interests of the principal. In this application, the executive in control (e.g., the president) serves as the agent (for the public), and the public serves as the principal. Downs and Rocke (1994) offer an example of the theory's application in the political science realm. While the public is unable to monitor all of an executive's actions, it can readily monitor the successes or failures of an executive's decisions (Downs and Rocke, 1994). More discussion of PAT's use and application in political science is detailed in chapter two.

Economics. One of the first applications of PAT in economics was Ronald Coarse's (1937) seminal work, "The Nature of the Firm." There, Coarse showed that traditional microeconomic theories were incomplete because they only included production and transport costs and failed to include the costs of entering into and executing contracts and managing organizations. These contracting costs, commonly known as transaction costs, account for a considerable share of the total use of resources in the economy (Coarse, 1937). By incorporating different types of transaction costs, Coarse (1937) paved the way for a systematic analysis of institutions in the economic system and their significance. Chapter two provides additional discussion of PAT's use and application in economics.

PAT in Higher Education. For the purposes of this research, the state takes on the role of principal and institutions of higher education take on the role of agent. More specifically, the principal (the state) "contracts" with the agent (the institutions) to educate students and award baccalaureate degrees in STEM disciplines (Hoenack, 1983). The use of principal agent theory (PAT) in higher education research is not widespread, but researchers such as Kivistö (2005, 2008), Lane (2007), Lane and Kivistö (2008), Nicholson-Crotty and Meier (2003), McLendon (2003), and McLendon, Hearn, and Deaton (2006) have used PAT in their research. A comprehensive review of the PAT literature and its application in the higher education arena is located in chapter two, but some brief examples of its application are provided in this chapter.

First, Kivistö's (2005, 2008) uses PAT to explain the government-university relationship and details three components required of the partnership: 1) tasks delegated to institutions (by the government), 2) government resources given to the institutions (used in the form of funding), and 3) government interest in assigned tasks. Second, Lane (2006) uses PAT and explores the types of oversight mechanisms informing the principal (state government) about the agent (an institution).

Production Function Theory. The second component of the theoretical framework for this study is production function theory (PFT). PFT can be defined as simply as "a relationship between inputs and outputs" (Chambers, 1988, p. 7). It can easily be applied to a variety of topics and situations.

One of the first known uses of production function theory was by three economists (Tolley, Black, & Ezekiel, 1924) working at the Bureau of Agricultural Economics at the United States Department of Agriculture. They aimed to construct an empirical framework to help agriculture producers in their entrepreneurial decisions (Chambers, 1988). This early work paved the way for Cobb and Douglas (1928). Their seminal work, *A Theory of Production*, helped to make production function commonplace in economics (Chambers, 1988). Cobb and Douglas (1928) applied PFT to the manufacturing industries in the United States and to the movements of labor, capitol, production, value, and wages. The theory is increasingly being applied to other industries. In secondary education, for example, the theory has been applied where inputs—the number of persons in the teaching/administrative staff and the educational expenditures (at the exclusion of the labor costs such as physical facilities, library holdings, computers available) are used to produce outputs—the number of high school diplomas awarded or the percentage of students with specific attainments (Bessent, Bessent, Kennington, & Reagan, 1982). The theory is also being increasingly applied to research in higher education (e.g., Ehrenberg, 2003; Hopkins, 1990; Titus, 2009; Titus & Eagan, 2016). One example of the theory's application is explores the impact of how per capita higher education student spending (input) affects degrees produced (output).

A further example of PFT's use in higher education research is Ehrenberg (2003). Ehrenberg postulates that PFT is appropriate when applying it to a state's role in public higher education. For example, states invest in postsecondary education (e.g., increased per capita higher education spending, scholarships, etc.) because they believe they will see returns on those investments (e.g., higher tax revenue) (Ehrenberg, 2003). Similarly, Hopkins (1990) uses the theory to better understand the impact of private and public institutions producing multiple types of outputs (i.e., degrees in different subject areas and at different levels [e.g., bachelor's, master's, etc.]) (as cited in Titus, 2009). Hopkins and Massy (1981) noted as early as the 1980s that, "the higher education production function describes the relationship between optimal outputs, such as college degrees awarded, and the optimal mix of inputs such as students, faculty and staff as well as physical and financial capital" (as cited in Titus, 2009, p. 443).

Methodology

This study uses an advanced quantitative method known as panel data analysis (PDA). Panel data refers to multi-dimensional data and contains observations on multiple phenomena observed over multiple time periods for the same unit of analysis (e.g., individuals, firms, states, etc.). This method is used to examine how undergraduate STEM degree production is influenced by state higher education STEM policies. The chosen method is the most appropriate to answer the main research question, which is seeking to examine the relationship between state-level STEM bachelor's degree production and state-level STEM policies.

There are at least four reasons why PDA is the most useful method for this research. First, PDA is informative because there is added variability and less collinearity (i.e., correlation among variables) (Allison, 1994; Halaby, 2004). Second, researchers using PDA can examine the relationship between and across variables over time (Allison, 1994; Halaby, 2004). Third, panel data also gives researchers the ability to test for "individual heterogeneity, statistical efficiency due to more information, a temporal dimension that enables dynamic adjustment, and better and more detailed data that allow researchers to model individual behaviors and identify effects" (Baltagi, 2008 as cited in Zhang, 2010, p. 308). Fourth, and perhaps most important, PDA allows researchers to control for unobserved heterogeneity (variation/differences among cases that are not measured). The following sub-sections briefly describe the research design, the data being used for analysis, the variables, the statistical techniques, and the limitations of this study.

Research Design. Using state-level data and incorporating theoretical frameworks derived from economics and political science described above, this study addresses the following questions:

1) How is undergraduate STEM degree production within a state related to state economic and higher education finance variables?
2) Controlling for state economic and higher education finance variables, how are states' undergraduate STEM degree production influenced by state higher education STEM policies?

The panel data set (also known as time series/cross sectional data) produced for this study contains data from 17 academic years (1999 to 2015) across all 50 states. The time period of 17 years was selected because it is the longest period (to date) where there is no missing data. The study design controls for heterogeneity or unobserved differences within states and across time. Data from the following variables are used to build the panel data set: undergraduate (baccalaureate) STEM degrees, state STEM policies (defined below), undergraduate enrollment per FTE, state research and development (R&D) funding for institutions, state per-capita income, state K-12 expenditures, state higher education appropriations, public in-state tuition per FTE student, state per-capita expenditures for Medicaid, state per-capita expenditures for corrections, state expenditures for need-based financial aid per undergraduate FTE student, and state expenditures for grant aid per FTE.

The input variables are state STEM policies. These variables were selected because they represent an input component of production function theory. The control variables are: undergraduate enrollment per FTE, state R&D funding for institutions, state per-capita income, state K-12 expenditures per capita, state higher education appropriations per capita, public in-state tuition per FTE, state per-capita expenditures for Medicaid, state per-capita expenditures for corrections, state expenditures for need-based aid per FTE, and state expenditures for grant aid per FTE. These variables symbolize the relationship between a principal and an agent (e.g., states and institutions). The output variable is undergraduate (baccalaureate) STEM degrees. This represents an output component of production function theory.

Utilizing concepts from principal agent theory and production function theory, this study examines how the production of undergraduate (baccalaureate) STEM degrees is influenced by the state (the principal) via selected higher education STEM policies (defined below) and state education finance policies (via the agents, higher education institutions). For the purposes of this study, state STEM policies are broadly operationalized because each state STEM policy is different. Research is conducted on every state to determine what postsecondary state STEM policies are currently in place. Three general examples of state STEM policies are: 1) individual incentives (e.g., scholarships) to pursue STEM degrees 2) institutional incentives (e.g., money earmarked in the state budget for STEM) to enhance retention and production of STEM majors and graduates, and 3) articulation agreements between public two and four-year institutions in STEM majors. The policies pursued by Ohio, Texas, and Washington described above are examples of state STEM policies.

In this study, a fixed-effects regression model and random-effects regression model is tested to determine the statistical technique. As explained later, a fixed-effects regression model was selected as the more appropriate test. These are two of many approaches that can be used in PDA. These two models were chosen as options because panel data may have group effects, time effects, or both (Park, 2009). A fixed-effect regression model assumes differences in intercepts across groups or time periods, whereas a random-effects regression model explores differences in error variances (Park, 2009).

Data. As previously noted, data for the study comes from 50 states over a 17-year period because it is the longest period (to date) where there is no missing data over multiple years. Components of the panel data set are drawn from the National Center for Education Statistics (NCES) Digest of Education Statistics, the National Science Foundation (NSF), the National Association of State Student Grant and Aid Programs (NASSGAP), the U.S. Census Bureau, and the National Association of State Business Officers (NASBO), and merged to construct a state-level panel dataset. These sources provide data on the state-level input variable, the state-level transactional variables, and state-level output variable across all 50 states. The following section provides a description of these three variable categories (i.e., input, control, and output).

Variables. The dependent variable for the study is undergraduate (baccalaureate) STEM degrees. For purposes of this study, STEM degrees include majors from the following disciplines: science (e.g., chemistry, biology, etc.), technology, engineering, and mathematics. Social/behavioral sciences like psychology, economics, sociology, and political science are not included as defined STEM majors. The dependent variable corresponds to the output variable—a key component of production function theory. The independent variables are divided into two categories—state STEM policies and state finance policies. State STEM policies are operationalized as: first—individual incentives (e.g., scholarships) to pursue STEM degrees; second—institutional incentives (e.g., money earmarked in the state budget for STEM) to enhance retention and production of STEM majors and graduates; third—articulation agreements between public two and four-year institutions in STEM majors. State finance policies are operationalized as state undergraduate enrollment per FTE, R&D funding to institutions, state per-capita income, state K-12 expenditures, state higher education appropriations per capita, public in-state tuition per FTE, state per-capita expenditures for Medicaid, state per-capita expenditures for corrections, state expenditures for need-based financial aid per undergraduate FTE student, and state expenditures for grant aid per FTE. These independent variables were selected because one of the variables corresponds to the input variable (i.e., state STEM policies)—a key component of production function theory. The remaining independent variables serve as control variables (i.e., state finance policies)—a key factor in principal agent theory—the relationship between states and institutions. A more detailed discussion of the variables is provided in chapter three.

Statistical technique. For the study, descriptive statistics are presented to provide simple summaries about the data and the variables. To address the research questions, more advanced statistical techniques are employed. More specifically, a fixed-effects regression model or random-effects regression model is used. Park (2009) notes that panel data may have group effects, time effects, or both, and the use of a fixed-effect regression model accounts for differences across groups or time periods and the use of a random-effects regression model accounts for differences in error variances. In order to determine which statistical model is most appropriate, a Hausman test is conducted. The

Hausman test evaluates the significance of the random-effects model verses the fixed-effects model (Park, 2009). Additional tests are also carried out to detect if heteroscedasticity, serial correlation, and endogeneity are present in the appropriate statistical model. The statistical techniques are described in greater detail in chapter three.

Limitations. This study is limited in several ways. First, as with any study involving secondary data, the research is limited to variables previously collected, in this case, it is limited to what is available from various data sources.

Second, different entities use different ways to identify the disciplines/majors included in STEM and this is a limitation. For example, the National Science Foundation (NSF) defines STEM fields more broadly, including mathematics, natural sciences, engineering, and computer and information sciences, but also such social/behavioral sciences as psychology, economics, sociology, and political science (Green, 2007). Because the federal government does not have one definition of what disciplines/majors are included in STEM, the different Federal agencies (e.g., NSF and the Department of Education) are defining it differently. This variation in definitions affects what data is collected.

Third, the panel data set created for this study contain data from 17 years (1999 to 2015) across all 50 states because it is the longest time period (to date) where there are no missing data. Preliminary examination of available data provided this insight. In the future, researchers may benefit from a longer time-sequence when conducting similar studies.

Fourth, this study only examines STEM degree production at the baccalaureate-degree level and not at the associate degree or graduate degree levels.

Implications

Despite these limitations, this study may have implications in several areas. This study may have potential implications for policy and practice. The results of the research may help federal and state policy-makers to understand the impact current policies have on STEM degree production. Additionally, the conceptual model developed for this study may provide an appropriate lens to understand the STEM degree production process through the application of constructs drawn from principal-agent theory and production function theory.

Chapter 2: Theoretical Framework

This study focuses on states' production of STEM degrees and approaches the topic from a microeconomic perspective using two theories, principal agent theory and production function theory. The conceptual model being used in this study combines these two theories (principal-agent theory and production function theory) to provide an appropriate lens to examine the relationship between state STEM policies and STEM undergraduate degree production. Using state-level data and incorporating theoretical frameworks derived from economics and political science, this study addresses the following questions:

1) How is undergraduate STEM degree production within a state related to state economic and higher education finance variables?
2) Controlling for state economic and higher education finance variables, how are states' undergraduate STEM degree production influenced by state higher education STEM policies?

This chapter is organized into three parts.

- Part one provides a critical review of the literature germane to degree production at the state level including state finance and education policies impacting education outcomes and STEM degree production.
- Part two is a critical review of literature pertinent to the two microeconomic perspectives being used in the conceptual model—principal agent theory (PAT) and production function theory (PFT).
- Part three is a description and explanation of the conceptual model.

Chapter 2 is an extensive review of a variety of different types of literature. Many

of the studies presented in Part One touch on degree production and/or enrollments but none of the research reviewed to date approaches questions about degree production through a specific lens on STEM through a state-level perspective. This study fills a void in the literature by examining the relationship between state STEM policies and financial aspects of state higher education policies on the production of postsecondary STEM degrees in a more comprehensive fashion. In Part Two, it is found that few studies in higher education research utilize PAT and the theory may offer a more theoretically robust explanation of current issues shaping higher education, when taking into account its origins (economics and political science). As for PFT,
all of the research reviewed for this study examined ways to think about how efficiencies in production can affect output, but the limitation of using just PFT is that it only looks at the inputs and the outputs. There is still a lack of clarity about what happens in the space between an input and an output and it not accounted for in PFT. Part three builds on key tenets from PAT and PFT to build a conceptual model that unites both theories to help explain how undergraduate STEM degree production is influenced by state higher education STEM policies.

Part one

Degree Production at the State Level

This section examines the literature on a state's role in degree production. The state's influences degree production in a number of ways. Examples of this influence include state education policies and state financial aid policies. This next section explores a variety of research on what impacts degree production and/or graduation rates at the state level.

Titus (2009a) explores how the inefficiency of bachelor degree production at the state level is affected by financial components of state higher education policy. In this research, Titus (2009a) uses stochastic frontier analysis and dynamic fixed-effects panel modeling to examine how changes in the x-inefficiency of bachelor's degree production are influenced by changes in state higher education policy. This research utilizes annual state-level panel data, over 12 years (1992-2004) from 49 states. There were two major findings in this study. First, states with inefficient bachelor degree production are technologically inefficient—meaning these states lack the necessary innovative financial practices (e.g., performance funding) that can positively affect inefficient practices (Titus, 2009a). Second, states are expending less effort on degree production in general than in the past. Over time, states with historical low-levels of inefficiency are moving towards increased levels of inefficiency. This inefficiency, however, can be offset with increases to state need-based student financial aid (Titus, 2009a). Titus' (2009a) study approaches the research with a belief that states are inefficiently producing bachelor's degrees and the inefficiency is exasperated by decreased spending on postsecondary education and a lack of innovative financial practices. The study provides a glimpse into how the variable, state expenditures on postsecondary education, affects degree production, but only looks at undergraduate degree production more generally and not by a specific type of degree production (i.e., STEM).

In a similar vein, Titus (2009b) drew on concepts from production function and principal-agent theories and used human capital theory to explain how production function theory is applicable in higher education—the individual demand for higher education drives production. Titus (2009b) notes that often individuals invest in their education at “suboptimal” levels and as a result, states governments invest in higher education to reap the benefits of this public good. Titus’ (2009b) research looked at how the production of bachelor’s degrees is influenced by selected financial aspects of state higher education policy. Similar to Titus (2009a), Titus (2009b) used annual state-level data from 49 states (1992-2004). Titus (2009b) employed a dynamic fixed-effects panel model combined with Generalized Method of Moments (GMM) techniques. This study had eight major findings. First, financial components of state higher education policy are interrelated and affected by external factors (Titus, 2009b). For example, the research suggests that tuition at public four-year colleges and universities increases with a delayed response when state allocations for postsecondary education decrease (Titus, 2009b). Additionally, state need-based student financial aid responds to tuition increases at two-year public institutions (Titus, 2009b). Second, postsecondary education and welfare compete for similar state funds (Titus, 2009b). Third, during high periods of postsecondary degree production (1992-2004), states with initial low levels of bachelor’s degrees per undergraduate enrollment are increasing their degree production at a substantially faster pace compared to states with initially high levels of bachelor’s degrees per undergraduate enrollment. Fourth, increases in bachelor’s degree production at public institutions are realized as private four-year institutions alter student input variables and other resources to result in increases in bachelor degree production. Fifth, with the presence of private higher education within a state, increases in tuition at four-year public colleges or universities do not influence the production of bachelor’s degrees. Sixth, increases in state need-based financial aid have a positive impact on bachelor’s degree production. Additionally, increases in need-based financial aid reduce the net price charged to students and result in an increase in the production of bachelor’s degrees. Seventh bachelor’s degree production within a state is positively related to state appropriations for higher education. Eighth, phenomena like state spending on outstanding debt, past economic performance, or current unemployment rates do not influence bachelor degree production. It is clear from Titus’ (2009b) research that state policy makers should pay careful attention to the role of state support in increasing bachelor degree attainment.

Similar to Titus’ (2009b) exploration of factors affecting state productivity, Fatima (2009) researched how investments in graduate education affect state workforce productivity growth (Fatima, 2009). Fatima’s (2009) conceptual framework was grounded in the theory that growth in state workforce productivity is dependent on three factors: 1) investment in master’s, professional, and doctoral education, 2) initial productivity, and 3) economic activity in different industry sectors. Multiple regression analysis techniques were used to examine the relationships between the growth in state workforce productivity between 1990 and 2000 and initial cumulative investment in higher education in 1990. Additionally, Fatima (2009) controlled for the effects of the initial level of state workforce productivity in 1990 and the percentage growth or decline in the economic activity of state economies between 1990 and 2000. Although Fatima’s study did not focus specifically on STEM degrees, the concept of relating state workforce policies to degree production lays some groundwork for the study. The independent variables in Fatima’s study were investment in master's degree education, investment in doctoral degree education, investment in professional degree education, initial productivity, and economic activity of different industrial sectors. The dependent variables were state workforce productivity growth (1990-2000). Fatima (2009) found that increasing investments in master's degree education, doctoral degree education, and professional degree education significantly affect the subsequent growth of state workforce productivity. Fatima’s research, however, did not provide information in two key areas being examined in this study. While Fatima’s (2009) study found positive correlation between increasing investment and growth in state workforce productivity, it 1) does not to provide analysis on the specific disciplines that affect a state’s productivity and 2) limits understanding of impact by only looking at graduate degrees. Given the small percentage of individuals that go on to pursue a master’s degree, the study’s findings are limited to this subset of the population. Differing from Fatima (2009), this study uses undergraduate populations and explores the impact of specific disciplines on undergraduate STEM degree production.

