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STEM in CSU: the Impact of Resources and the Recession on the STEM Pipeline

A Dissertation submitted in partial satisfaction
of the requirements for the degree of

Doctor of Philosophy

in

Education

by

Mark Katayama

September 2018

Dissertation Committee:
Dr. Uma M. Jayakumar, Co-Chairperson
Dr. Gregory J. Palardy, Co-Chairperson
Dr. Eddie Comeaux

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The Dissertation of Mark Katayama is approved:

Committee Co-Chairperson

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ABSTRACT OF THE DISSERTATION

STEM in CSU: the Impact of Resources and the Recession on the STEM Pipeline

by

Mark Katayama

Doctor of Philosophy, Graduate Program in Education
University of California, Riverside, September 2018
Dr. Uma M. Jayakumar, Co-Chairperson
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The objective of this research was to identify relationships that are associated with science, technology, engineering, and mathematics (STEM) graduation rates among the California State University (CSU) system. Specifically targeting resource allocation strategies and institutional characteristics, this investigation examined relationships unique within the STEM pipeline and success rates of underrepresented minority (URM, including Black, Latinx, and Southeast Asian) STEM students. The dataset for this investigation was constructed from three public access sources, with research questions targeting aspects unique to public comprehensive universities in California. The statistical technique employed was a piecewise-multilevel growth model used to examine relationships among resource allocation strategies, institutional characteristics, the Great Recession, and URM STEM graduation rates with overall STEM graduation rates.

Analysis revealed a positive relationship of overall STEM graduation rates to student services support, a negative relationship to institutional support, and no significant relationship found with federal training grant support. Latnix STEM graduation rates showed the strongest positive relationship with overall STEM graduation rates, and both Black and Southeast Asian showing a positive relationship but to a lesser degree. The unique context of comprehensive institutions highlights the need for decision-makers to evaluate their resource allocation strategies and possibly divert more resources to student services support over instructional support. This research clearly highlights the importance of better understanding the relationship between institutional efforts and STEM student outcomes.

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CHAPTER 1

Introduction: The STEM Decline and the Great Recession

The United States (U.S.) has long been considered a scientific and technological global leader, with approximately half of the nation's economic growth in the second half of the twentieth century attributed to Science, Technology, Engineering, and Mathematics (STEM) developments and a strong STEM workforce (NSF, 2013; Rosen, 2013). However, the size and quality of the U.S. STEM workforce is now being outpaced by other nations, which is attributed to the decline of qualified graduates (Cannady, Greenwald, & Harris, 2014; Carnevale, Smith, & Melton, 2011; Xie & Killewald, 2012). As a result, the U.S. jeopardizes its ability to leverage on future advances in STEM disciplines and may lose its place as a global leader in innovation and discovery, if improvements to degree attainment in the STEM pipeline do not occur (Cannady et al., 2014; Carnevale et al., 2011).

Additionally, during this period of STEM decline, the Great Recession occurred and disproportionately impacted higher education funding and support (Zumeta, 2010). Many states shifted from state appropriations to pointing higher education institutions toward private and/or federal support after the Great Recession (Barr & Turner, 2013). This caused institutions receiving significant state appropriations in their budget to explore alternative means to raise revenues, often raising tuition and/or attaining large research grants (Brown & Hoxby, 2014) and thereby, disrupting the flow of the STEM pipeline into the STEM workforce (Chen & Soldner, 2013).

Degree Attainment and the STEM Pipeline

Ideally, the STEM pipeline prepares students with the expertise and abilities necessary to secure jobs and have long-term success in the STEM workforce (Burke & Mattis, 2007; Cannady et al., 2014; Committee on Science, Engineering, and Public Policy (CSE) 2007; National Academy of Sciences (NAS), 2011). One marker of a successful STEM workforce is the amount of qualified workers holding STEM degrees (Carnevale et al., 2011). However, recent data from the Organization for Economic Cooperation and Development (OECD) indicate that the U.S. now ranks 15th among industrialized nations in college completion rates, down from #1 in 2005 (Kelly & Schneider, 2012; OECD, 2015; Perna & Finney, 2014). Additionally, STEM degree attainment in major cities falls outside of the top 20 (Carnevale et al., 2011; Gonzalez & Kuenzi, 2012; Xie & Killewald, 2012). Therefore, the decline of the STEM workforce pool and lack of qualified STEM personnel point to potential flaws in the higher education sector.