Similar to Titus (2009a), Trostel (2012) explores if/how state financial support for postsecondary education can increase college attainment levels. Trostel (2012) used a two-stage instrumental-variables approach to account for the possibility that state funding for higher education may endogenously depend on anticipated college enrollment. Using 22 years of data to build the interstate panel data set (1985-2006), Trostel (2012) controlled for fixed state effects and found that state funding for higher education has significant causal effects on both college enrollment and degree attainment. (Trostel, 2012). As with Fatima (2009), Trostel (2012) explores similar variables to those being explored in this study (i.e., state spending), but looks at how that spending (i.e., financial support for postsecondary education) effects enrollment and degree production. While Trostel (2012) only considers the impact of financial support for postsecondary education, financial support for postsecondary education is but one of nine control variables being used better understand undergraduate STEM degree production in the study. The array of variables in this study allows for a more in-depth understanding of undergraduate STEM degree production.

Curs, Bhandari, and Steiger (2011) also use state-level panel data (1970-2005), this time to explore if the privatization of higher education within a state can bias the relationship between state higher education spending and economic growth. Economic growth models were used in the analysis of a 50-state sample between 1975 and 2005 to estimate the effect of higher education expenditure on growth at a state level. The study found that the omission of the size of the private higher education system may negatively bias the estimated relationship between higher education spending and economic growth (Curs, Bhandari, & Steiger, 2011). More specifically, in states with a high percentage of students enrolled in private postsecondary institutions, higher education spending is negatively related to economic growth. By contrast, states with a large percentage of students enrolled in public institutions have a positive relationship (Curs et al., 2011). While Curs et al. (2011) use state-level panel data, as does this study, they only explore how privatization affects higher education spending and economic growth. While the effect of higher education spending on the economy is an important policy question, its answer does little to address whether the increases spending actually leads to an increased production of degrees. By contrast, this study uses state-level data to explore how higher education spending (among other variables) as well as postsecondary policies affects undergraduate STEM degree production.

In contrast to studies correlating state spending and economic growth, Heck, Lam, and Thomas (2014) examine if different state political cultures (i.e., underlying traditions, values, and public policy choices) are reflected in variability between state finance policy indicators and institutional variables affecting undergraduate graduation rates. Heck et al. (2014) built on Elazar's (1984) framework and proposed that three different political cultures (i.e., individualist, moralist, and traditionalist) were dominant in particular parts of the United States because of historical settlement patterns related to expansion in the west, government's role in organizing state political and economic life and engaged citizens in the democratic process. To test this model, Heck et al. (2014) use longitudinal data on states' economic indicators, legislative appropriations for higher education, family share of higher education costs, and public four-year institutions' graduation rates for full-time students pursuing a bachelor's degree over an 11-year period (1997-2007). Through this research, Heck et al. (2014) sought to answer two questions. "Are there differences among states in their economic contexts and patterns of higher education financial support associated with their political cultures? Does political culture interact with state higher education financial policy to explain student graduation rates and growth in graduation rates?" (Heck, Lam, & Thomas, 2014, p.16). The study found that differences in political culture are a contributing factor in a state's economic contexts and levels of higher education allocations. These differences in culture are also a factor in undergraduate graduation rates over time (Heck et al., 2014). Heck et al. (2014) explored how a moderator variable—culture—affects levels of higher education funding allocations and degree production (Sower & Sower, 2005). Using a moderator variable like culture has the potential to improve the external validity of the study by providing a more complete picture of the relationship between dependent and independent variables

(Sower & Sower, 2005).

Like Trostel's (2012) study, Zhang (2009), explores how state funding affects graduation rates at public four-year institutions. For each entering freshman cohort from academic years 1991-1992 to 1998-1999, Zhang (2009) examined graduation rates for each four-year institution from Integrated Postsecondary Education Data System (IPEDS). Zhang's study builds on and extends the established literature on college graduation by focusing on institutional-level graduation rates. Zhang found a positive effect on graduation rates with increased state funding (Zhang, 2009). More specifically, with every 10% increase in postsecondary education appropriations per FTE at a four-year public institution, there is a 0.64 percentage increase in graduation rates. Zhang's (2009) research is more limited than this study in that he only explores the impact of state funding on graduation rates. This study, however, builds on Zhang's (2009) research. This study adds to Zhang's approach in that it specifically looks at STEM degree production and explores how a broader range of variables affects STEM degree production.

A final study again raises the recurrent need to examine the impact of public financing on higher education (Fatima & Paulsen, 2004). Fatima and Paulsen (2004) used multiple regression analysis to test relationship hypotheses and to estimate the effects of three independent variables—initial workforce productivity, initial cumulative investment in higher education, and economic activity in the state economies—on the dependent variable, growth in state workforce productivity between 1990 and 1999. The most important finding from this study is that investment in higher education had a direct and positive effect on state workforce productivity growth in the 1990s. This finding is consistent with earlier research that used data from the 1980s (Fatima & Paulsen, 2004). Fatima's and Paulsen's (2004) research does not explain how increases in state allocation for postsecondary education can result in increased levels of degree productivity. While the researchers do look at state workforce productivity, it is not clear how increased postsecondary funding affects degree production. Further, Fatima and Paulsen (2004) do not explore how specific disciplines (e.g., STEM) affect degree productivity. Similar to Fatima and Paulsen (2004), this research explores state allocations for postsecondary education, but also includes other variables like state STEM policies, to determine the impact on degree production. Findings from this study allow the researcher to connect how STEM policies may or may not affect STEM degree production.

The variety of research (i.e., Titus, 2009a,b; Fatima, 2009; Trostel, 2012; Curs et al., 2011; Heck et al., 2014; Sower & Sower, 2005; Sower, Abshire, & Shankman, 1998; Zhang, 2009; and Fatima & Paulsen, 2004) explored in this section emphasizes how the financial aspects of higher education policy can impact undergraduate graduation rates and postsecondary degree production. While the highlighted research lays a foundation for exploring the impact of specific variables (e.g., state allocations of postsecondary education, state finance policies), the presented studies are limited by only looking at degree production or economic productivity. This is particularly important for states interested in growing a specific workforce sector to boost the economy. Exploring specific disciplines, such as STEM, allows for a variety of constituents (e.g., institutional presidents and administrators, legislators, governors, parents, students) to understand how a degree production in specific disciplines (e.g., cybersecurity, computer science) can help to boost regional economic development and a benefit a host of stakeholders (e.g., institutional presidents and administrators, legislators, governors, parents, students). This study expands on the prior research to better understand STEM degree production.

Impact of State Finance Policies on Other Higher Education Outcomes

This section examines literature on the impact of state finance policies on other higher education outcomes like increased local enrollment. State finance policies are operationalized as state undergraduate enrollment per FTE, state R&D funding to institutions, state per-capita income, state K-12 expenditures, state higher education appropriations per capita, public in-state tuition per FTE, state per-capita expenditures for Medicaid, state per-capita expenditures for corrections, state expenditures for need-based aid per FTE, and state expenditures for grant aid per FTE. These variables are included in this research.

Zhang and Ness (2010) examined the effect of state merit-based scholarship programs on reducing brain drain from states and explored if there was variation across states by different types of institutions. Zhang and Ness (2010) additionally determined if these variations were due to eligibility criteria and/or award amounts of the merit scholarship program. Zhang's and Ness' research is grounded in two related literature bases—the determinants of student migration and the effect of state merit aid programs. The main data source for their study is the Enrollment Survey from IPEDS. Control variables include the number of recent high school graduates, state per capita personal income, and state unemployment rates. Zhang's and Ness' panel data set included four-year institutions from all 50 states over a 13-year period.

Zhang and Ness (2010) found that state merit scholarship programs do mitigate the migration of the most talented students to other states. Additionally, because of state merit aid programs, merit aid states see increases in the total first-year student enrollments and increases in the resident college enrollments. Lastly, Zhang and Ness (2010) did find variations across states due to eligibility criteria and award amounts of the merit scholarships. Zhang and Ness (2010) effectively show that state finance policies can impact a state's retention of talented students.

Nevertheless, while Zhang and Ness (2010) explore the impact of state finance policies on limiting a state's "brain drain," they did not assess how including other variables (e.g., state STEM policies including finance related policies like state allocations/programs specifically for STEM) could potentially provide a more nuanced understanding of factors affecting enrollment and retention of a state's students at an in-state institution. Understanding the impact of specific state policies (e.g., STEM) allows researchers to better understand how to enroll, retain, and increase a states' productivity. No research known to date has explored the effects of state STEM policies on STEM degree production. Building on the work of Zhang and Ness (2010), this study explores how state policies in STEM can affect a state's productivity. Findings from this study could potentially be linked back with research like Zhang and Ness (2010) as state STEM policies could affect state enrollment and retention of students at in-state institutions.

Impact of State Finance and Education Policies on STEM Degree Production

This section examines the existing literature on the impact of state finance and education policies on STEM degree production. Several studies have examined how state higher education finance policies can affect STEM degree production and one study focused on how education policies can affect STEM degree production.

Zhang (2011) explored how the state-sponsored merit aid programs in Georgia and Florida affected bachelor degree production in STEM disciplines for both males and females. Zhang collected data on the number of baccalaureate degrees conferred by every institution in 16 Southern Regional Education Board (SREB) states between academic years 1991–1992. Two key findings emerged from this study. Zhang (2011) found that in general, with the use of the Georgia HOPE scholarship and the Florida Bright Future scholarship, there was an increased level of baccalaureate degree production in STEM fields. Second, the programs in Georgia and Florida have positive effects on both male and female students, but the positive effects on females are larger (Zhang, 2011). More specifically, the number of STEM degrees in Georgia has increased by 7.6% for women and 2.8% for men and the number of STEM degrees in Florida has increased by 14.1% for women and 6.9% for men (Zhang, 2011). Although Zhang (2011) is able to show positive correlation between state scholarships and STEM degree production, it is unclear what are the effects of other variables. For example, how do increases in state allocations (i.e., funding provided by a state) affect STEM degree production? Additionally, Zhang's (2011) study only explores how scholarships affect the behavior in two states. This study builds on Zhang's (2011) study by including all 50 states and a larger selection of variables.

Sjoquist and Winters (2013) examined whether state merit-aid programs affected college major decisions in STEM disciplines. Sjoquist and Winters (2013) were specifically interested in whether merit-based aid has an unintended consequence of reducing STEM majors. Sjoquist and Winters (2013) used a treatment and control research design implemented via a difference-in-differences regression framework. The treatment group consists of individuals who were exposed to a broad-based state merit-aid program when they graduated high school and the control group consists of individuals who were not. Unlike Zhang (2011), who considers the merit-based aid program in only two states, Sjoquist and Winters (2013) studied the effects in the 27 states that adopted merit-based aid programs between 1991-2005, but ended up focusing on the 9 states that have more significant merit-aid programs. Microdata from the American Community Survey and student records from the University System of Georgia found that state merit programs decrease the chances of an individual earning a STEM degree (Sjoquist & Winters, 2013). Findings from this study are different than many other studies presented previously in chapter two. Sjoquist and Winters (2013) found that men are more likely to major in STEM fields. However, their data showed that the negative effect of state merit aid on earning a degree in STEM is larger for women. Sjoquist's and Winters' (2013) study is limited in that only looking at college major decisions does not illuminate the rate at which a state is actually producing the degrees. This study uses undergraduate degree data from all 50 states and includes an array of variables when building the panel data set, which provides a more comprehensive view.

Arcidiacono, Aucejo, and Hotz (2013) explored how K-12 education policy (e.g., academic curriculum) can affect STEM graduation rates and what differences exist among STEM graduates compared to non-STEM graduates. The researchers used student-level data on applicants, enrollees and graduates of baccalaureate programs at the various campuses within the University of California (UC) system that includes measures of students' academic preparation, intended major, and, conditional on graduating, their final major. The data includes fall semester numbers from three years (1995-1997).

Arcidiacono et al. (2013) used the data to show across-campus differences in the rates at which minority students persisted in and graduated with STEM and non-STEM majors. As a result, Arcidiacono et al. (2013) developed an econometric model of the decision of students to graduate in alternative majors or not graduate. Three main findings emerge from this study. First, Arcidiacono et al. (2013) found that sorting into majors is based on academic preparation. More specifically, STEM majors at each campus have stronger academic credentials than non-STEM majors, and less academically prepared students are significantly more likely to leave STEM and take longer to graduate at each campus (Arcidiacono, Aucejo, & Hotz, 2013). Second, students with relatively weaker academic preparation are significantly more likely to leave the sciences and take longer to graduate at each campus (Arcidiacono et al., 2013). Lastly, Arcidiacono et al. (2013) found that minority students would be more likely to graduate with a STEM degree in less time if they would have attended a lower ranked university. Interestingly, the researchers found that these results do not apply for non-minority students. The study from Arcidiacono et al. (2013) was limited in three ways: 1) the results are limited to one state, making generalizability across states more difficult, 2) the study only looks at data from one state system—the UC System—and it does not account for the other state four-year institutions, and 3) only looking at the impact of K-12 education policy does not account for the impact of other factors like state finance policies in STEM that could affect enrollment and completion. This study uses undergraduate degree data from all public four-year institutions in all 50 states to build the panel data set, and considers the impact of other factors.

The studies (i.e., Zhang, 2011, Sjoquist & Winters, 2013, and Arcidiacono et al.,

2013) reviewed in this section detail how financial aspects of higher education policy affect STEM degree production and one study described how K-12 education policy (e.g., academic curriculum) can affect STEM degree production. As with the first study of this section, it is important to consider the recipients of the scholarships. For example, if the scholarships are given to individuals who would have gone to college even without receiving financial support, it is not clear that the states are truly expanding the college-going population and creating more wide-spread benefit (Zhang, 2011).

The study from Arcidiacono et al. (2013) also raises the concept of matching as an important area of concern because of its potential relationship to graduation rates. If minority students are more likely to graduate with a STEM degree in less time if they attend a lower ranked university, policies to improve the matching of students to college—especially when a minority student shows interest in STEM—may ease the shortage of minority student representation in STEM degree production (Arcidiacono et al., 2013).

Additionally, it is important to note that Zhang (2011) and Arcidiacono et al. (2013) focused on how state finance and education policies affect STEM graduation rates and did not take into account how state STEM policies affect STEM degree production. One approach to understand STEM degree production is to explore the effect of state STEM policies as these policies often use encouragement (e.g., financial incentives or scholarships for STEM students) with the hope there will be increased STEM productivity.

While many of the studies presented in Part One touch on degree production and/or enrollments, none of the research reviewed to date approaches questions about degree production through a specific lens on STEM through a state-level perspective. This perspective is important as states continuously seek to promote strong economic health and vitality. This study fills a void in the literature by examining the relationship between state STEM policies and financial aspects of state higher education policies on the production of postsecondary STEM degrees in a more comprehensive fashion, using state-level data covering 17 years and pulled from a variety of publically available secondary sources.

Venturing further, this study theorizes that when principal-agent theory and production function theory are combined, they create a conceptual model that provides an appropriate lens to examine the relationship between state STEM policies and STEM degree production. Part two is a review of the two microeconomic perspectives being used in the combined conceptual model. This next part describes more broadly why these two perspectives are appropriate. Part two ends by detailing why these two theories are appropriate to use when examining the undergraduate STEM degree production.

Part Two

The conceptual model combining principal-agent theory and production function theory provides an appropriate lens to examine the relationship between state STEM policies and STEM degree production. The use of these two theories is particularly important because state STEM policies can include providing financial resources to higher education institutions and college students interested in STEM, and in this study, the production of bachelor's STEM degrees is hypothesized to be a function of state STEM policies and selected financial aspects of state higher education policy such as tuition, state appropriations to higher education institutions, and financial aid, controlling for other variables. The conceptual model also suggests that current state STEM policies and selected financial aspects of state higher education policies are interrelated and influenced by history as well as other state policies (e.g., funding for Medicare).

Principal Agent Theory

Principal agent theory (PAT) is a microeconomic model rooted in political science and economics and is used to describe an arrangement where one person or entity (the agent) acts on behalf of another (the principal). The subsection below provides some basic definitions of PAT, issues in the application of PAT, and possible concerns about situations that could arise with PAT. Following that, the subsequent two subsections describe PAT's roots in political science and economics. The last subsection describes PAT's use and application in the higher education arena and PAT's application in STEM policies in higher education.

Operational Definitions and Issues in General Application of Principal Agent Theory. In PAT, the principal and agent are two key actors involved in an exchange of resources. The principal is the actor disposing resources (e.g., money, space, political backing/support) in pursuit of task completion. The agent is the actor accepting the resources and is able to further the interests of the principal (Braun & Guston, 2003).

There are typically two issues that arise in PAT's application to real world scenarios—adverse selection and moral hazard (Braun, 1993). Adverse selection arises when one party has relevant information about a situation that the other party lacks (Braun, 1993). This unbalanced information is often referred to as information asymmetry and it can lead to poor decision-making and choices (Braun, 1993; Miller, 2005; Weber, 1958). For example, a state, acting as a principal may have inadequate information about the true cost of a program to be implemented by public higher education institutions as an agent. Different information might lead to different decision-making. Moral hazard occurs when a party, insulated from risk, behaves differently than it would behave if it were fully exposed to the risk. For example, suppose an institution receives state funding specifically to increase the number of students majoring in a STEM discipline. If there is no risk of the funding disappearing, the institution may engage in more risky behavior, such as not evaluating the effectiveness of the program. In this scenario, the principal agent relationship creates a moral hazard. Suppose, however, that an institution has to show a 5% increase in retention and/or completions in order to keep current funding levels for the next fiscal year. In this scenario, the institution evaluates the program to ensure they are making adequate progress toward the 5% benchmark (Braun, 1993). Thus, the moral hazard is limited in this scenario. Examples of moral hazard in education can be controversial, but they do exist, especially around accountability (e.g., institutions not being held accountable[1] for high student dropout rates and/or failure in STEM).

A third challenge to the application of PAT may occur if the interests of the agent and the principal are not aligned, incentivizing the agent to act inappropriately (from the viewpoint of the principal) (Braun & Guston, 2003). This behavior can lead principals to be concerned about an agent's potential avoidance of duty or shirking on the part of the agent (Braun, 1993). This can arise when there are differences between the preferences of the two parties. While diverging preferences might tempt the agent to act against the

[1] An example of an accountability measure is placing a program (i.e., teaching and student support services) under review for lack of student success.

principal's best interests, the principal can use certain tools (e.g., initial screening process for selecting potential agents, on-the-job monitoring of the agent's performance, and the creation of incentives by the principal to encourage compliance) to reduce this risk (Miller & Moe, 1986). The issues and concerns just raised are direct concerns for states and institutions. For example, the state could have multiple goals—raise STEM degree production to boost the state's economy and strengthen the tax revenues. Institutions could loosely go along with those goals, but may be less concerned with STEM degree production and may rather focus on engaging in research rather teaching (i.e., producing degrees). In this instance, an institution may engage in shirking to focus on engaging in research rather teaching (i.e., producing degrees).

Principal Agent Theory's Application in Political Science

As previously noted, principal agent theory (PAT) originated in political science and economics. PAT has given political scientists a way to think formally about how power (i.e., a modified incentive) can be used to induce actions in the interests of the principal. In this application, the executive in control (e.g., the president) serves as the agent (for the public), and the public serves as the principal. The political science perspective of PAT explores how incentives can affect organizational thinking (Lane & Kivistö, 2008). Lane and Kivistö (2008) further note that these oversight tools are employed so that "bureaucratic agents pursue legislated goals" (p. 146). Moreover, Lane (2007) notes that:

> Political scientists have used the principal-agent model to describe the different aspects of the relationships between various types of politicians and political organizations: policy products, bureaucratic influence, oversight, control,

> shirking, and information asymmetry. The model's level of flexibility and adaptability in studying an array of political relationships and products is one of the reasons for its popularity and usage in political science. (p. 621).

An important distinction between perspectives is in the number of principals in the theory's structure (Moe, 1990). From the political science perspective, there can be multiple principals and one or more agents. Societal demands for more public accountability make PAT particularly useful in the political science realm since principals are able to judge the performance of their agents (Healy & Malhotra, 2010). According to Gailmard (2013), the application of PAT in political science is an increasingly popular paradigm for studying public accountability because "it provides a flexible framework for modeling innumerable variations in institutional arrangements, and comparing their potential for inducing desirable behavior by agents" (p. 2).

Many relationships studied in the political science arena can be described as principal and agent arrangements. Three examples are detailed here. The first example is an elected official serving as the agent and the people doing the electing as the principals; this example represents a situation where the elected official works on behalf of the people (Braun, 1993). The second example is of the research councils that act as agents on behalf of the Office of Science and Technology (the principal) to complete work for the Office (Braun, 1993). The third example is of state and federal bureaucrats acting as agents for a mix of political principals—most often Congress, the president, other individuals within the executive branch, and/or the courts; this example represents a situation where state and federal bureaucrats work to implement policy for the political principals (Braun, 1993). All three examples represent cases where agents are trusted by the principals to function on their behalf. With tools borrowed from economics, the application of PAT in political science has given political scientists new insights into the role of incentives in political relationships.

Incentives. Spence and Zeckhauser (1971) note that appropriate incentives can reduce moral hazard, but only if the agent's incentives can be manipulated sufficiently to overcome problems caused by information asymmetry. Weber (1958) notes that asymmetric relationships are a common part of politics: meaning that authority is located on one side of the relationship and an informational advantage lies on the other. While Weber (1958) suggests that power tends to reside with the expert (e.g., the agent), this may not hold true in the political sphere, especially in relationships between elected officials (i.e., agents) and their constituencies (i.e., principals). Miller (2005) notes that "the principal has the formal authority, but in PAT, the attention is on a particular form of formal authority—the authority to impose incentives on the agent" (p. 204). By manipulating the agent's incentives, the principal can minimize shirking (Miller, 2005). This is directly related to the study presented here; states (principal) can use financial aspects of state higher education policies to impact STEM degree production (Zhang, 2011; Sjoquist & Winters, 2013).

Another incentive example comes from Down and Rocke (1994) who identify the chief executive (e.g., the President) as being the agent of the public (the principal). The public's control over the chief executive happens through the electoral process and the outcome of this process is often reflective of the chief executive's prior actions (Down & Rocke, 1994). A similar scenario can occur in higher education. For example, a provost's successes or failures during a scandal about teaching and learning climates for women and minorities in STEM may concern faculty. The faculty are unable to monitor the provost's immediate actions to change the environment, but can readily monitor the success or failure of his/her decisions in future faculty senate meetings (e.g., casting a vote of no confidence). Down and Rocke (1994) note that because of the large costs associated with monitoring an executive, constituents (i.e., faculty in this example) must base their "contracts" on outcomes rather than on the executive's actions along the way. This creates an incentive for future executives operating under the same outcome-based contract (p. 367). Further, Downs and Rocke (1994) note that constituents must punish (i.e., vote out of office) losing, but well-intentioned executives because without this action, future executives may be freed of the "incentive effect" (p. 368).

While incentives in political relationships motivate individuals perform in order to be rewarded (i.e., being reelected or retained as president of a college), high levels of shirking can occur without the public ever knowing. As a result, executives may be forced to take more risks to save their position. Focusing on outcomes has the potential to be an unanticipated cost for agents (Downs & Rocke, 1994). For example, suppose a scandal resulted from a college president trying to cover up a study revealing that an institution had a hostile culture towards women and minorities in STEM, causing those students to migrate out of STEM at higher rates than men or non-minorities. In this scenario, the college president may hide the scandal based on the narrow possibility that the scandal will be resolved in her favor because of the inevitability of being voted out of office when the failing scandal cover-up becomes evident to the faculty (Downs & Rocke, 1994). Downs and Rocke (1994) labeled this phenomenon "gambling for resurrection" and it is an example of unanticipated agency costs (p. 375).

PAT suggests that "gambling for resurrection" behaviors can occur in the context of higher education. Agents (e.g., faculty) may get into situations that they would have otherwise avoided if they would have been fully informed and the chief executives (e.g., college presidents) often suffer the costs of the poor decisions (e.g., not being retained as college president) (Down & Rocke, 1994, p. 375). While more transparent behavior could improve specific negative outcomes (e.g., "gambling for resurrection"), PAT's application in political science suggests remedies more complex than mere transparency (Down & Rocke, 1994, p. 375). Holmstrom (1978) notes that the chief executive (e.g., college presidents) and constituents (e.g., faculty) would be better off with improvements around the monitoring process (i.e., moving away from outcomes-based decision making, giving faculty enhanced and increased shared governance, and the opportunity to vet and assess decisions along the way). However, the current state of affairs (e.g., low levels of STEM degree productivity among minorities in STEM compared to non-minorities) demonstrates that better monitoring (i.e., faculty input in how resources are allocated on campus to ensure programs to assist minorities in STEM are well-funded) is an unlikely solution (Miller, 2005). Moreover, the information asymmetry between a chief executive (e.g., college presidents) and constituents (e.g., faculty) is too complicated and dynamic to be resolved with improvements in monitoring (Miller, 2005). Given this application of PAT, this study is guided by how political science recognizes that multiple principals can exist. For this study, the state represents multiple principals (e.g., consolidated governing board or coordinating boards and the political party of the governor versus majority of the state legislature).

Principal Agent Theory's Application in Economics

In economics research, PAT has also been useful in attempting to understand how incentives, interests, and information shape organizational thinking. One distinction to note between political science PAT and economics PAT is that economics PAT focuses more on the type of behavior to be managed rather than the mechanisms used to manage the behavior (Lane & Kivistö, 2008). According to Lane and Kivistö (2008), "the basic idea behind monitoring behavior is to decrease the information asymmetry between the principal and the agent" (p. 146). Additionally, this perspective assumes that much of organizational behavior is based on people's self-interest (Lane & Kivistö, 2008). Another important distinction is in the number of principals in the theory's structure. In the economic perspective, there is one principal and one agent. For example, state government (as a whole group) acting as the principal and state institutions of higher education (as a whole group) acting as the agent. This is important to the study because the perspective of one principal and one agent is being used.

Principal agent theory is grounded in the work of new institutional economics (Williamson, 1975, 1985; Moe, 1984; and Miller 1992). New institutional economics (NIE) incorporates a theory of institutions—laws, rules, customs, and norms—into economics, and NIE has developed as a movement within the social sciences that unites theoretical and empirical research examining the role of institutions in furthering or preventing economic growth (Coarse, 1937). While similar with most principal agent relationships, in higher education, the relationships between states and institutions may be imperfect, but states are better suited to work with institutions that are motivated to achieve state goals than with institutions that are more concerned with their needs, and require enhanced monitoring to stay on task of meeting the state's goals.

The next section describes PAT's application in higher education and is followed by a section on PAT's similarities and differences.

Principal Agent Theory's Application in Higher Education

PAT's application in political science enabled political scientists to explore oversight and accountability from a different perspective. The application of PAT in higher education has the potential to expand how higher education researchers think about governance and policy (Lane & Kivistö, 2008). The use of principal agent theory (PAT) in higher education research is not widespread, but researchers such as Kivistö (2005, 2008), Lane (2007), Lane and Kivistö (2008), Nicholson-Crotty and Meier (2003), McLendon (2003), and McLendon, et al. (2006) have used PAT in their research. This section provides an overview of how PAT has been applied in this prior research as well as some critique of the use of PAT.

Kivistö (2005, 2008) uses PAT to explain the government-university relationship and details three components required of the partnership: 1) tasks delegated to institutions (by the government), 2) government resources given to the institutions (used in the form of reward), and 3) government interest in assigned tasks. Additionally, the author notes that PAT helps explain certain governmental procedures used when dealing with low performance and high cost of education as well as clarifies the complexities governments face when attempting to govern institutions (Kivistö, 2005, 2008). Despite the many useful applications, Kivistö does suggest some weaknesses of PAT. For example, Kivistö argues that the theory relies too much on narrow assumptions such as those related to human character and motivation. This weakness affects the application of PAT because other factors like the "multilateral networks" of internal and external stakeholders that may influence performance are not examined (Kivistö, 2008). Additionally, Kivistö's application of PAT is limited to the economic perspective and only one principal was explored. This limited scope prevents the review of multiple principals that could potentially affect the government and higher education institution relationship.

Lane (2007) also uses PAT in a study that "investigates how actors and mechanisms at the local and state levels aid the state government in compensating for the inherent information asymmetries in the system" (p. 616). In this research, Lane (2007) uses a conceptual framework derived from PAT that is structured around external actors and the forms of oversight used to monitor higher education. Specifically, this conceptual framework suggests that, "oversight is not a singular event; rather, it is a complex array of interactions among external actors as well as among latent and manifest oversight mechanisms" (Lane, 2007, p. 617).

Lane's (2007) study explores the types of oversight mechanisms informing the principal (state government) about the agent (an institution). Lane (2007) found that multiple entities engage in the oversight process and that some are more active than others even if they do not directly influence the operation of the institution. Moreover, Lane (2007) notes the important role multiple campuses can provide for legislators. Specifically, Lane (2007) states that, "in Pennsylvania, nine of the interviewees noted the size of the institution as having a significant impact on its relationship with the government and the public" (Lane, 2007, p. 627). Further, "the size and direct personal influence of the institution on constituents contributed significantly to the amount of attention paid to institutional activities" (Lane, 2007, p. 627). While the principals' level of involvement in the oversight may vary from principal to principal, some informally engage in activities based on personal interest. Using PAT to analyze this research is advantageous since it provides a lens for having multiple principals. This aligns with PAT's roots in political science (i.e., multiple principals) since in this situation, there are multiple principals affecting the oversight of institutions. Moreover, these findings may encourage institutional leaders to question how they respond to multiple principals that are attempting to control behavior.

Lane and Kivistö (2008) provide a detailed explanation of PAT and describe how applying PAT can help researchers understand: 1) why postsecondary institutions respond to legislative action differently, 2) the impact of competing governmental demands, and 3) how the governmental structure can impact effectiveness and autonomy. The authors explore how future research may benefit from using PAT as a tool to understand governance and policy implementation in higher education. Questions emerged from the work of Lane and Kivistö (2008) in five areas:

1) How can PAT improve understanding of policy and policy-making?
2) Does shirking exist in postsecondary governance structures? What might such shirking look like? How does it manifest itself?
3) How do governments oversee university activities? What are the costs and impacts of different oversight mechanisms? To what extent do oversight mechanisms differ between systems/structures?
4) What is the differential impact of single, collective, and multiple principals?
5) How do interests, information, and incentives motivate institutional behavior? (p.

169-172)

These questions and the authors' discussion provide an extremely useful exploration of PAT—how its historical underpinnings in economics and political science have shaped PAT, and whether these influences affect the theory's use in higher education research.

Lane and Kivistö (2008) provide readers with a solid explanation of PAT, but Marginson (2007) suggests an additional nuance to consider. According to Marginson (2007), the impact of different outcomes from the economics (private good) and political science (public good) perspectives need more consideration because higher education is viewed largely as both a public and a private good. Public goods are products (goods and services) whose production or consumption is inherently collective in nature. Private goods are products with properties that are wholly controllable by their lawful owners (Marginson, 2007). By contrast the notion of the "public" in public goods refers to the legal authority to act on behalf of the common good (Marginson, 2007). While an individual can produce products with the characteristics of public goods, it is only the government that produces public goods. Marginson (2007) and Moe (1990) both demonstrate that government (e.g., states) can be involved in producing public and private goods through higher education. The private and public benefit when people go to college and as a result gains a more educated working population as well as an increased economic-base, and the individual also benefits from college and experiences increased income and an improved knowledgebase (Marginson, 2007). Although Lane and Kivistö (2008) detail how PAT can be applied in higher education, their study is limited because the impact of different outcomes is not considered.

In other research, Nicholson-Crotty and Meier (2003) examine whether governance structures in higher education facilitate or impede progress toward institutional and/or state goals. The authors explore the structures of higher education boards in order to understand how their political interactions affect higher education policy. The research from Nicholson-Crotty and Meier (2003) produced mixed results. More specifically, whether particular structures "reveal a clear and consistent set of relationships" was unclear in their final analysis (Nicholson-Crotty & Meier, 2003, p. 95). These findings suggest that additional theoretical work is needed in order to determine "what kinds of political forces are mediated by the various structures and how in combination these affect higher education policy" (Nicholson-Crotty & Meier, 2003, p. 95). The study from Nicholson-Crotty and Meier (2003) produced weak results and point to a call for more research to better understand the role of governance structures in making progress toward state goals like undergraduate degree production.

A final perspective on applying PAT to higher education comes from McLendon (2003), who sought to explicitly incorporate political science research to see if the "underpinnings of politics of higher education scholarship" could be broadened and/or enriched (McLendon, 2003, p. 172). While McLendon's (2003) work utilized PAT from the political science perspective. He noted that this approach was useful in thinking about future research like the impact of multiple principals and how agents may play the principals off one another. Researchers may want to consider what types of gaming strategies (e.g., playing principals off one another) institutions use to advantage them when using PAT from the political science perspective. While McLendon (2003) notes that using the economic perspective of PAT may benefit future research, such an approach would limit the study because there is one principal and one agent. Despite this, McLendon's (2003) work is germane to this research because understanding the impact of multiple agents could allow for deeper understanding of how individual institutions could be on meeting state goals. Following McLendon (2003), this study does not limit its focus to the use of individual agents.

Building on earlier work (i.e., McLendon, 2003), McLendon, Hearn, and Deaton (2006) explored how theoretical perspectives such as PAT, policy innovation, and policy diffusion can be used to explain how variations of socio-political policies over time and across states affected the adoption of accountability policies in higher education. This research had mixed findings, but the authors noted that, "the primary drivers of policy adoption were legislative party strength and higher-education governance arrangements" (p. 1). Findings from McLendon et al. (2006) suggest that a single principal (e.g., the legislative party in control) controlled higher education policy adoption. The use of one principal is grounded in the economic perspective of PAT; this may be a limitation of the economic aspect of PAT when applied to higher education institutions (i.e., the agent).

Furthermore, while the finding that "the primary drivers of policy adoption were legislative party strength and higher-education governance arrangements," was conclusive for McLendon et al. (2006), more research is needed to confirm such results. It may be that in other states multiple principals influence policy adoption (McLendon, Hearn, & Deaton, 2006, p. 1). While McLendon et al. (2006) takes into account the role of multiple principals (i.e., for states—consolidated governing board or coordinating boards and the political party of the governor versus majority of the state legislature), caution should be used if generalizing this finding beyond that study. The study from McLendon et al. (2006) is relevant to this research because it allows the researcher to better understand what drives policy adoption. Understanding factors contributing to policy adoption is useful context for exploring the impact of state STEM policies on STEM degree production. This knowledge is beneficial for the implications section of the study as more information about what contributes to STEM degree production has the potential to inform those looking to affect policy development around STEM.

Similarities and Differences of PAT. This section details the similarities and differences of PAT derived from economics and political science to explain and better understand particular situations such as degree production in higher education.

Similarities. It is important to note that while differences do exist between these two perspectives (i.e., economics and political science), some things remain constant such as: 1) the principal(s) contract(s) with the agent to engage in certain functions that will improve the status of the principal relative to the status quo; 2) principal(s) seek out assistance from the agent because the principal(s) cannot perform the requested function (i.e., not enough time, knowledge, energy, etc.); 3) the agent acts on behalf of the principal(s); and 4) a primary goal is to avoid "shirking" (i.e., getting the agent to act on the interests of the principal). While PAT's roots are grounded in economics and political science, neither perspective has sole ownership of the theory. Kivistö (2005) notes that, "agency theory is not and has never been the exclusive property of a certain scientific paradigm; rather, it has been and could be a useful theoretical framework for many different disciplines and approaches" (p. 2). The following sections detail the uniqueness of the economic and political science perspectives.

Differences in Assumptions. There are six differences in assumptions between the political science and economic perspectives (Lane & Kivistö, 2008). Differences in assumptions around the contract, unit of analysis, actor motivation, principal's primary mode of control, output, and source of shirking are described below.

Contracts. Contracts in the economics perspective between the principal and agent are more formal and explicit in order for more "economic co-operation" to occur (Lane & Kivistö, 2008, p. 150). In political science perspective, the relationship between principals and agents is also a contractual one, but the contracts tend to be more vague and implicit. Much control is given to the agent to determine the best way to execute the contract (Lane & Kivistö, 2008).

Unit of Analysis. The unit of analysis in the economic perspective focuses on economic components of the principal agent relationship. More specifically, this perspective ensures that the principal's interests are maintained and secured. In the political science perspective, the principals and agent are viewed more equally. Lane and Kivistö (2008) note that since it is difficult to exchange political agents, "recognizing and understanding the impact of a principal agent relationship on the agent (e.g., politician or a public bureaucracy) is much more important in political science than economics" (p. 152).