Unfortunately, the STEM pipeline is losing students at many points across the educational spectrum. Students lose interest in STEM from K-12 to post-secondary settings (Chen & Soldner, 2013; Xie & Killewald, 2012). Top performing high school graduates enter into non-STEM majors or leave a STEM major prior to college graduation (Lowell, Salzman, Bernstein, & Henderson, 2009). Not only are universities and schools unable to attract and retain students in STEM programs (Altonji, Blom, & Meghir, 2012), but financial and academic barriers also hinder students from participating in STEM programs and graduating with a STEM degree (Brown, Brown, Reardon, & Merrill, 2011; Hurtado, Cabrera, Lin, Arellano, & Espinosa, 2009; NAS, 2016; Pascarella & Terenzini, 2005). This has led many to describe the STEM pipeline as “leaky” and sparked a search for interventions by academic leaders, policymakers, and scholars (Allen-Ramdial & Campbell, 2014; Gonzalez, Siler-Evans, Hunter, & Baird, 2016; Whalen & Shelley, 2010).

Many scholars believe the main leak of the STEM pipeline is in the post-secondary level. Indeed, the period between college entry and graduation accounts for 55% of the attrition in STEM degree attainment (Chen & Soldner, 2013). Previous research has found students are weeded out of STEM through difficult gateway courses and poor performance in early STEM coursework (Barr, Gonzalez & Wanat, 2008; Blickenstaff, 2005; Hurtado, Eagan, Tran, Newman, Change, & Velasco, 2011; Stolk & Herter, 2009; Vanasupa, Seymour & Hewitt, 1997). In other cases, faculty and staff at the institution actively direct students towards non-STEM majors by faculty and staff at the institution (Gasiewski, Eagan, Garcia, Hurtado, & Chang, 2012; Tobais, 1990). This highlights potential gaps that exist in the STEM pipeline at the college level as students depart from STEM fields both early on in their college experience and late in their academic career (Gayles & Ampaw, 2014).

Comprehensive Institutions and Underrepresenting Minority Students in STEM

Two factors affect STEM degree production in the STEM pipeline: (1) various types of institutions in the pipeline and (2) success of underrepresented minority STEM students. First, there are various types of institutions that enroll, train, and graduate STEM students (Bowen, Chingos, & McPherson, 2009). Each type of institution has a unique set of learning environments, support, and instructional philosophies that provide skills to students entering the STEM workforce (Cannady et al., 2014; Dowd, Malcom, & Bensimon, 2009). While elite research universities enroll the most well-prepared students and provide a breadth of opportunities for students to develop STEM skills, the majority of students attend other types of institutions, specifically, public comprehensive universities (Schneider & Deane, 2014).

Historically, public comprehensive universities developed in the U.S. during the "Golden Era of higher education," through which higher education experienced a "dramatic expansion of enrollments as well as numerous curricular innovations" (Thelin, 2011, p. 261). Throughout the Golden Era, expansion of postsecondary education fused together state and federal policy to provide the masses with greater access to a college education (Henderson, 2007; Thelin, 2004). Consequently, the primary goal of higher education aimed to enhance democratic life and advocate for equity in U.S. education and comprehensive institutions became central to achieving this promise (Clark, 1987).

Public comprehensive institutions embody three public purposes: (1) focus on teaching-centric and student-centered philosophies; (2) implementing accessible and/or open enrollment policies for their constituencies; and (3) focus on regionally related issues and needs (Henderson, 2013). These purposes lay the foundation for expanding postsecondary education to the masses and establishing equity across ethnic and socioeconomic groups (Schneider & Deane, 2014).

To meet those purposes, comprehensive institutions consist of a wide-range of institutions with diverse degree programs and primarily award baccalaureate degrees.

One of the unique qualities of comprehensive institutions is that they provide an individualized approach that provides lasting knowledge and relationships for students who are otherwise overlooked by highly selective institutions (Henderson, 2009; Schneider & Deane, 2015). Many faculty and staff provide support for learning through specialty learning communities (Bowen et al., 2009; Hurtado et al., 2009). Moreover, many of the students enrolled at comprehensive institutions identify with an underrepresented population (Fryar, 2015). With the projected demographic shift in the U.S., these populations in STEM fields necessitate inclusion in plans to increase STEM graduation rates (NSF, 2015).

The second factor affecting the STEM pipeline is the success of underrepresented minority (URM) students. Although URM enrollment at elite, research universities increased since 1990, comprehensive institutions continue to enroll the majority of diverse and non-traditional student populations at the undergraduate level (Ashkenas, Park, & Pearce, 2017; Schneider & Deane, 2015). As of 2010, these institutions enrolled 85% of Black, 74% of Latinx, 70% of America Indian, and 69% of Southeast Asians of undergraduate students (Fryar, 2015; Museus, Palmer, Davis, & Maramba, 2011) and many of these students are the first to attend college in their family (Pascarella, Pierson, Wolniak, & Terenzini, 2004; Ward, Siegel, & Davenport, 2012).

Despite the high numbers of URM students, STEM degree production remains well behind enrollment and workforce demographics (Museus et al., 2011; Xie & Killewald, 2012). Many of these students begin their academic careers aspiring to achieve a STEM degree and moving into graduate level training, yet leave STEM before their second year of undergraduate enrollment (Herrera & Hurtado, 2011; Strayhorn, 2010; Wang, 2013). This exodus from STEM particularly affects URM students, calling higher education leaders to reimage the STEM pipeline and develop new approaches for training future scientists (Allen-Ramdial & Campbell, 2014; Espinosa, 2011; Hurtado et al., 2009). Combining these characteristics, comprehensive institutions not only enroll a majority of the undergraduate population in general, they enroll the majority of the URM undergraduate populations as well. This is the focus of this investigation: the effectiveness of comprehensive institutions in supporting and broadening the STEM pipeline.

Significance of the STEM Problem

More advances in STEM fields are expected to happen over the next few decades (Noonan, 2017). Whether the U.S. is positioned to capitalize on them, however, remains in question for many U.S. economic, educational, and political leaders. In 2010, the STEM pipeline was in turmoil, being described by the National Academy of Sciences (NAS) and the National Science Foundation (NSF) as the “STEM Crisis,” identifying significant drop-offs in STEM majors, graduates, and workforce entrances in 2005 and 2010. Carnevale et al. (2011) and other STEM researchers reaffirmed these trends, projecting the U.S. STEM pipeline will not produce enough STEM workers for the projected need in the STEM workforce by 2020. These trends show the valid concerns of the STEM crisis and demonstrate the significant problem a poorly functioning pipeline.

Another pressing issue in the STEM workforce is the looming retiring of many baby-boomers. This generation comprised approximately 25% (potentially more) of the

STEM workforce in 2014 (Carnevale et al., 2011; Xie & Killewald, 2012). By the end of 2014, many Baby-boomers in the STEM workforce had filed their retirement dates, marking a gap of 450,000 STEM jobs without qualified domestic STEM workers to fill openings (NSF, 2015; U.S. Census, 2015). Without the number of qualified workers to fill the void, the U.S. will be unable to sustain global competitiveness and fail to continue as a global leader in STEM development and innovation (Carnevale et al., 2011; Dowd et al., 2009; Kanny, Sax, & Riggers-Piehl, 2014).

Lastly, the STEM workforce currently has a racial and gender imbalance that previous policy discussions have repeatedly failed to address (Xie & Killewald, 2012). The vast majority of middle- and upper-level managers in STEM are white males; URM and women employees struggle to break through (Xue & Larson, 2015). These blocks and barriers restrict URM populations and women from increasing their salary earnings (Broyles, 2009; Carnevale et al., 2011). More importantly, the exclusion of URM populations in the STEM workforce hinders the development of a diverse STEM workforce as well as fails to create solutions to problems that address populations of color (Burke & Mattis, 2007; Hurtado et al., 2010).