Actor Motivation. There is not a great deal of difference between the actor motivation of the economic and political science perspective of PAT. Both perspectives view the principal(s) and agent as "utility maximizers" (Lane & Kivistö, 2008, p.152). One difference to note from the political science perspective is how political power and policies are implemented. The desire for political power may be an enticing goal for a principal and may not be consistent with the stated outcomes the principal seeks from the agent.

Principal's Primary Mode of Control. In the economic perspective, the contract serves as the principal's primary mode of control. The contract enables economic co-operation between the principal and agent. The contract really serves as a taskmaster for the agent and details how an agent will be compensated. Whereas in the political science perspective, control is less explicit and is often regulated by "elections, appointment of intermediary principals, power brokering, and signaling from political elites" (Lane & Kivistö, 2008, p.153).

Output. The output from the economics perspective of PAT is a private good between the principal and agent—there is one principal and one agent that benefit. For example, the output (e.g., STEM degrees) is observable to the state, an institution, but also the general public—despite it being a private good. The output from the political science perspective is a pubic good—meaning that there are multiple principals and multiple agents that benefit. More specifically, the public benefits when people go to college and as a result, society gains a more educated working population as well as an increased economic base (Marginson, 2007). The state can also benefit from individuals going to college resulting in an increased economic-base with higher taxable salaries. While Lane and Kivistö (2008) note that governments tend to produce public goods as an output, Moe (1990) used PAT (from the political science perspective) in an empirical study and measured institutional outputs (i.e., graduation rates, exam scores, and graduate school acceptance) as a private good. This discrepancy of private versus public good is discussed in the limitations section.

Source of Shirking. The economic perspective assumes that agents are "self-interested, utility maximizers" (i.e., they engage in shirking) (Lane & Kivistö, 2008, p.154). This is an important component of this assumption because if the principal and agent where given the same information, shirking would not be an option for agents since the principal would detect it (the information) and put an end to the behavior. While the political science perspective has similar assumptions regarding sources of shirking, it is important to note that in this perspective, shirking can occasionally occur as a result of the structures. As a result, unintentional shirking occurs such as communication issues between the principals and the agent may result in unintentional shirking despite the fact that an agent was really attempting to meet the goals of the principal (Lane & Kivistö, 2008, p.154). For example, a state has a goal of increasing STEM degree production and an institution (i.e., agent) may be working on turning around low-performing STEM departments within the institution, but, if this effort is not explicitly communicated and connected to work associated with increasing a state's STEM degree production, it may appear that the institution was shirking the state despite the fact that the agent was attempting to meet the goals of the principal.

Principal Agent Theory's Application in STEM Policies in Higher Education

In order to understand the impact of state STEM policies (i.e., the input) on undergraduate STEM degree production (i.e., the output), it is imperative to understand the relationship between principals (i.e., the state) and the agents (i.e., institutions) that work to utilize the state STEM policies that may or may not affect STEM degree production. The use of PAT in this research to explore the impact of state STEM policies on undergraduate degree production allows for a clearer look at the complex relationships between principals and the agents and the work they do when applying STEM policies for potential enhanced STEM degree production. Multiple principals exist in this scenario. For example, institutions (i.e., the agent) are held accountable by various principals at the state level including: the governor, legislators, governing boards and system offices (Lane, 2008). These same principals are also held accountable—particularly when taxpayers demand accountability from legislators for re-election purposes. Additionally, legislators demand accountability from state agencies and governing boards in order to continue to provide support. The use of the principal agent model (Hoenack, 1983) where the state serves as the principals (i.e., the governor, legislators, governing boards and system offices), acting on behalf of society, and contracts with higher education institutions to serve as agents that provide educational opportunities and award undergraduate STEM degrees is particularly useful and appropriate.

Limitations and Gaps in the Literature for Principal Agent Theory

While previous researchers (i.e., Kivistö, 2005, 2008; Lane, 2007; Lane & Kivistö, 2008; Nicholson-Crotty & Meier, 2003; McLendon, 2003; and McLendon, et al., 2006) have provided useful insights in both applying and understanding how principal agent theory (PAT) can be applied to higher education, it is important to note the limitations and gaps in the current literature.

The review of literature revealed seven limitations. First, PAT in higher education research has been used by only a small group of researchers thus far (i.e., Kivistö, 2005, 2008; Lane, 2007; Lane & Kivistö, 2008; Nicholson-Crotty & Meier, 2003; McLendon, 2003; and McLendon, et al., 2006). Second, despite this use, borrowing theories from other disciplines especially economics or political science is not widespread in higher education research even though much of higher education's structure relies on principles from those disciplines. Moreover, the relationship between states and institutions and the impact higher education outcomes can have in achieving long-term state goals is not always considered. Third, explanations of higher education issues may be limited by the use of theoretical perspectives that are well known and "comfortable" to researchers. This is a limitation because perspectives like political science or economics may not traditionally be used to explore phenomenon in higher education, but can actually provide a more complete understanding of the issue in question than historically used theories. PAT's use in higher education research can evoke new and unexpected insights since the problem is being viewed from a new theoretical perspective. Fourth, despite its potential utility, PAT is a complex theory and it can be difficult to identify the principal and agent in certain situations (Borgos, 2013). Fifth, PAT's use in economics is different from how it is applied in political science. While new insights can occur as a result of exploring issues from a new theoretical perspective, it is also important to note that understanding the underpinnings of PAT is crucial because the theory can be misused if both perspectives (economics and political science) are not accounted for in research. Sixth, a clearer understanding of PAT and how the economic and political perspectives affect outputs is needed. While one perspective is being used in this research, acknowledging the other perspective allows for further conversations and future research. Seventh, current researchers have conflicting views on which (i.e., the political science or economic perspective) are more appropriate for higher education research. For example, Lane and Kivistö (2008) note that governments tend to pursue and desire outputs producing public goods, yet Moe (1990) uses PAT in an empirical research study measuring institutional outputs including both public goods (i.e., graduation rate) and private goods (i.e., exam scores and graduate school acceptance). This is a limitation in the current understanding of PAT's use in higher education research because higher education can be seen as both a public and private good.

Lastly, it is important to take into account the role of externalities in this research. An externality is the effect of an economic activity felt by those not directly involved in the economic activity (Moretti, 2004). Positive externalities are often described as spillover effects felt by consumers who were not directly intended by their producers (Moretti, 2004). But most positive externalities are so pervasive, affecting everyone within their range, they cannot be effectively contained through regulation (Moretti, 2004). Where externalities are so positive and pervasive, government enters the market directly as an entrepreneur to produce them (Moretti, 2004). Examples include education whose positive effects are so far beyond its benefits to the individual, society at large derives extensive benefits from the individual's education. Understanding a state's role in producing private and public goods is needed in this research.

Conclusions Around Principal Agent Theory's Multiple Applications

PAT is grounded in both economics and political science and as a result, it is particularly useful and versatile. This versatility makes it exceptionally useful in higher education research because it can be used to explain a variety of phenomenon facing postsecondary education today (i.e., accountability, degree production, longitudinal data tracking). While few studies in higher education research utilize PAT, the theory may offer a more robust explanation of current issues shaping higher education, when taking into account its origins (economics and political science). Each perspective of PAT's origin are helpful when explaining the inner-workings of governmental bureaucracies (i.e., a state and a system of higher education), but not fully accounting for differences between the varying perspectives can lead to misapplication of PAT. Additionally, it is important to note that both perspectives are equally applicable to higher education research. Therefore, individual situations or phenomenon should dictate which perspective is more useful; one is not better than the other (Lane & Kivistö, 2008). This is germane to this research because the microeconomic perspectives—principal agent theory and production function theory—allow researchers to explore the different perspectives based on the research questions. Highlighting this feature showcases how the microeconomic perspectives—principal agent theory and production function theory—are useful in answering certain types of research questions about productivity.

The following section marks the beginning of the second half of Part Two and provides a critical review of literature pertinent to the second microeconomic perspectives being used in the conceptual model—production function theory. Following that, the chapter ends with Part three, a description and explanation of the conceptual model.

Production Function Theory

The second theory comprising part of the conceptual framework for this study is production function theory. This theory may be appropriate for analyzing problems in higher education because it allows the researcher to understand how the input (i.e., state STEM policies) affects the output (i.e., STEM degree production). One of the first uses of production function theory was by Cobb and Douglas (1928). The theory was used to explain why output payments for labor were constant despite the capital/labor ratio not being constant. This theory is still widely used for theoretical and empirical analyses of growth and productivity and is central to much of today's work on growth, technological change, productivity, and labor (i.e., Ehrenberg, 2003, Monk, 1989, Titus, 2009).

While Cobb and Douglas' (1928) production function theory was developed from "the movement of labor, capitol, production, value, and wages for the manufacturing industries of this country as a whole," this theory has been applied to other industries (p. 165). Bowles (1970) began using it to describe the relationship between school and student inputs and a measure of school output (K-12 schools). Examples of inputs are parental education levels, family size, race, family income, education level of teachers, and class size. Bowles (1970) grouped inputs into three categories: underlying influence on learning, home, and school. It is important to note that Bowles (1970) excluded input variables like student and parental attitudes toward schooling because of their exogenous nature. Bowles (1970) defined outputs as achievement scores on standardized tests. Findings from this early research indicate that there are some school inputs that do seem to affect learning. While Bowles's (1970) early research pertained to output of K-12 schools, it laid the foundation for studying inputs and outputs at the postsecondary level.

While Bowles' (1970) early work applied this theory to K-12 settings, Monk (1989) explains how and why production function theory can help analyze postsecondary education policy. The author notes that the theory is applicable in postsecondary education because production function theory can specify what is currently possible and it gives researchers a baseline to evaluate productivity (Monk, 1989). Additionally, Monk (1989) further explains why the theory is especially useful for higher education administrators and policy analysts. He states that, "with this knowledge, administrators can make accurate assessments of efficiency and have the requisite knowledge to effect improvement" (Monk, 1989, p. 32). While the author argues for the theory's appropriateness, it is clear he also has some reservation about whether or not there is a real production function in education—meaning do the inputs really affect the outputs (i.e., education is not about producing widgets)? This viewpoint is echoed in Hanushek's (1972; 1976) work. For example, Hanushek (1972; 1976) notes that the transformation of inputs into outputs may differ drastically by race, sex, socio-economic demographics, or other student characteristics. While a valid concern, Monk (1989) notes that, "a single, albeit highly complex, production function can be posited that accounts for all contingencies and complexities associated with the production of education outcomes" (p. 32). Lastly, Monk (1989) raises one critical point about the theory's symmetry, indicating that researchers may want to consider if or how "education actors" can play a leading role in the "creation, destruction, and recreation" of the production function process (inputs affecting outputs) (p. 33). This is important to take into consideration for this research because there are characteristics like institutional culture that are not being measured by this research, but variable like this (i.e., different to measure and assign values) could potentially impact the outputs.

While Monk (1989) generally took a positive stance on education research being grounded in production function theory, researchers (i.e., Cuban, 1983; Purkey & Smith, 1983; Rowan, Bossert, & Dwyer, 1983) question if applying it to education all together is too risky because research findings are not consistently able to show effects. When assessing these reservations, it is important to note that the research in question focuses on work conducted in elementary and secondary school settings. The applicability of the theory in explaining productivity in postsecondary education settings may be more appropriate.

Production Function Theory's Application in Higher Education

Indeed, production function theory has been applied in higher education research. Ehrenberg (2003) postulates that production function theory is especially useful when applied to a state's role in public higher education. Many states invest in postsecondary education because they believe they will see returns on those investments such as a more educated workforce and higher tax revenues (Ehrenberg, 2003). Ehrenberg's (2003) literature review on the use of econometrics in higher education provides readers with questions to consider; one in particular is, "does a state's investment in higher education lead to an increased representation of college-educated workers in the state's population?" (p. 4). A second question Ehrenberg identified (2003) is "can a mass of college-educated employees can result in positive externalities (e.g., higher wages or other social benefits) for other employees without college degrees?" (p. 4). While Ehrenberg's (2003) work is a review of the literature and not a formal research study, it still allows readers to consider how state investments can be used as an input variable when applying production function theory to postsecondary education

Hopkins (1990) theorizes that private and public institutions attempt to produce multiple types of outputs (i.e., degrees in different subject areas and at different levels [bachelor's, master's, etc.]). Hopkins' (1990) research includes several inputs (new students matriculating, faculty time and effort, student time and effort, staff time and effort, buildings and equipment, library holdings and acquisitions, and endowment assets) that affect outputs (student enrollment in courses, degrees awarded, research awards, articles, and citations, and services rendered to the general public), production function theory allows researchers to define inputs and outputs differently. Hopkins' (1990) findings are similar to earlier work from Hopkins and Massy (1981) where researchers concluded that a higher education production function describes the relationship between outputs and inputs. Examples of outputs include college degrees awarded and examples of inputs include students, faculty, staff and physical and financial capital as inputs (Titus, 2009). Other researchers applying PFT in higher education research echo this conclusion. The study from Hopkins (1990) is limited in that it explores only institutional inputs (i.e., faculty time and effort, student time and effort, and library holdings). Although Hopkins (1990) uses PFT, the study is limited because the author uses institutional inputs and those can vary from school to school within a state, making state generalization more difficult. Unlike Hopkins (1990), this research study relies on secondary state level data to explore STEM degree production.

Dolan and Schmidt (1994) explored how an institution's human and physical resources lead to the production of students that earn post-baccalaureate degrees (e.g., master's, doctorates, and law degrees). The inputs were variables like student quality (operationalized via SAT scores), faculty quality (operationalized via compensation levels), expenditures, student-faculty ratios, diversity of students, diversity of faculty, and variety of among academic majors. Dolan and Schmidt (1994) collected information for the outputs (e.g., production of alumni earning post-baccalaureate degrees) from organizations like the National Research Council, College Board, Academy of Medical Colleges, American Bar Association, and American Association of University Professors. The authors concluded that faculty quality and student to faculty ratios were significantly related to a higher production of alumni earning post-baccalaureate degrees (Dolan &

Schmidt, 1994). While Dolan and Schmidt (1994) suggests that institutions seeking to increase the number of students earning post-baccalaureate degrees should pay close attention to the faculty quality at the institution, validity questions arise in two areas. First, Dolan and Schmidt (1994) used faculty compensation as a measure of faculty quality, but higher compensation levels do not necessarily mean better teaching. Second, Dolan and Schmidt (1994) used higher SAT scores as a measure of student quality. Research has shown that higher SAT scores do not equate to higher quality students (Baron & Norman, 1992). Although Dolan and Schmidt (1994) use PFT in production research, this study is limited because the authors use institutional inputs and those can vary from institution to institution within a state making state generalization more difficult. The present study relies on secondary state level data to explore STEM degree production.

Researchers' choices in designing studies based on PFT can also undermine its usefulness if the inputs are not widely applicable, as shown in a 2009 study. Agasisti and Johnes (2009) examined the production efficiencies of bachelor's degrees, master's degrees, and research grants between English and Italian universities. Agasisti and Johnes (2009) used institutional data (e.g., total number of undergraduate students during the three-year study period, financial resources, total number of doctoral students, and the total number of academic faculty and staff) as the input variables and the output variables were production of bachelor's and master's degrees and research grants. While Agasisti and Johnes' (2009) study has similarities to studies previously mentioned in the sections above, it does not describe how the inputs affect the outputs, but rather describes which group (i.e., English versus Italian universities) is more efficient. Because the Agasisti and

Johnes (2009) study is limited to efficiency it does not directly answer questions about how to obtain more STEM degrees. Nevertheless, Agasisti and Johnes' (2009) study is germane to this study in that it uses PFT in its production research. The research is limited because the authors use institutional inputs, which can vary from institution to institution within a state. The research relies on secondary state level data to explore STEM degree production.

The previous two sections explored the use of PFT from the labor movement, through secondary education, and finally to postsecondary education. All of the research reviewed for these sections examined ways to think about how efficiencies in production can affect output, but the limitation of using just PFT is that it only looks at the inputs and the outputs. There is still a lack of clarity about what happens between an input and an output. This is not accounted for in the theory.

Limitations of Production Function Theory

There are four key limitations to consider when applying production function theory to postsecondary education. First, the applicability of production function lies in the hands of key stakeholders' desires to improve degree productivity (i.e., improved outputs). Second, researchers need to be aware of whether or not production function and the use of inputs and outputs really exists (i.e., education is not about producing widgets). More specifically, it is critical to understand how inputs can affect outputs. Third, it is important to consider the roles "education actors" have in the production function process (i.e., changing inputs for improved outputs) (Monk, 1989, p. 33). Education actors (i.e., principals and agents) each can play a role in the undergraduate STEM degree production function process. This role can positively or negatively affect undergraduate STEM degree production. It is important to consider the role that education actors may have on equitable outcomes as part of a production function analysis. Different education actors can play either a positive or negative role in assuring equitable outcomes. For example, an education actor focused on obtaining resources (i.e., inputs) for one institution may negatively impact outcomes at another institution. Fourth, the main limitation of production function theory is its application to the firm (e.g., institution). This study explores activity at the state level, but at the state level, one has to look that the relationship between the institution and the state. This is why production function theory is combined with principal agent theory in this study.

Conclusions Around Production Function Theory's Applications

The sections above provided a review of the relevant literature on production function theory (PFT) and it helps to inform this study. A portion of the conceptual model relies on the values postulated by PFT and applies it (along with principal agent theory) to understanding the impact of state STEM policies (e.g., incentives or scholarships/aid for individuals to pursue STEM degrees, incentives or money earmarked in the state budget for STEM disciplines for institutions to enhance retention and production of STEM majors and graduates, and articulation agreements between public two and four-year institutions in STEM majors) on the production of a state's undergraduate STEM degrees.

The sections above on PFT began by describing how one of the earliest applications of PFT was used to explain why output payments for labor were constant despite the capital/labor ratio not being constant and the theory is still widely used for theoretical and empirical analyses of growth and productivity. From there, the author of this study explored how PFT has been applied to higher education. More specifically, the reviewed research examined how inputs in higher education research affect outputs. Although much of the literature described above focused more on efficiency rather than on the relationship between the input and output and what happens during the process of going from an input to and output (this is done in the conceptual model), understanding how PFT can be applied to in higher education research is critical for the development of the conceptual model.

Appropriateness of Combing Theories

The use of these two theories is particularly important because state STEM policies can include providing financial resources to higher education institutions and college students interested in STEM, and in this study, the production of bachelor's STEM degrees is hypothesized to be a function of state STEM policies and selected financial aspects of state higher education policy such as tuition, state appropriations to higher education institutions, and financial aid, controlling for other variables. The conceptual model also suggests that current state STEM policies and selected financial aspects of state higher education policies are interrelated and influenced by history as well as other state policies (e.g., funding for Medicaid).

The figure depicted in part three below shows how principal agent theory and production function theory is combined, so that the relationship between state STEM policies and undergraduate STEM degree production are taken into account and how the conceptual model is applied in this study.

Part three

Conceptual Model

The conceptual model developed for this study may provide an appropriate lens to understand the STEM degree production process through the application of constructs drawn from principal-agent theory and production function theory. This study focuses on states' production of STEM degrees. As explained in chapter one and earlier in this chapter, this research approaches the topic from a microeconomic perspective uniting two theories—principal agent theory (PAT) and production function theory (PFT). This study suggests that when the two theories (principal-agent theory and production function theory) are combined, the conceptual model provides an appropriate lens to examine the relationship between state STEM policies and STEM degree production.

The dependent variable for the study is undergraduate (baccalaureate) STEM degrees. For purposes of this study, STEM degrees are operationally defined to include majors from the disciplines: science (e.g., chemistry, biology, etc.), technology, engineering, and mathematics. Social/behavioral sciences like psychology, economics, sociology, and political science are not included as defined STEM majors. The dependent variable was selected because it serves as the output variable—a key component of production function theory. The independent variables are divided into two categories—state STEM policies and state finance policies. These independent variables were selected because one of the variables serves as an input variable (i.e., state STEM policies)—a key component of production function theory— and the remaining independent variables serve as control variables (i.e., state finance policies). The control independent variables play a key role in the application of principal agent theory to better understand the relationship between states and institutions and how that impacts STEM degree production. In Chapter 3, Table 2 displays how the constructs used in this study are mapped to the variables.

The first category—state STEM policies—are operationalized as 1) individual incentives (e.g., scholarships) to pursue STEM degrees; 2) institutional incentives (e.g., money earmarked in the state budget for STEM) retention and production of STEM majors and graduates; and 3) articulation agreements between public two and four-year institutions in STEM majors. As discussed earlier in the literature review, state STEM policies are included as an input in the model because there is a gap in the current literature and production models that exist around the inclusion of state STEM policies as a variable for understanding STEM degree production.

The second category—state finance policies—are also included in the model as an independent control variable and operationalized as state undergraduate enrollment per FTE, state R&D funding to institutions, state per-capita income, state K-12 expenditures, state higher education appropriations per capita, public in-state tuition per FTE, state per-capita expenditures for Medicaid, state per-capita expenditures for corrections, state expenditures for need-based aid per FTE, and state expenditures for grant aid per FTE. Some researchers (Titus, 2009a; Trostel, 2012; and Titus, 2009b) have explored the impact of state finance policies on degree production. More specifically, Titus (2009) explored the impact of state allocations for higher education, need-based student financial aid, tuition, and state per-capita expenditures on welfare. State allocations for higher education, state expenditures for need-based financial, and public in-state tuition are independent control variables in this study. While this study does not explore the impact of state welfare, similar financial competitors to higher education—Medicaid and corrections—are being used as independent control variables. State expenditures on postsecondary education are being used in this study and builds on Titus' (2009a) work by providing a more nuanced understanding of how state expenditures on postsecondary education affects STEM degree production.

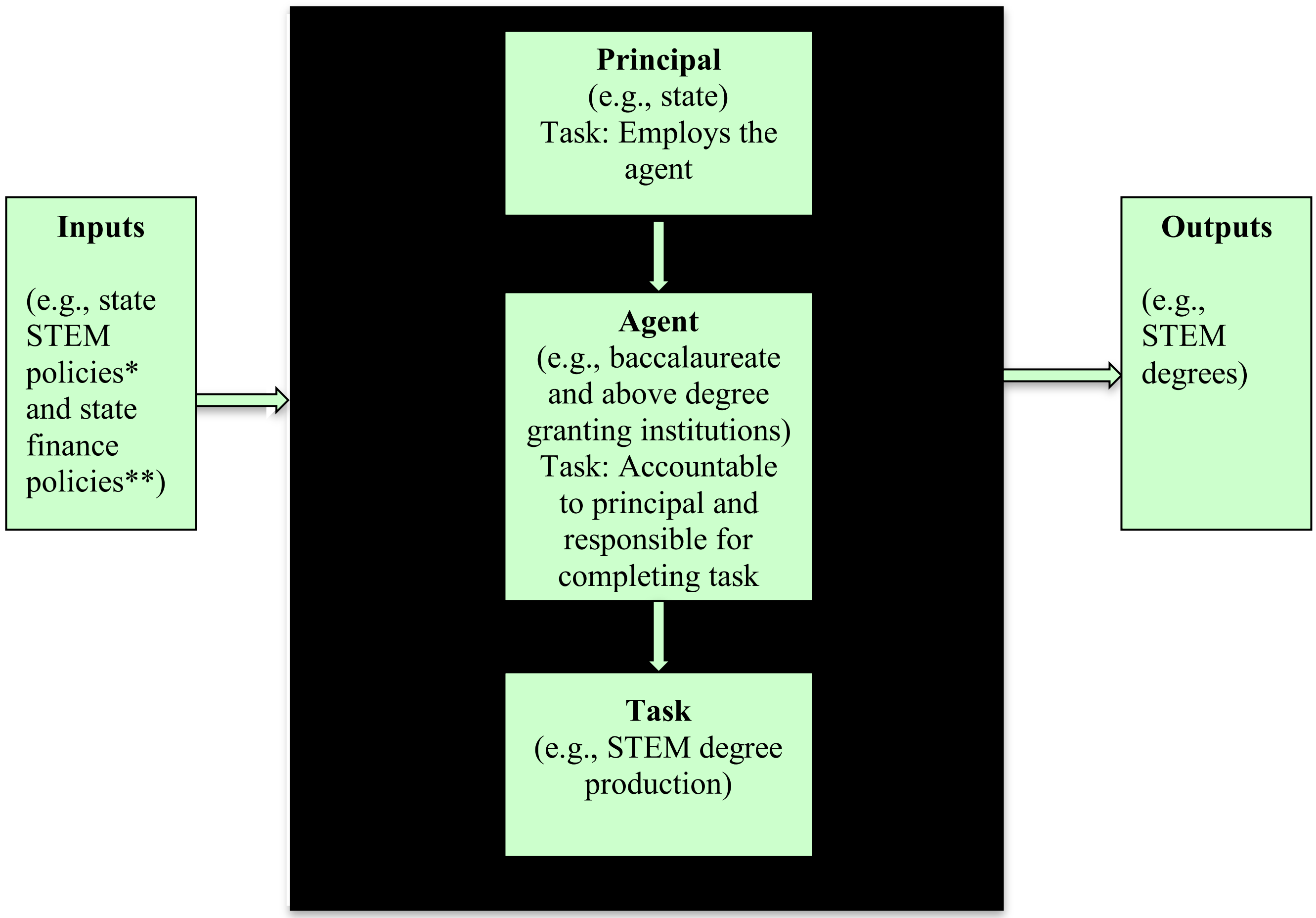
Another researcher, Zhang (2009), studied the impact of state allocations (i.e., a control independent variable in the study) to degree production, and a smaller number of researches have hypothesized about the impact of policies on STEM degree production (Zhang, 2011). For example, Zhang (2011) explored the impact of state finance policies (e.g., Georgia Hope and Florida Bright Futures scholarships) on STEM degree production, and Sjoquist and Winters (2013) explored the role of merit scholarships on college majors in STEM, which ultimately can lead to STEM degree production. Arcidiacono, Aucejo, and Hotz (2013) reviewed the impact of K-12 education policies (e.g., academic curriculum) on STEM degree production.

Other researchers (Liang & Ness, 2010) have explored the impact of state finance policies on other higher education outcomes like increased local enrollment. Liang and Ness (2010) examined the effect of state merit-based scholarship programs on reducing the "brain drain" in states and explored if there was variation across states by different types of institutions (Liang & Ness, 2010). While Liang and Ness (2010) explore the impact of state finance policies on limiting a state's brain drain, this study did not assess how including other variables (e.g., state STEM policies including finance related policies like state allocations/programs specifically for STEM) could potentially provide a more nuanced understanding of factors affecting enrollment and retention of a state's students at an in-state institution. No research known to date has explored the effects of state STEM policies.

Building on key tenets from principal agent and production function theories, a conceptual model was developed uniting both theories to explain how undergraduate STEM degree production is influenced by state higher education STEM policies. This conceptual model may allow researchers, administrators, and policy analysts to understand how the theories can be used to explain how both the inputs and the process affect the outputs. The process portion of the conceptual model can be visualized as a black box. Within the black box are the actors of PAT (i.e., the principal and the agent) as well as the task is being asked of the agent. The Figure 1 on the following page illustrates how the model unites the two theories. In order to understand the impact of state STEM policies (i.e., the input) on undergraduate STEM degree production (i.e., the output), it is imperative to understand the relationship between principals (i.e., the state) and agents (i.e., institutions) that work to utilize the state STEM policies that may or may not affect STEM degree production.

Figure 1

Principal Agent Production Function Theory Conceptual Model



*State higher education STEM policies are operationalized as: first—individual incentives (e.g., scholarships) to pursue STEM degrees; second—institutional incentives (e.g., money earmarked in the state budget for STEM) to enhance retention and production of STEM majors and graduates; third—articulation agreements between public two and four-year institutions in STEM majors.

**State finance policies are operationalized as state undergraduate enrollment per FTE, state R&D funding to institutions, state per-capita income, state K-12 expenditures, state higher education appropriations per capita, public in-state tuition per FTE, state per-capita expenditures for Medicaid, state per-capita expenditures for corrections, state expenditures for need-based aid per FTE, and state expenditures

Chapter 3: Methodology

This study focuses on states' production of STEM degrees and approaches the topic from a microeconomic perspective using two theories, principal agent theory and production function theory. This study posits that when these two theories are combined, the conceptual model provides an appropriate lens to examine the relationship between state STEM policies and STEM undergraduate degree production. The conceptual model uniting both theories is described at the end of this chapter. Using state-level data and incorporating theoretical frameworks derived from economics and political science described above, this study addresses the following questions:

1) How is undergraduate STEM degree production within a state related to state economic and higher education finance variables?
2) Controlling for state economic and higher education finance variables, how are states' undergraduate STEM degree production influenced by state higher education STEM policies?

This chapter describes the research design, data sources, statistical methods, variables, and limitations of this study.

Research Design

The panel data set (also known as time series/cross sectional data) produced for this study contains data from 17 academic years (1999 to 2015) across all 50 states. The time period of 17 years was selected because it is the longest period (to date) where there is no missing data. The study design controls for heterogeneity or unobserved differences within states and across time. Data from the following variables are used to build the panel data set: undergraduate (baccalaureate) STEM degrees, state STEM policies (defined below and in chapter one), undergraduate enrollment per FTE, state research and development (R&D) funding for institutions, state per-capita income, state K-12 expenditures, state higher education appropriations per capita, undergraduate four-year public in-state tuition per full-time equivalent (FTE), state per-capita expenditures for Medicaid, state per-capita expenditures for corrections, state expenditures for need-based aid per undergraduate FTE, and state expenditures for grant aid per FTE.

The use of panel data allows the researcher to better understand the relationship between state STEM policies and STEM undergraduate degree production. This design is most appropriate because 1) panel data has variability and less collinearity (i.e., correlation among variables) (Allison, 1994; Halaby, 2004); 2) panel data allows researchers to examine the relationship between and across variables over time (Allison, 1994; Halaby, 2004); 3) panel data gives researchers the ability to test for "individual heterogeneity, statistical efficiency due to more information, a temporal dimension that enables dynamic adjustment, and better and more detailed data that allow researchers to model individual behaviors and identify effects" (Baltagi, 2008 as cited in Zhang, 2010, p. 308); and 4) panel allows researchers to control for unobserved heterogeneity (variation/differences among cases that are not measured).

Data Sources

This study utilizes data drawn from six sources. The first data source is the Integrated Postsecondary Education Data System (IPEDS), sponsored by the National Center for Education Statistics (NCES). IPEDS is the U.S. Department of Education's postsecondary education data collection program (Fuller, 2011). Institutions that receive Title IV funds under the Higher Education Act are required to submit data or risk the loss of funding, so nearly all postsecondary institutions operating in the United States participate in the IPEDS surveys (Fueller, 2011).

Upon receipt of the surveys, NCES staff checks the data and contacts institutions if there are any errors. Regular technical quality checks ensure the surveys are standardized across institutions and the integrity of the data is maintained (Jackson, Peecksen, Jang, Sukasih, & Knepper, 2005).

IPEDS data are compiled from various surveys and currently include 12 components collected directly from providers of postsecondary education in the United States. NCES has collected data through IPEDS from colleges and universities since 1986 (Fuller, 2011). Examples of the surveys in IPEDS include the: 1) Institutional Characteristics, 2) Completions, 3) 12-Month Enrollment, 4) Human Resources, 5) Fall Enrollment, 6) Finance, 7) Student Financial Aid, and 8) Graduation Rate surveys (Fueller, 2011). The data collected in these surveys provide aggregate measures of an institution's yearly financial, enrollment, graduation, and institutional characteristics. This study draws data from the three IPEDS surveys: 1) Institutional Characteristics, 2) Completions, and 3) Finance surveys. First, the IPEDS Institutional Characteristics Survey provides general information about the institution including educational offerings, mission statements, admissions requirements, and student charges (Fueller, 2011). This study utilizes student charges (e.g., tuition) from the Institutional Characteristics Survey from 1999-2015. Second, the Completions Survey captures data on the number of credentials awarded by an institution, by academic program, gender, and race (Fueller, 2011). This study utilizes credentials awarded by academic program from the Completions Survey from 1999-2015. Third, the Finance Survey describes the financial condition of each institution. Data elements from the finance data include financial aid, expenditures, and revenues (Fueller, 2011). This study utilizes expenditures and financial aid data from this survey from 1999-2015. Data from these surveys, representing public four-year institutions, are aggregated at the state level.

The second data source draws from an annual survey of the National Science Board (NSB)—Science and Engineering Indicators State Data Tool, sponsored by the National Science Foundation. The NSB State Data Tool presents state-specific information about a variety of science, engineering, technology, and education measures (National Science Foundation, 2014). This study utilizes the state-level data on research and development expenditures from 1999-2015.

The third data source, the Statistical Abstract of the United States, is the authoritative and comprehensive summary of statistics on the social, political, and economic organization of the United States (U.S. Census Bureau, 2012). This study utilizes state-level data on per-capita income from 1999-2015 from the Statistical Abstract.

The fourth data source draws from a semi-annual survey, Fiscal Survey of States, sponsored by the National Association of State Budget Officers (NASBO). The Fiscal Survey of States gathers data from all 50 state budget offices and provides the fiscal condition of states (e.g., data summaries of state general fund revenues, expenditures, and balances) (National Association of State Budget Officers, 2001-2011). This study utilizes state-level data on K-12 expenditures from 1999-2015.

The National Association of State Student Grant and Aid Programs (NASSGAP) Annual Survey is the fifth data source. This survey collects data of state-funded student financial aid and this study utilizes state-level data of higher education appropriations from 1999-2015 (National Association of State Student Grant and Aid Programs (2001-2011).

The sixth data source draws from the Education Commission of the States (ECS) Annual Compilation of ECS Publications. ECS regularly issues useful compilations, summaries and/or comparisons of state policies—enacted or pending—on a wide variety of education topics (Education Commission of the States, 2012; Education Commission of the States, 2014). This study utilizes state-level data from three areas: 1) individual incentives (e.g., scholarships) to pursue STEM degrees, 2) institutional incentives (e.g., money earmarked in the state budget for STEM) to enhance retention and production of STEM majors and graduates, and 3) articulation agreements between public two and four-year institutions in STEM majors from 1999-2015. Data are presented in a binary fashion (e.g., 0 or 1).

Variables

The dependent variable for the study is the number of baccalaureate STEM degrees completed at public, four-year institutions. For purposes of this study, STEM degrees are operationally defined to include majors from the following disciplines: science (e.g., chemistry, biology, etc.), technology, engineering, and mathematics. Social/behavioral sciences like psychology, economics, sociology, and political science are not included as defined STEM majors. The dependent variable corresponds to the output variable—a key component of production function theory. The dependent continuous variable is transformed to natural logarithms for easier interpretation of the results. The independent variables are divided into two categories—state STEM policies and state finance policies. These independent variables were selected because one of the variables serves as an input variable (i.e., state STEM policies)—a key component of production function theory—and the remaining independent variables serve as control variables (i.e., state finance policies). The control independent variables play a key role in the application of principal agent theory to better understand the relationship between states and institutions and how that impacts STEM degree production. Further in this chapter, Table 2 maps the constructs used in this study to the variables.

The first category—state STEM policies—are operationalized as: 1) individual incentives (e.g., scholarships) to pursue STEM degrees; 2) institutional incentives (e.g., money earmarked in the state budget for STEM) to enhance retention and production of STEM majors and graduates; and 3) articulation agreements between public two and four-year institutions in STEM majors. Data from the Education Commission of the States (ECS) Annual Compilation of ECS Publications from 1999-2015 are used to operationalize state STEM policies and is presented in a binary fashion (e.g., 0 or 1).

The second category—state finance policies—are also included in the model as a set of independent control variables and operationalized as state R&D expenditures to higher education institutions, state K-12 expenditures, state higher education appropriations per capita, public in-state tuition at four-year institutions per undergraduate FTE, state per-capita expenditures for Medicaid, state per-capita expenditures for corrections, state expenditures for need-based aid per undergraduate FTE, and state expenditures for grant aid per FTE. Data from 1999-2015 are collected for this study and adjusted for inflation. Additionally, the independent continuous variables are transformed to natural logarithms for easier interpretation of the results.

Some researchers (Titus, 2009a; Trostel, 2012; and Titus, 2009b) explored the impact of state finance policies on degree production. More specifically, Titus (2009) explored the impact of state allocations for higher education, need-based student financial aid, tuition, and state per-capita expenditures on welfare. State allocations for higher education, state expenditures for need-based financial, and public in-state tuition at four-year institutions are independent control variables in the study. While this study does not explore the impact of state welfare, similar financial competitors to higher education—Medicaid and corrections—are being used as independent control variables.

Zhang (2009), studied the impact of state allocations (i.e., a control independent variable in the study) on degree production, and a smaller number of researches have hypothesized about the impact of policies on STEM degree production (Zhang, 2011). For example, Zhang (2011) explored the impact of state finance policies (e.g., Georgia Hope and Florida Bright Futures scholarships) on STEM degree production, and Sjoquist and Winters (2013) explored the role of merit scholarships on college majors in STEM, which can be a precursor to STEM degree production. Arcidiacono, Aucejo, and Hotz (2013) reviewed the impact of K-12 education policies (e.g., STEM curriculum) on STEM degree production.