Through Critical Race Theory (CRT) and Critical Race Praxis for Education (CRP-Ed) lens, the root problem is racism, racist structures, and power dynamics that have been subtly normalized in the STEM pipeline (Baber, 2015). Moreover, colorblind policies that address diversity in STEM and the STEM workforce do not solve the root problem that continues to reinforce the racial exclusion of minority populations and often hides covert racist practices through normalized and common sense behaviors

(Jayakumar & Adamian, 2016). CRP-Ed challenges the the colorblind policies regarding diversity in STEM and the STEM workforce, highlighting the focuses towards economic outcomes and potential future economic challenges, which often benefit upper- and middle-class white populations (Museus et al., 2011). This has created a cyclical, race-neutral discussion that fails to disrupt the current structures established by federal and state policies (Basile & Lopez, 2015; Chen & Buell, 2018; Dowd, 2012). Drawing from the CRT and CRP-Ed interest convergence tenet, the significance of the problem highlights the underlying structures that maintain this unbalance and highlights the ineffectiveness of federal policies to act as systemic disruptions to these disparities.

Purpose of the Investigation

The purpose of this quantitative investigation is to expand the range of research on the links between institutional resource allocations and the STEM pipeline by analyzing the relationship between expenditures and STEM graduation rates at comprehensive institutions. Scholarly attention to STEM experiences and degree production mostly focus on the two ends of the public higher educational spectrum – community colleges and flagship, research-intensive universities (Henderson, 2007; Schenider & Deane, 2015). However, what about the "caught in the middle" (Henderson & Kane, 1991, pg. 393) institutions that are instrumental in expanding the STEM pipeline stewarding a majority of URM students into the STEM workforce? These institutions provide a unique set of relationships between resource allocations and STEM student outcomes that provides a counter-narrative to the current perspective.

Although increasing the effectiveness and efficiency of the STEM pipeline both overall and for URM students specifically is part of the national and states' agenda, there is limited research focused on STEM six-year graduation rates and the direct link to institutional expenditures. Previous research has predicted graduation and retention rates using institutional expenditures and characteristics for the overall student population (Gansemer-Topf & Schuh, 2006; Ryan, 2004). These studies find significant positive results of student-targeted resources on graduation and retention rates and provide the foundation for many of the variables selected in this investigation. However, these studies adopted the traditional ordinary least squares (OLS) technique or utilized panel modeling across decades of data. Thus, although causal effects were found, important between institutional differences were eliminated.

Further, these studies are limited by the broad application across disciplines and their focus on community colleges or research-intensive universities. Research rarely accounts for the unique context of comprehensive institutions and STEM disciplines within these campuses, with little attention given to STEM graduation rates of URM populations in STEM (Hurtado et al., 2010). Additionally, while institutional resource allocation research has been conducted, these studies often neglect STEM outcomes. Thus, the present investigation will address this gap in the scholarly literature and specifically focus on STEM graduation rates at comprehensive institutions, including specific analyses aimed at URM graduation rates and using a critical lens. Using a theoretical framework that draws on previous literature, this investigation employ multilevel growth modeling statistical techniques to assess the different relationships between the comprehensive institutions included in the dataset.

The current study examines differences in specific expenditure categories between institutions across yearly STEM graduation rates. Specifically, this investigation considers the relationships between student services, instructional support, and federal training grants and examines the Great Recession's impact on STEM graduation rates. Drawing on the extant research regarding the aggregate student characteristics related to STEM graduation rates, analyses will consider important institutional controls: selectivity and STEM cohort size were included to account for the association between institutional characteristics and STEM graduation rates.

By comparing the relationships between resource allocations and STEM graduation rates, as well as how the relationships of these allocations and institutional characteristics change after the Great Recession, this investigation will shed light upon possible institutional resource allocations strategies associated with changes in STEM graduation rates and federal funding for diverse student populations. Additionally, this investigation has broad applications to other comprehensive institutions in the improvement their performance in the STEM pipeline.