Other researchers (e.g., Liang & Ness, 2010) have explored the impact of state finance policies on other higher education outcomes, such as increased local enrollment in higher education. Liang and Ness (2010) examined the effect of state merit-based scholarship programs on reducing the “brain drain” in states and explored if there was variation across states by institution type (Liang & Ness, 2010). While Liang and Ness (2010) explored the impact of state finance policies on limiting a state’s “brain drain,” this study did not assess how including other variables (e.g., state STEM policies including finance related policies like state allocations/programs specifically for STEM) could potentially provide a more nuanced understanding of factors affecting enrollment and retention of a state's students at an in-state institution. No research known to date has explored the effects of state STEM policies.

Table 1 details the variables being used in this study. Immediately following Table 1, the constructs used in this study are mapped to the variables in Table 2. Following Table 2, the next section details the statistical technique being employed in this study.

Table 1

Description of variables

Variable	Definition	Sources
Dependent variable		
Undergraduate (baccalaureate) STEM degrees	STEM degrees include majors from the disciplines: science (e.g., chemistry, biology, etc.), technology, engineering, and mathematics. Social/behavioral sciences like psychology, economics, sociology, and political science are not included as defined STEM majors.	IPEDS, NCES
Control variables		
State finance policies	State finance policies are operationalized as:	
	state undergraduate enrollment per FTE,	IPEDS, NCES
	state R&D funds to institutions per capita,	NSF
	state per-capita income,	U.S. Census, Statistical Abstract
	state K-12 expenditures per capita,	National Association of State Budget Officers
	state higher education appropriations per capita,	National Association of State Student Grant and Aid Programs Annual Survey
	public in-state tuition at four-year institutions per FTE	IPEDS, NCES

	state per-capita expenditures for Medicaid,	National Association of State Budget Officers
	state per-capita expenditures for corrections,	National Association of State Budget Officers
	state expenditures for need-based financial aid per undergraduate FTE student, and	IPEDS, NCES
	state expenditures for grant aid per FTE.	IPEDS, NCES
Independent variables		
State STEM policies	State STEM policies are operationalized as: first—incentives (e.g., scholarships) for individuals to pursue STEM degrees;	Education Commission of the States
	second—incentives (e.g., money earmarked in the state budget for STEM) to institutions to enhance retention and production of STEM majors and graduates; and	Education Commission of the States
	third—articulation agreements between public two and four-year institutions in STEM majors/programs.	Education Commission of the States

Table 2

Relationship of constructs to variables

Variable Name	Principal Agent Theory	Production Function Theory
Control variables		
State undergraduate enrollment per per FTE		✓
State research	✓	✓
and development (R&D) for institutions per capita (2015 dollars)		
State per-capita income per capita 2015 dollars)		✓
State K-12 Expenditures per capita (2015 dollars)		✓
State higher education appropriations per capita (2015 dollars)		✓
Undergraduate four-year public in-state tuition per FTE		✓
State expenditures for Medicaid per capita (2015 dollars)		✓
State expenditures		✓

for corrections per capita (2015 dollars)		
State expenditures for need-based aid per undergraduate FTE		✓
State expenditures for non-need-based aid per FTE		✓
State STEM variables		
Incentives (e.g. (scholarships) for individuals to pursue STEM degrees	✓	
Incentives (e.g., money earmarked in the state budget for STEM) to institutions	✓	
Articulation agreements between public two and four-year institutions in STEM majors	✓	

Statistical Techniques

For this study, descriptive statistics are presented to provide simple summaries of the data and the variables. To address the research questions, more advanced statistical techniques are employed. More specifically, the used of fixed-effects regression models or random-effects regression models was tested. Panel data may have group effects, time effects, or both (Park, 2009). The use of a fixed-effect regression model account for unobserved differences across groups or time periods, and the use of a random-effects regression model accounts for differences in error variances. In order to determine which statistical model is most appropriate, a Hausman test is conducted. The Hausman test evaluates the significance of the random-effects model versus the fixed-effects model (Park, 2009). Additional tests are carried out to detect if heteroscedasticity, serial correlation, and cross-sectional dependency are present in the appropriate statistical model. Heteroscedasticity occurs when the variability of a variable is unequal across the range of values of another variable that predicts it (Pindyck & Rubinfeld, 2005). Heteroscedasticity is tested using post-estimation tests including a Modified Wald test for heteroscedasticity. Serial correlation occurs when error terms from different (usually adjacent) time periods (cross-sectional dependency) are correlated and this occurs in time-series studies when the errors associated with a given time period carry over into future time periods (Pindyck & Rubinfeld, 2005). The presence of serial correlation is tested using the Durbin-Watson Test (Pindyck & Rubinfeld, 2005). If applicable, year fixed-effects can take into account time-variant exogenous shocks across all states (e.g., decreased state appropriations to higher education institutions).

Stata (SE version 15), a statistical software package, is used to analyze the influence of state STEM policies by employing fixed-effects regression models or random-effects regression models.

Limitations

This study is limited in several ways. First, as with any study involving secondary data, this research is limited to variables previously collected, in this case, limited to what is available from various secondary data sources.

Second, different entities use different ways to identify the disciplines/majors included in STEM and this is a limitation because there is not one universal definition being followed by entities collecting data. For example, the National Science Foundation (NSF) defines STEM fields more broadly, including not only mathematics, natural sciences, engineering, and computer and information sciences, but also such social/behavioral sciences as psychology, economics, sociology, and political science (Green, 2007). Because the federal government does not have one definition of what disciplines/majors are included in STEM, the different Federal agencies (e.g., NSF and the U.S. Department of Education) are defining it differently. This variation in definitions affects what data is collected.

Third, the panel data set that created for this study contains data from 17 academic years (1999 to 2015) across all 50 states because it is the longest time period (to date) where there are no missing data. Preliminary examination of the available data provided this insight. In the future, researchers may benefit from a longer time-sequence when conducting similar studies, so that they can include longer time periods in order to see the long-term impact of policies (e.g., funding patterns).

Fourth, this study only examines STEM degree production at the baccalaureate-degree level and not at the associate degree or graduate degree levels. Future research may consider incorporating associate or graduate degree levels.

Fifth, this study utilizes data for STEM degree production at the baccalaureate-degree level for public institutions and not private institutions. Future researchers may consider conducting a similar study to this one, but for private institutions. Future research has the potential to benefit from better understanding how private institutions are performing at undergraduate STEM degree production.

Lastly, this study is correlational rather than causal in nature. Future research using quantitative techniques such as difference-in-differences regression techniques and synthetic control methods, may be able to provide causal inferences regarding state STEM policies and undergraduate STEM degree production. Future research using qualitative techniques such as case studies, may help researchers understand how state-level policies used to increase the production of STEM degrees are being developed and implemented.

Summary

Drawing on microeconomic principles and employing two theories—principal agent theory and production function theory—a conceptual model was developed for the study that combines principal agent theory and production function theory to examine the relationship between state STEM policies and STEM undergraduate degree production. This new conceptual model provides an appropriate lens to examine this relationship. This chapter describes how fixed-effects regression models or random-effects regression models are used to examine the relationship between undergraduate STEM degree production and state higher education STEM policies. While five limitations are described in the previous section, the study may have potential implications for policy and practice. The results of this research may help federal and state policy-makers to understand the impact current policies have on STEM degree production. Additionally, the conceptual model being developed for this study may provide an appropriate lens to understand the STEM degree production process through the application of constructs drawn from principal agent theory and production function theory.

Chapter 4: Results

Using state-level data and incorporating theoretical frameworks derived from economics and political science, principal agent theory and production function theory, this study addresses the following questions:

1. How is undergraduate STEM degree production within a state related to state economic and higher education finance variables?
2. Controlling for state economic and higher education finance variables, how are states' undergraduate STEM degree production influenced by state higher education STEM policies?

This chapter begins by presenting a number of descriptive statistics on the variables within this study including undergraduate (baccalaureate) STEM degrees which for purposes of this study, STEM degrees include majors from the following disciplines: science (e.g., chemistry, biology, etc.), technology, engineering, and mathematics. Social/behavioral sciences like psychology, economics, sociology, and political science are not included as defined STEM majors. Other variables include: state finance policies which are operationalized as state undergraduate enrollment per FTE, state research and development (R&D) funding for institutions, state per-capita income, state K-12 expenditures, state higher education appropriations per capita, undergraduate four-year public in-state tuition per full-time equivalent (FTE), state per-capita expenditures for Medicaid, state per-capita expenditures for corrections, state expenditures for need-based aid per undergraduate FTE, and state expenditures for non-need-based aid per FTE. The final variables include state STEM policies which are operationalized as 1) individual incentives (e.g., scholarships) to pursue STEM degrees; 2) institutional incentives (e.g., money earmarked in the state budget for STEM) to enhance retention and production of STEM majors and graduates; and 3) articulation agreements between public two and four-year institutions in STEM majors. After displaying the descriptive statistics, the results of a fixed-effects regression model are shown.

Descriptive Statistics

STEM Degrees. The descriptive statistics, shown in Table 3, include information about the analytic sample of all 50 US states over a period of 17 years (1999 to 2015). Table 3 depicts the descriptive statistics on state undergraduate enrollment per FTE, state research and development (R&D) funding for institutions per capita, state income per capita, state K-12 expenditures per capita, state higher education appropriations per capita, state expenditures for Medicaid per capita, and state expenditures for corrections per capita, expressed in 2015 dollars using the Consumer Price Index (CPI) Inflation Multiplier. Additionally, state STEM degree production, per FTE, vary from a minimum of 2.494 per FTE to a maximum of 4.611 per FTE, portraying the fluctuation of STEM degree production across states and over this period of time.

Table 3

Descriptive Statistics

Variable Name	Mean	SD	Minimum	Maximum	25th Percentile	75th Percentile	Percent
Dependent variable							
STEM bachelor's degrees per undergraduate FTE	3.539	0.408	2.494	4.611	3.224	3.829	

Control variables							
State undergraduate enrollment per FTE	151,134	162,319	10,246	1,100,000	43,131	178,725	
State research and development (R&D) for institutions per capita (2015 dollars)	0.35	0.44	0.008	3.71	0.13	0.36	
State per-capita income per capita 2015 dollars)	37,699	8,744	21,039	68,918	31,020	43,230	
State K-12 Expenditures per capita (2015 dollars)	1.73	0.52	0.90	4.87	1.37	1.95	
State higher education appropriations per capita (2015 dollars)	222	77	57	678	177	252	
Undergraduate four-year public in-state tuition per FTE	6,904	2,939	2,119	16,100	4,597	8,846	
State expenditures for Medicaid per capita (2015 dollars)	2,948	3,433	108	17,559	817	3,536	
State expenditures for corrections per capita (2015 dollars)	151	64	0	544	114	172	
State expenditures for need-based aid per undergraduate FTE	389	445	0	2,191	55	513	
State expenditures for non-need-based aid per FTE	284	512	0	3,314	14	235	
State STEM variables							
Incentives (e.g. (scholarships) for individuals to pursue STEM degrees	0.102	0.303					10.2%
Incentives	0.231	0.421					23.1%

(e.g., money earmarked in the state budget for STEM) to institutions			
Articulation agreements between public two and four-year institutions in STEM majors	0.06	0.238	6.0%

State Finance Variables. State finance variables were measured in 2015 dollars and per capita with the exception of state undergraduate enrollment per FTE, undergraduate four-year public in-state tuition per undergraduate FTE, state expenditures for need-based aid per undergraduate FTE, and state expenditures for non-need-based aid per undergraduate FTE. As shown in Table 4.1, state research and development (R&D) funding for institutions per capita, K-12 expenditures per capita, and state expenditures for corrections per capita, on average, were funded at lower levels compared to higher education. However, state expenditures for Medicaid per capita, on average, were funded at higher levels compared to higher education appropriations. In addition, several other characteristics emerged from the state-level data:

- State undergraduate enrollment per FTE, varying from a minimum of 10,245 to a maximum of 1,100,000, shows the fluctuation of undergraduate enrollment per FTE across states and over this period of time.
- State research and development (R&D) funding for institutions per capita vary from a minimum of $0.008 to a maximum of $3.71. R&D funding is not consistent across states over this period of time.
- As would be expected, state per capita income varied across states, ranging from $21,000 to $69,000.

- States are also not consistent in their approach to funding K-12 education. States varied \$0.90 to \$4.87. Some of this variation may be explained by different funding approaches (e.g., funding by local rather than state government) taken between states.
- State higher education appropriations per capita vary from \$57 to \$687. In short, some states invest more in higher education than others. Additionally, state higher education appropriations are also funded at higher levels compared to K-12 education.
- State undergraduate four-year public in-state tuition per FTE varies from \$2,119 to \$16,100.
- State expenditures for Medicaid per capita vary from \$108 to \$16,559. This shows that states are often positioned very differently in terms of competing funding priorities. It follows that a state that is making very large Medicaid expenditures likely has less to invest in higher education.
- State expenditures for corrections per capita vary from a minimum of \$0 to a maximum of \$554, portraying the fluctuation of state expenditures for corrections per capita across states and over this period of time.
- State expenditures for undergraduate need-based aid per FTE vary from \$0 to \$2,191. Such a variation could be consistent with variation in the amount that states are willing to invest in need-based aid, as well as the number of students qualified for such assistance.

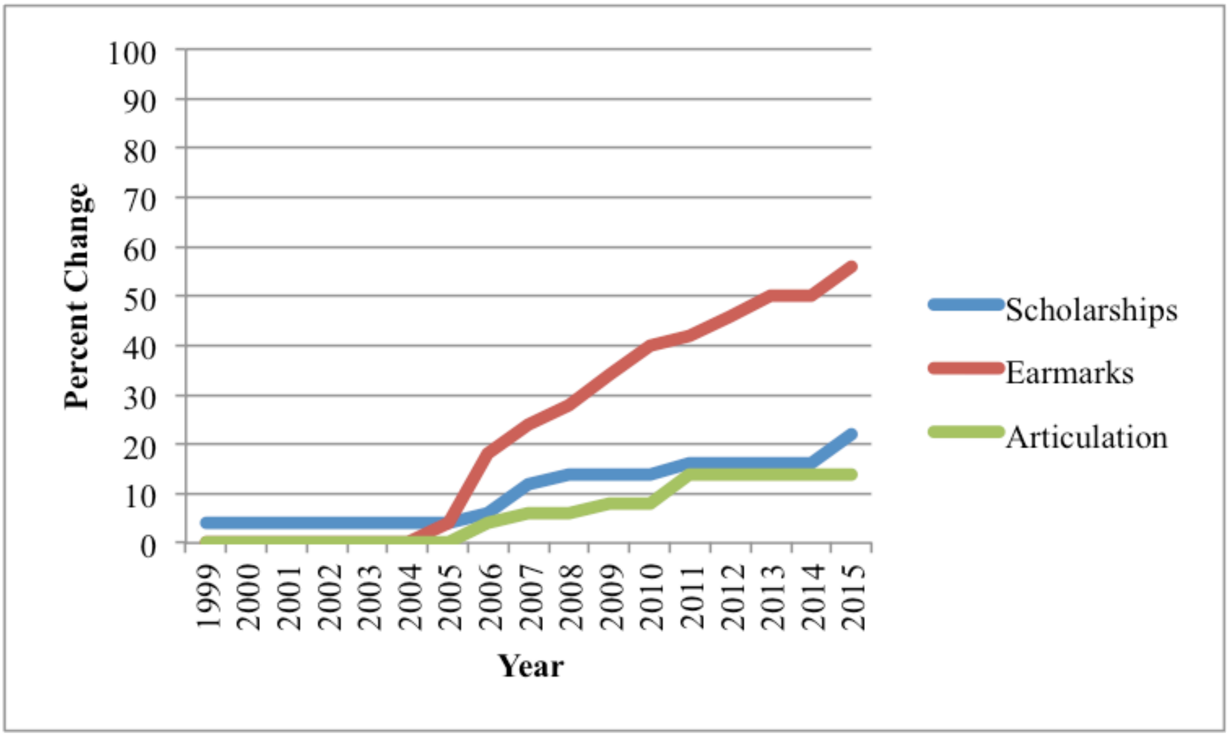
- State expenditures for undergraduate non-need-based aid per FTE vary from $0 to $3,314, reflecting different choices that states make regarding non-need-based incentives to obtain post secondary education.

State STEM Variables. Figure 1 shows that 10.2% of the U.S. states offered individual incentives (e.g., scholarships) to pursue STEM degrees. Additionally, 23.1% offered institutional incentives (e.g., money earmarked in the state budget for STEM) to enhance retention and production of STEM majors and graduates and 6.0% had articulation agreements between public two and four-year institutions in STEM majors from 1999 to 2015. Figure 4 shows changes over time and details variables associated with Principal Agent Theory used in this study.

Despite flat increases between 1999-2005 (i.e., less than a 10% change during this time period), the amount of states offering scholarships to students to pursue STEM degrees increased from 4.0% in 1999 to 22.0% in 2015. A similar pattern can also be seen for earmarks and articulation agreements. For earmarks, states experienced a steady increase of institutional incentives (e.g., money earmarked in the state budget for STEM) to enhance retention and production of STEM majors and graduates between 2005 (4.0%) and 2015 (56.0%). For articulation agreements, data indicates slow but steady growth for states offering articulation agreements between public two and four-year institutions in STEM majors between 2006 (4.0%) and 2015 (14.0%).

Figure 1

Changes over time for scholarships, earmarks for STEM to institutions and articulation agreements between public two and four-year institutions in STEM majors from 1999 to 2015



Results by Research Question

The results of each of the two research questions are described in this chapter.

Research Question 1. How is undergraduate STEM degree production within a state related to state economic and higher education finance variables?

Before examining the influence of state higher education STEM policies on states' undergraduate STEM degree production, a number of variables (i.e., state economic and higher education finance variables) analyzed in previous literature are examined to determine their influence on STEM degree production. As outlined in Chapter 3, this study uses an advanced quantitative method known as panel data analysis (PDA). Panel data refers to multi-dimensional data and contains observations on multiple phenomena observed over multiple time periods for the same unit of analysis (e.g., individuals, firms, states, etc.). There are at least four reasons why PDA is the most useful method for this research. First, PDA is informative because there is added variability and less collinearity (i.e., correlation among variables) (Allison, 1994; Halaby, 2004). Second, researchers using PDA can examine the relationship between and across variables over time (Allison, 1994; Halaby, 2004). Third, panel data also gives researchers the ability to test for "individual heterogeneity, statistical efficiency due to more information, a temporal dimension that enables dynamic adjustment, and better and more detailed data that allow researchers to model individual behaviors and identify effects" (Baltagi, 2008 as cited in Zhang, 2010, p. 308). Fourth, and perhaps most important, PDA allows researchers to control for unobserved heterogeneity (variation/differences among cases that are not measured).

A Hausman test was conducted to determine if the use of either a fixed-effects regression model or random-effects regression model is appropriate as the statistical technique. These are two of many approaches that can be used in PDA. These two models were chosen as options because panel data may have group effects, time effects, or both (Park, 2009). A fixed-effect regression model assumes differences in intercepts across groups or time invariant group heterogeneity, whereas a random-effects regression model explores differences in error variances (Park, 2009). When assessing the results of the Hausman test, a cutoff value of .05 is employed to used to determine whether or not to reject the null hypothesis. Using this cutoff, the null hypothesis is rejected; therefore, the fixed-effects regression model (Prob>chi2 = 0.0325, $p<0.05$) is used.

Additional tests were carried out to detect if heteroscedasticity, serial correlation, and cross-sectional dependency are present in the appropriate statistical model. Heteroscedasticity occurs when the variability of a variable is unequal across the range of values of another variable that predicts it (Pindyck & Rubinfeld, 2005). Heteroscedasticity was tested using post-estimation tests including a Modified Wald test for heteroscedasticity. When assessing the results of the Modified Wald test, a cutoff value of .05 is employed to evaluate whether or not to reject the null hypothesis. Using this cutoff, the null hypothesis is rejected; therefore, heteroscedasticity is present (Prob > chi2 = 0.0186, $p<0.05$).

Serial correlation occurs when error terms from different (usually adjacent) time periods (cross-sectional dependency) are correlated and this occurs in time-series studies when the errors associated with a given time period are related over time (Pindyck & Rubinfeld, 2005). The presence of serial correlation was tested using the Breusch-Godfrey LM test (Breusch, 1978; Godfrey, 1978). When assessing the results of the Breusch-Godfrey LM test, a cutoff value of .05 is employed to determine whether or not to reject the null hypothesis. Using this cutoff, the null hypothesis is not rejected; therefore, serial correlation is not present (Prob > F = 0.2271).

The Pesaran's test of cross sectional independence was conducted and a cutoff value of .05 is employed to evaluate whether or not to reject the null hypothesis. Using this cutoff, the null hypothesis is rejected, and cross-sectional dependence was confirmed (Pesaran's test of cross sectional independence = 83.607; $p < 0.001$).

As displayed in Table 4 state undergraduate enrollment per FTE is statistically significant and positively related to STEM degree production (beta=0.0723; $p<0.001$); state expenditures for need-based aid per undergraduate FTE are also statistically significant, but negatively related to STEM degree production (beta=-0.002; $p< 0.01$). The following variables are not statistically significant and not associated with STEM degrees production: state research and development (R&D) funding for institutions per capita (beta=-0.001; p=0.412), state income per capita (beta=-0.006; p=0.372), state K-12 expenditures per capita (beta=-0.004; p=0.078), state higher education appropriations per capita (beta=0.003; p=0.390), undergraduate four-year public in-state tuition per FTE (beta=0.009; p=0.120), state expenditures for Medicaid per capita (beta=0.001; p=0.904), state expenditures for corrections per capita (beta<0.001; p=0.955), and state expenditures for non-need-based aid per FTE (beta<0.001; p=0.479).

Table 4

Results of the fixed-effects regression model with Driscoll-Kraay (D-K) standard errors 1999-2015

Variable Name State Finance Variables	Coefficient
Control Variables	
State undergraduate enrollment per FTE	.073*** (.010)
State research and development (R&D) for institutions per capita (2015 dollars)	-.001 (.001)

State income per capita (2015 dollars)	-.006 (.007)
State K-12 Expenditures per capita (2015 dollars)	-.004 (.002)
State higher education appropriations per capita (2015 dollars)	.003 (.003)
Undergraduate four-year public in-state tuition per FTE	.009 (.006)
State expenditures for Medicaid per capita (2015 dollars)	.001 (.011)
State expenditures for corrections per capita (2015 dollars)	-.000 (.001)
State expenditures for need-based aid per undergraduate FTE	-.002** (.001)
State expenditures for non-need-based aid per FTE	.000 (.000)
Year Dummies	Yes
Observations	844
Number of states	50

Notes: * p<0.05; ** p<0.01; *** p<0.001; standard errors are in parentheses. All continuous variables in this study are log transformed. All applicable financial variables were adjusted to 2015 dollars.

Research Question 2. Controlling for state economic and higher education finance variables, how are states' undergraduate STEM degree production influenced by state higher education STEM policies?

The second research question seeks to understand whether state higher education STEM policies [i.e., individual incentives (e.g., scholarships) to pursue STEM degrees];

institutional incentives (e.g., money earmarked in the state budget for STEM) to enhance retention and production of STEM majors and graduates; and articulation agreements between public two and four-year institutions in STEM majors], influence STEM degree production. Three different models were used for the second research question: model 1 is controlling with state economic and higher education finance variables and contemporaneous STEM variables are not lagged, model 2 is controlling with state economic and higher education finance variables and contemporaneous STEM variables are lagged by one year, and model 3 with state economic and higher education finance variables and contemporaneous STEM variables are lagged by five years. It is important to note that with model 3, there is a five-year lag with respect to the STEM variables, which means five years of data (i.e., 5 x 50 = 250) are excluded and consequently there are less cases than a model without lagged variables. As shown in table 4.3, model 1 is significant [$F(13, 49) = 342.14$; $p<.001$]; model 2 is significant [$F(29, 49) = 9781431.15$; $p<.001$]; and model 3 is significant [$F(29, 49) = 11735.96$; $p<.001$]. The hypothesis for using three different models to lag the STEM variables is because it takes time to see the impact of policy.

In model 1, two of the variables representing state finance policies—state income per capita, and state expenditures for non-need-based aid per undergraduate FTE are statistically significant and are positively related to STEM degree production (beta=.071; $p<.001$, beta=.036; $p<.01$, and beta=.001; $p<.05$). Two of the three variables representing state STEM policies—incentives (e.g., money earmarked) in the state budget for STEM and articulation agreements between public two and four-year institutions in STEM majors—are statistically significant and positively related to STEM degree production (beta=.008; p<.01 and beta=.010; p<.01). The following variables are not statistically significant and not associated with STEM degree production: state research and development (R&D) funding for institutions per capita (beta=-.008; p=0.091), state K-12 expenditures per capita (beta=-.020; p=0.093), state higher education appropriations per capita (beta=-.018; p=0.239), undergraduate four-year public in-state tuition per FTE (beta=-.001; p=0.937), state expenditures for Medicaid per capita (beta=.058; p=0.095), state expenditures for corrections per capita (beta=.001; p=0.674), state expenditures for need-based aid per FTE (beta<.001; p=0.712), and individual incentives (e.g., scholarships) to pursue STEM degrees (beta=.002; p=0.492). The results of model 1 are summarized in Figure 2.

Figure 2

Results of model 1 with state economic and higher education finance variables and non-lagged state STEM variables

Model 1	
Variable Type	**Variables Related to Undergraduate STEM Degrees:**
State finance policies	• State income per capita (positively related) • State expenditures for non-need-based aid per undergraduate FTE (positively related)
State STEM policies	• Institutional incentives (positively related) • Articulation agreements (positively related)

In model 2, one of the variables representing state finance policies—ate expenditures for need-based aid per undergraduate FTE—is statistically significant. State expenditures for need-based aid per undergraduate FTE are negatively related to STEM degree production (beta=.071; p<.001 and beta=-.002; p<.01). None of the variables representing state STEM policies are statistically significant and none are associated with STEM degree production. Additionally, the following variables are not statistically significant and not associated with STEM degree production: state research and development (R&D) funding for institutions per capita (beta=-.001; p=0.361), state income per capita (beta=-.008; p=0.323), state K-12 expenditures per capita (beta=-.003; p=0.115), state higher education appropriations per capita (beta=.003; p=0.355), undergraduate four-year public in-state tuition per FTE (beta=.008; p=0.165), state expenditures for Medicaid per capita (beta=.003; p=0.765), state expenditures for corrections per capita (beta<.001 ; p=0.876), state expenditures for non-need-based aid per FTE (beta<.001; p=0.500), individual incentives (e.g., scholarships) to pursue STEM degrees (beta=-.002; p=0.142), incentives (e.g., money earmarked) in the state budget for STEM (beta=.001; p=0.538), and articulation agreements between public two and four-year institutions in STEM majors (beta=.002; p=0.157). The results of model 2 are summarized in Figure 3.

Figure 3

Results of model 2 with state economic and higher education finance variables and STEM variables lagged by 1 year

Model 2	
Variable Type	**Variables Related to Undergraduate STEM Degrees:**

State finance policies	• State expenditures for need-based aid per undergraduate FTE (negatively related)
State STEM policies	• Undergraduate STEM degree production is not related to state STEM policies

In model 3, five of the variables representing state finance policies—state income per capita (beta= -.034; p<.01), undergraduate four-year public in-state tuition per FTE (beta=.013; p<.01, state expenditures for Medicaid per capita (beta= .034; p<.001), state expenditures for need-based aid per FTE (beta= -.002; p<.01), and state expenditures for non-need-based aid per undergraduate FTE (beta=.001; p<.001)—are statistically significant. Of those six variables, three are positively related to STEM degree production (undergraduate four-year public in-state tuition per FTE, state expenditures for Medicaid per capita, and state expenditures for non-need-based aid per undergraduate FTE), and two are negatively related to STEM degree production (state income per capita and state expenditures for need-based aid per FTE). All three of the variables representing state STEM policies—individual incentives (e.g., scholarships) to pursue STEM degrees (beta=.002; p<.01), incentives (e.g., money earmarked) in the state budget for STEM (beta=-.002; p<.01), and articulation agreements between public two and four-year institutions in STEM majors (beta=.004; p<.001)—are statistically significant and of those three variables, two are positively related to STEM degree production [individual incentives (e.g., scholarships) to pursue STEM degrees and articulation agreements between public two and four-year institutions in STEM majors], and one is negatively related to STEM degree production [incentives (e.g., money earmarked) in the state budget for STEM]. The following variables are not statistically significant and not associated with STEM degree production: state research and development (R&D) funding for institutions per capita (beta=-.001; p=0.335), state K-12 expenditures per capita (beta=.011; p=0.095), state higher education appropriations per capita (beta=-.002; p=0.463), and state expenditures for corrections per capita (beta<.001; p=0.853). The results of model 3 are summarized in Figure 4 and all of the results of the fixed-effects regression model with Driscoll-Kraay (D-K) standard errors 1999-2015 are displayed in Table 5.

Figure 4

Results of model 3 with state economic and higher education finance variables and state STEM variables lagged by 5 years

Model 3	
Variable Type	**Variables Related to Undergraduate STEM Degrees:**
State finance policies	• State income per capita (negatively related) • Undergraduate 4-year public in-state tuition per FTE (positively related) • State expenditures for Medicaid per capita (positively related) • State expenditures for need-based aid per FTE (negatively related) • State expenditures for non-need-based aid per undergraduate FTE (positively related)
State STEM policies	• Individual incentives (positively related) • Institutional incentives (negatively related) • Articulation agreements (positively related)

Table 5

Results of the fixed-effects regression model with Driscoll-Kraay (D-K) standard errors 1999-2015

Variable Name *State finance variables*	Model 1 coefficient	Model 2 coefficient	Model 3 coefficient
Control variables			
State undergraduate enrollment per FTE	.071*** (.020)	.0713*** (.009)	.046*** (.0124)
State research and development (R&D) for institutions per capita (2015 dollars)	-.008 (.004)	-.001 (.001)	-.001 (.001)
State per-capita income per capita (2015 dollars)	.036** (.012)	-.008 (.008)	-.034** (.010)
State K-12 expenditures per capita (2015 dollars)	-.020 (.011)	-.003 (.002)	.011 (.007)
State higher education appropriations per capita (2015 dollars)	-.018 (.015)	.003 (.003)	-.004 (.005)
Undergraduate four-year public in-state tuition per FTE	-.001 (.008)	.008 (.006)	.013** (.005)
State expenditures for Medicaid per capita (2015 dollars)	.058 (.034)	.003 (.011)	.0345*** (.007)
State expenditures for corrections per capita (2015 dollars)	.001 (.002)	beta<.001 (.001)	beta<.001 (.001)

State expenditures for need-based aid per undergraduate FTE	.000 (.001)	-.002** (.001)	-.002** (.001)
State expenditures for non-need-based aid per undergraduate FTE	.001* (.000)	beta<.001 (.000)	.001*** (.000)
State STEM Variables			
Incentives (e.g., scholarships) for individuals to pursue STEM degrees	.002 (.003)	-.002 (.002)	.002** (.001)
Incentives (e.g., money earmarked in the state budget for STEM) to institutions to enhance retention and production of STEM majors and graduates	.008** (.002)	.001 (.001)	-.002** (.001)
Articulation agreements between public two and four-year institutions in STEM majors	.010** (.004)	.002 (.002)	.004*** (.001)
Constant	-.282 (.251)	.406** (.146)	
Year fixed-effects	No	Yes	Yes
Observations	844	844	596
Number of states	50	50	50

Notes: * p<0.05; ** p<0.01; *** p<0.001; standard errors are in parentheses. All continuous variables in this study are log transformed. All applicable financial variables were transformed into 2015 dollars.

Summary

This chapter presents the results of the two research questions in this study. The first research question seeks to examine how state economic and higher education finance variables, are related to STEM degree production within a state. A fixed-effects regression model with Driscoll-Kraay (D-K) standard errors was utilized to address this question. For the first research question, the findings presented in this chapter show that state undergraduate enrollment per FTE and state expenditures for need-based aid per undergraduate FTE influence STEM degree production in a state. The second research question in this study examined whether state higher education STEM policies [i.e., individual incentives (e.g., scholarships) to pursue STEM degrees; institutional incentives (e.g., money earmarked in the state budget for STEM) to enhance retention and production of STEM majors and graduates; and articulation agreements between public two and four-year institutions in STEM majors], influence STEM degree production. A fixed-effects regression model with Driscoll-Kraay (D-K) standard errors is utilized across the three models for the second research question. In model 1, three of the variables representing state finance policies—state undergraduate enrollment per FTE, state income per capita, and state expenditures for non-need-based aid per undergraduate FTE—influence STEM degree production in a state. Two of the three variables representing state STEM policies—incentives (e.g., money earmarked) in the state budget for STEM and articulation agreements between public two and four-year institutions in STEM—influence STEM degree production in a state. In model 2, two of the variables representing state finance policies—state undergraduate enrollment per FTE and state expenditures for need-based aid per undergraduate FTE—influence STEM degree production in a state. None of the variables representing state STEM policies are related to STEM degree production in a state. In model 3, six of the variables representing state finance policies—state undergraduate enrollment per FTE, state income per capita, undergraduate four-year public in-state tuition per FTE, state expenditures for Medicaid per capita, state expenditures for need-based aid per FTE , and state expenditures for non-need-based aid per undergraduate FTE—influence STEM degree production in a state. All three of the variables representing state STEM policies—individual incentives (e.g., scholarships) to pursue STEM degrees, incentives (e.g., money earmarked) in the state budget for STEM, and articulation agreements between public two and four-year institutions in STEM majors—influence STEM degree production in a state. The STEM variables in model 3 were lagged by five years, unlike in model 2 where the state STEM variables were lagged by one year, and model 1, where the state STEM variables are not lagged. This is an important distinction to note as policy implementation may take longer to yield results; given this lag, five years were built into the model to account for this time. The following chapter discusses these results within the context of the literature.

Chapter 5: Discussion

State-level data and theoretical frameworks derived from economics and political science, principal agent theory and production function theory, were used to examine the relationship between state STEM policies and STEM bachelor's degree production. This study addresses two questions.

1. How is undergraduate STEM degree production within a state related to state economic and higher education finance variables?
2. Controlling for state economic and higher education finance variables, how are states' undergraduate STEM degree production influenced by state higher education STEM policies?

Chapter 5 first provides a discussion of the results presented in chapter 4. The results are compared with prior research related to state economic and higher education finance variables and state higher education STEM policies. This chapter also details contributions to the literature, conclusions, implications for theory and policy, and recommendations for future research.

Discussion of the Findings

As explained in chapter 4, the first research question is how undergraduate STEM degree production within a state is related to state economic and higher education finance variables. The findings for this question show that state undergraduate enrollment per FTE and state expenditures for need-based aid per undergraduate FTE influence STEM degree production in a state.

The second research question asks whether state higher education STEM policies (e.g., scholarships for students pursuing STEM bachelor's degrees, earmarks for institutions for STEM, and articulation agreements between public two and four-year institutions in STEM majors), influence STEM bachelor's degree production. Three models were utilized to help answer the second research question. In model 1, where the state STEM variables are not lagged, two variables representing state finance policies were found to influence STEM bachelor's degree production: state income per capita and state expenditures for non-need-based aid per undergraduate FTE. Two of the three variables representing state STEM policies were found to influence STEM bachelor's degree production in a state: incentives (e.g., money earmarked) in the state budget for STEM and articulation agreements between public two and four-year institutions in STEM. In model 2, which lagged the data by one year, only one of the variables representing state finance policies—state expenditures for need-based aid per undergraduate FTE—influence STEM degree production in a state. None of the variables representing state STEM policies are related to STEM bachelor's degree production in a state. In model 3, which lagged the data by five years to account for the time required to see results of policy implementation, five of the variables representing state finance policies—state income per capita, undergraduate four-year public in-state tuition per FTE, state expenditures for Medicaid per capita, state expenditures for need-based aid per FTE, and state expenditures for non-need-based aid per undergraduate FTE—influence STEM degree production in a state. All three of the variables representing state STEM policies—individual incentives (e.g., scholarships) to pursue STEM degrees, incentives (e.g., money earmarked) in the state budget for STEM, and articulation agreements between public two and four-year institutions in STEM majors—influence STEM bachelor's degree production in a state. The following two sections compare the findings from this study to the results from prior research.

State Finance Variables. One variables are statistically significant in the first research question. State expenditures for need-based aid per undergraduate FTE are also statistically significant, but are negatively related to STEM bachelor's degree production.

In the second research question, three different models are used to address the second research question: model 1 is controlling with state economic and higher education finance variables and contemporaneous non-lagged state STEM variables, model 2 is controlling with state economic and higher education finance variables and contemporaneous state STEM variables are lagged by one year, and model 3 with state economic and higher education finance variables and state STEM variables are lagged by five years. It is important to note that with model 3, there is a five-year lag with respect to the STEM variables, which means five years of data (i.e., 5 x 50 = 250) are excluded and consequently there are fewer cases than a model without lagged variables. Two of the variables representing state finance policies in model 1, state income per capita and state expenditures for non-need-based aid per undergraduate FTE, are statistically significant and are positively related to STEM bachelor's degree production. In model 2, one of the variables representing state finance policies are statistically significant. State expenditures for need-based aid per undergraduate FTE are negatively related to STEM bachelor's degree production. Five of the variables representing state finance policies in model 3 are statistically significant. Of those six variables, three are positively related to STEM bachelor's degree production (undergraduate four-year public in-state tuition per

FTE, state expenditures for Medicaid per capita, and state expenditures for non-need-based aid per undergraduate FTE), and two are negatively related to STEM bachelor's degree production (state income per capita and state expenditures for need-based aid per FTE).

In this study, state undergraduate enrollment per FTE, a control variable, is statistically significant and positively related to STEM bachelor's degree production in a state, in the first research question as well as in all three models of the second research question. While this finding specifically pertains to STEM undergraduate degree productivity, the overall takeaway that higher enrollments tend to equate increased degree productivity is consistent with previous research portraying enhanced degree productivity when enrollments increased after the 2008 Great Recession. Desrochers and Hurlburt (2016) found the number of degrees awarded per 100 FTE enrolled students increased across all types of colleges and universities as a result of increased enrollments after 2008.

A different variable in this study, state research and development (R&D) funding for institutions per capita, had no effect on STEM bachelor's degree production within a state for both research questions. This finding is consistent with past research (i.e., Irwin and Klenow, 1996; Lerner 1999) showing the impact of R&D funding on other types of productivity within a state, such as knowledge production (i.e., primary research and dissemination of results through publications such as peer-reviewed journals), but not on overall degree productivity. Similar results are also seen in another study (Jacob & Lefgren, 2011), which utilizes administrative data from the National Institutes of Health (NIH) on all training and standard grant proposals submitted between 1980 and 2000 and explores the impact of receiving a grant on the productivity of an individual researcher. The NIH study finds a positive effect of funding on subsequent publications, but makes no attempt to link funding to degree production.

While R&D funding had no effect on STEM bachelor's degree production within a state, state income per capita did influence STEM bachelor's degree production in models 1 and 3 of the second research question. In model 1 it is statistically significant and positively related to STEM degree production and in model 3, it is statistically significant and negatively related to STEM degree production in a state. The findings from model 1 are consistent with prior research (Berger & Fisher, 2013; Carroll & Erkut, 2009; Trostel, 2008) showing the impact of state per capita income levels and corresponding tax revenue on education outcomes. Using data from the U.S. Census Bureau's Annual Social and Economic Supplement of the Current Population Survey, Berger and Fisher (2013) found high-wage states tend to have a well-educated workforce.

More specifically, these findings show a clear correlation between the educational attainment of a state's workforce and median wages in the state (Berger & Fisher (2013). This finding indicates a statewide economic success and prosperity can be achieved by investing in education. In turn, states can use the increased tax revenues from income and reinvest back in state programs such as grants. Prior research found that an increase in grant aid can increase a student's likelihood of enrolling (Dynarski 2003). Moreover, using data from the from the U.S. Census Bureau's Survey of Income and Program Participation (SIPP) to model the effects of education level, Carrol and Erkut (2009) found the higher income realized by more highly educated people results in higher federal and state income taxes. Thought it is speculative, one can draw the inference that higher per capita income results in higher state tax collections. Those higher tax collections can, in turn, be used to increase support for higher education (e.g., direct support to colleges and universities or student scholarships).

However, in model 3, state per-capita income is negatively related to STEM bachelor's degree production when the five-year time lag was introduced in the third model. This finding may indicate state STEM policies have a stronger impact on STEM undergraduate degree productivity with a five-year lag than state per-capita income. Similar to the effect of R&D funding, K-12 expenditures also showed no effect on STEM bachelor's degree production. This finding aligns with previous economic research (i.e., Hanushek, 2006, 2003, 1989) noting that while spending on inputs has increased, there have been no corresponding improvements in student achievement according to the National Assessment of Educational Progress (NAEP) data. Yet, other researchers (Hedges, Laine, Greenwald, 1994) found a contradiction to this finding. Using data from Hanushek's (1989) study, Hedges, Laine, and Greenwald (1994) find no consistent effect between resources and academic outcomes. While the outcomes in this research are not degree production, the findings are consistent in terms of impact. Additionally, in Titus's (2009) study, longitudinal production of bachelor's degrees was tied to selected financial aspects of state higher education policy (i.e., state appropriations to higher education institutions and tuition levels). In addition to the role of state appropriations to higher education institutions and degree production being consistent with this study, the impact of tuition also aligns. Tuition was positively related to STEM degree production in this study.

While prior researchers examined the relationship between Medicaid appropriations and state funding to higher education (e.g., Okunade, 2004; Tandberg & Ness, 2011), and Zhang (2009), studied the impact of state allocations on degree production, the impact of Medicaid appropriations on STEM bachelor's degree production has not been widely explored. In this study, there is a statistically significant positive association between Medicaid appropriations and STEM degree production. One may speculate that increased access to healthcare may be associated with better educational outcomes. Similarly, the impact of corrections appropriations on STEM bachelor's degree production has not been widely explored. Other researchers sought to understand how allocations for corrections impacts funding for higher education within states (Kane, Orszag, & Apostolov, 2005; Okunade, 2004), but exploring the role of corrections spending on STEM bachelor's degree production is a unique approach has not been extensively studied. There was no statistically significant association between corrections spending and STEM degree production in this study.

Another variable, state expenditures for need-based aid per undergraduate FTE, negatively influences undergraduate STEM degree production in a state in this study for the first research question and models 2 and 3 for the second research question. While prior research has shown increases to state need-based student financial aid can have a positive impact on bachelor's degree production (Titus, 2009a), this study found a negative influence of state expenditures for need-based aid per undergraduate FTE for undergraduate STEM degree production. One may speculate that despite state-level investments in need-based aid per undergraduate FTE, students from low-income backgrounds tend to be lower academically prepared, and earn STEM degrees at lower rates. Eagan, Hurtado, Figueroa, and Hughes (2014) found racial disparities in undergraduate STEM degree production regardless of increased interest in the field. For example, 29% of Latinx and 22% of black aspirants complete an undergraduate STEM degree compared to 52% of Asian American and 43% of white aspirants who complete an undergraduate STEM degree (Eagan, Hurtado, Figueroa, & Hughes, 2014).

Prior research (Titus, 2009a) did not show a statistically significant association between non-need based aid levels and degree production. In this study, state expenditures for non-need-based aid per undergraduate FTE, are statistically significant and are positively related to STEM degree production. One speculation of this finding is that merit-based financial investments can lead to higher levels of STEM degree production. Another speculation is perhaps individuals who receive merit-aid are more likely to complete STEM degrees.

State STEM Variables. Three different models were used for the second research question: model 1 is controlling with state economic and higher education finance variables and contemporaneous STEM variables are not lagged, model 2 is controlling with state economic and higher education finance variables and contemporaneous STEM variables are lagged by one year, and model 3 with state economic and higher education finance variables and contemporaneous STEM variables are lagged by five years. It is important to note that with model 3, there is a five-year lag with respect to the STEM variables, which means five years of data (i.e., 5 x 50 = 250) are excluded and consequently there are less cases than a model without lagged variables.

In model 1, two of the three variables representing state STEM policies—incentives (e.g., money earmarked) in the state budget for STEM and articulation agreements between public two and four-year institutions in STEM—positively influence bachelor's STEM degree production in a state. In model 2, none of the variables representing state STEM policies are related to STEM degree production in a state. All three of variables representing state STEM policies—individual incentives (e.g., scholarships) to pursue STEM degrees, incentives (e.g., money earmarked) in the state budget for STEM, and articulation agreements between public two and four-year institutions in STEM majors—influence STEM bachelor's degree production in a state are statistically significant. Two variables are positively related to STEM bachelor's degree production [individual incentives (e.g., scholarships) to pursue STEM degrees and articulation agreements between public two and four-year institutions in STEM majors], and one is negatively related to STEM bachelor's degree production [incentives (e.g., money earmarked) in the state budget for STEM] for model 3. The impact of scholarships on STEM degree production is consistent with prior research (e.g., Zhang, 2011) which found that the Georgia HOPE scholarship and the Florida Bright Future scholarship led to increased levels of baccalaureate degree production in STEM fields. Similarly, the use of articulation agreements as a tool to increase STEM degree production aligns with recent research about minority males in STEM (Avery & Bartee, 2018), and more generally, research showing that articulation agreements can lead to increased degree completion by maximizing the transfer of credits from a community college to a four-year institution (Townsend, 2007). Like scholarships, articulation agreements were positively related to STEM degree production in this study. One speculation about this finding is that establishing articulation agreements between two and four-year institutions in STEM is an effective strategy to increase STEM degree production despite data showing slow growth of states offering articulation agreements between public two and four-year institutions in STEM majors between 2006 (4.0%) and 2015 (14.0%).

The impact of earmarks has been shown to increase research productivity (Payne, 2002), but the role of earmarks on STEM degree production has not been widely studied. In this study, earmarks were negatively related to STEM degree production. Two speculations about this finding are 1) earmarks were not targeted enough to impact how individuals pursue postsecondary degrees or 2) earmarks were not guaranteed funding, which makes long-term financial investments for programs or scholarships difficult and inconsistent.

Conclusions

There are at least four conclusions that can be drawn from this study. First, policy implementation may take multiple years to see outcomes and understand impacts. The STEM variables in model 3 were lagged by five years, unlike in model 2 where the state STEM variables were lagged by one year, and model 1, where state STEM variables are not lagged. This is an important distinction to note as policy implementation should not be expected to yield immediate results. An intervention that encourages more students to select a STEM major in 2019 will not have a perceptible effect on degree production until four or more years into the future. Sufficient time is required to understand the impact of policy change; change does not happen overnight. It requires patience, persistence, and multiple years of data collection and research to understand the impact of policy on STEM bachelor's degree production.

Second, principal agent theory (PAT) and production function theory (PFT), when combined, are an effective conceptual model for studying the role of policies such as financial support for higher education institutions and college students interested in STEM. In this study, the production of bachelor's STEM degrees is a function of state STEM policies and selected financial aspects of state higher education policy such as tuition, state appropriations to higher education institutions, and need-based aid. Moreover, state STEM policies and selected financial aspects of state higher education policies are interrelated and influenced by history as well as other state policies (e.g. funding for Medicaid).

Third, this study expanded previous research investigating the influence of state finance policies on degree production by examining the influence of state STEM policies on state STEM bachelor's degree production. While research from Zhang (2011) and Arcidiacono et al. (2013) focused on how state finance and education policies affect STEM undergraduate graduation rates, their research does not take into account how state STEM policies affect STEM bachelor's degree production. None of the research reviewed for this dissertation approaches questions about undergraduate degree production through a specific lens on STEM through a state-level perspective; this is important as states continuously seek to promote strong economic health and vitality. This study fills a void in the literature by examining the relationship between state STEM policies and financial aspects of state higher education policies on the production of postsecondary STEM degrees.

Fourth, this study demonstrates that advanced statistical methods can be used to examine the predictors of state STEM degree production. In particular, this dissertation utilized a fixed-effects regression model with Driscoll-Kraay (D-K) standard errors to accurately examine the influence of state STEM policies (i.e., scholarships to individuals for STEM, earmarks for institutions for STEM, and articulation agreements in STEM fields) on STEM degree production. The study design used undergraduate (baccalaureate) STEM degrees, undergraduate enrollment per FTE, state R&D funding for institutions, state per-capita income, state K-12 expenditures, state higher education appropriations per capita, undergraduate four-year public in-state tuition per FTE, state per-capita expenditures for Medicaid, state per-capita expenditures for corrections, state expenditures for need-based aid per undergraduate FTE, and state expenditures for non-need-based aid per FTE to understand the impact on STEM degree production. In summary, the results of this study confirm that research on STEM degree production should be investigated using sophisticated quantitative methods to appropriately examine how of state STEM policies are influenced by a number of independent variables.

Implications for Theory and Policy

The results of this dissertation offer a number of implications. The next section of this chapter discusses the implications for theory and policy and provides recommendations for future research on state appropriations to higher education.

Implications for Theory. This dissertation provides two major contributions to the literature. First, this study connects two theories with roots in political science and economics to the higher education literature. Second, the conceptual model provides an appropriate lens to understand the STEM degree production process through the application of constructs drawn from principal-agent theory and production function theory.

This study is distinct in that it combines two theories from political science and economics to examine the influence of state finance variables and state STEM policies on

STEM degree production. In particular, drawing on microeconomic principles and employing two theories—principal agent theory (PAT) and production function theory (PFT)—this a conceptual model was used for the first time to examine what influences undergraduate STEM degree production, and to examine the relationship between state STEM policies and STEM bachelor's degree production. This conceptual model allows researchers, administrators, and policy analysts to understand how theories can be used to explain how the inputs and the process affect the outputs. The process portion of the conceptual model can be visualized as a black box and within the black box are the actors of PAT (i.e., the principal and the agent) as well as the task is being asked of the agent. In order to understand the impact of state STEM policies (i.e., the input of PFT) on undergraduate STEM degree production (i.e., the output of PFT), it is imperative to understand the relationship between principals (i.e., the state) and agents (i.e., institutions) that work to utilize the state STEM policies that may or may not affect STEM degree production.

Implications for Policy. This dissertation showed a number of variables influence STEM degree production. Three potential policy implications emerged from the research.

1) Policy-focused research can be used to inform stakeholders and the public of what are the influencers of STEM degree production and the impact of policy on STEM degree production.
2) Data can be used to drive policy development focused on meeting state completion objectives and economic goals.

3) Understanding what drives policy adoption is useful context for states looking to impact policy development around STEM.

Undergraduate STEM reform efforts such as coordinated statewide scholarship programs for STEM have often not been the focus of statewide policies with the exception of some states (e.g., Florida and Georgia) offering individual incentives (e.g., scholarships) to pursue STEM degrees. As depicted in Figure 1, despite no increases between 1999-2005, the amount of states offering scholarships to students to pursue STEM degrees increased from 4.0% in 1999 to 22.0% in 2015. State stakeholders may consider aligning their state-level programs and policies in a more coordinated manner in order to maximize the types of incentives available to undergraduate students interested in STEM in order to increase state undergraduate STEM degree production. Moreover, in order to fully utilize state scholarship programs, targeted outreach efforts are needed early and often throughout a student's entire academic career. For example, state stakeholders may consider informational programs for students and families in order to promote pathways and career options within STEM fields. Additionally, it will be increasingly important for states to create partnerships between school districts, high schools, community colleges, and four-year institutions, as pathways to completing a STEM degree has diversified. State stakeholders may also think about prioritizing funding initiatives for students utilizing aspects of these partnerships to emphasize and reward coordinated approaches to outreach.

Similar to state-level student incentives, maintaining and developing articulation agreements between public two and four-year institutions in STEM majors can impact state STEM bachelor's degree production. For articulation agreements, data indicates growth, yet changes have been steady and slow for states offering articulation agreements between public two and four-year institutions in STEM majors between 2006 (4.0%) and 2015 (14.0%). Articulation agreements between academic departments and public institutions can simplify the transfer process and support transfer students. More specifically, these agreements can reduce course-sequencing restrictions and can reduce degree requirements and prerequisites outside of the major. Given the current pattern of frequent transferring between institutions and in earning credits at multiple institutions (Hossler, Shapiro, Dundar, Ziskin, Chen, Zerquera, & Torres, 2012), adopting state policies, such as articulation agreements, are critical to increasing degree production. The results of this study, and more directly, the impact of articulation agreements on state STEM bachelor's degree production, shown the value of ensuring articulation agreements as a state policy tool. States without widespread articulation agreements may consider adopting it as a regular practice and the expectation for public institutions and STEM departments.

Policies focused on incentivizing (i.e., student scholarships) and enabling (i.e., articulation agreements) students to pursue STEM degrees are potentially more effective than state policies that incentivize institutions to promote STEM degrees. Policymakers may want to consider focusing on the incentives and barriers facing potential STEM students rather than on the interests of institutional actors.

Recommendations for Future Research

Several recommendations for future research emerged. This study fills a void in the literature by examining the relationship between state STEM policies and financial aspects of state higher education policies on the production of postsecondary STEM degrees. Using state-level data drawn from publicly available secondary data sources over a 17-year period, this study explores how the production of STEM bachelor's degrees is related to state STEM policies and selected financial aspects of state higher education policy. This study builds on Zhang's (2011) study on the effect of merit-aid programs on the production of STEM degree for males and females. Moreover, the use of state STEM policies addresses a gap in the current literature and production models that exist around the inclusion of state STEM policies as a variable for understanding STEM degree production. Future research may consider exploring additional state-level variables such as workforce demand data, college debt and default rates, migration data of individuals earning a STEM degrees to determine if they leave the state upon graduation, and the production rates of undergraduate STEM degree through alternative academic routes (i.e., apprenticeship programs). This information may be useful for policy makers as they consider state-level investments.

The panel data set that was created for this study contained data from a 17-year period (1999 to 2015) across all 50 states because it is the longest time period (to date) where there are no missing data. In the future, researchers may benefit from a longer time frame when conducting similar studies to see the long-term impact of policies (e.g., impact, changes). Similarly, researchers may consider expanding the lag time for STEM variables during analysis to determine if there's an impact on undergraduate STEM degree production (e.g., lagging STEM variables by 6, 7, or 8 years) Additionally, this study only examines STEM degree production at the baccalaureate-degree level and not at the associate degree or graduate degree levels. Future research may consider incorporating associate or graduate degrees into a panel data set for more levels of analysis.

This study utilizes data for STEM degree production at the baccalaureate-degree level for public institutions and not private institutions. Future research may consider conducting a similar study to this one, but for private institutions. Recent research (Ransom, Gebhardt, Knepler, & Selfa, 2019; Rine 2014) details the important role of private institutions in undergraduate STEM degree production. Using data from the U.S. Department of Education's 2003–04 Beginning Postsecondary Students Longitudinal Study, Second Follow-up (BPS: 04/09), researchers found students who start at private institutions in STEM complete bachelor's degrees (in STEM) at higher rates than undergraduate students from public institutions (i.e., 56% for private non-doctoral institutions and 58% for private doctoral institutions compared to 43% for public non-doctoral institutions and 52% for public doctoral institutions). Future research has the potential to benefit from better understanding how private institutions are performing at undergraduate STEM degree production. Similarly, future research may also consider expanding what majors are included in how STEM is being defined such as STEM teaching majors (i.e., individuals teaching STEM in secondary school settings). This expanded definition has the potential to provide more information about the number of individuals earning STEM degrees.

Additionally, this study is correlational rather than causal in nature. Future research, using quantitative techniques such as difference-in-differences regression techniques and synthetic control methods, may be able to provide causal inferences regarding state STEM policies and undergraduate STEM degree production. Lastly, future research, using qualitative techniques such as case studies, may help researchers understand how state-level policies used to increase the production of STEM degrees are being developed and implemented.

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