Research Questions

In order to evaluate the extent that resource allocation and the impact of the Great Recession explain the variance in six-year STEM graduation rates at California comprehensive universities, this investigation seeks to answer two overarching research questions:

Primary Research Questions:

- ✓ To what extent did the Great Recession have an impact on STEM graduation rates at comprehensive institutions?
- ✓ To what extent are various forms of resource allocations associated with STEM graduation rates and URM STEM graduation rates at comprehensive institutions?

Significance of the Investigation

A healthy STEM workforce will contribute to U.S. economic prosperity now and in the future. For example, approximately half of U.S. economic growth over the past 50 years is attributed to technological and scientific innovation. A glimpse into the future shows that the 30 of the fastest-growing occupations in the next decade will require formal training in STEM and 10 of those occupations will require at least a baccalaureate degree in one of the STEM disciplines. Moreover, STEM occupations and career pathways are projected to grow by 28.2 percent from 2014 to 2024, compared to 6.5 percent growth for non-STEM occupations (Fayer, Lacey, & Watson, 2017; See Appendix A for further detail on STEM occupation projections and degree requirements). It is clear that STEM related jobs and careers are now the backbone of the global economy and remains a clear area for improvement for the U.S. workforce.

In order for the U.S. to continue as a STEM global leader, comprehensive institutions will be an important player in attaining the goals outlined in domestic policy as well as maintaining a systemic flow of STEM workforce entrants. Assessing the approaches and techniques that improve STEM student outcomes, comprehensive institutions provide a unique lens into institutional behaviors aimed at accomplishing that goal, in particular with regard to addressing the success of URM student populations. Broadening the understanding of institutional behaviors that retain and develop STEM students at comprehensive institutions will broaden our understanding of behaviors that work in the STEM pipeline for comprehensive institutions. This investigation provides insight into the institutional behaviors important to STEM outcomes within a subset of comprehensive institutions: the California State University (CSU) system.

The body of literature on graduation rates and the STEM pipeline does not focus enough attention toward comprehensive institutions (Dalbey, 1995; Henderson, 2009; Schneider & Deane, 2015; Schultz et al., 2011; Wong, 1990). Indeed, most STEM undergraduate and URM students in the STEM pipeline are enrolled at comprehensive institutions across the U.S. Therefore, more focus on these institutions will provide an opportunity for policymakers, administrators, and faculty to be more efficient and effective with resources and funding mechanisms that support the success of STEM students in the pipeline and aid in meeting the lofty demands of producing one million more STEM degrees domestically by 2025 and closing the continuing attainment gap between ethnic minorities and the majority population in STEM (NSF, 2014).

The negative impact of the Great Recession on higher education funding is well documented, yet not well studied (Brown & Hoxby, 2014; Craig, 2015; Zumeta, 2010). Despite increased enrollment, STEM outcomes and graduation rates remain largely unexplored (Barr & Turner, 2013). The context of the CSU system highlights the policy and funding adaptations that comprehensive institutions attempted during the Great

Recession to maintain institutional success during the financial retrenchment, while also remaining dependent primarily on state and federal funds (Schneider & Deane, 2015). Despite encompassing a large system of comprehensive institutions, CSU campuses were forced to be nimble and thoughtful in their efforts to incorporate policy interventions, yet remain colorblind to maintain interest convergence across campuses and populations.

Some policy interventions at CSU campuses took broad strokes cover large numbers of students. For example, there were increases in financial and enrollment targets to defuse some of the negative effects on URM students, in particular in STEM disciplines (Bardhan & Walker, 2010; CSU, 2016). CSU campuses created a number of low-cost policies: developing coursework polices and units restrictions; the Highly Valued Degree Initiative, which focused on faculty and staff engagement for producing degrees within STEM disciplines; offering financial aid packages that included more grants through the state (Cal-Grant and middle-class grant); incorporating more development preparation in college-level curriculum in mathematics and English; targeted recruitment to attract students into STEM majors for undeclared students; and an increased funding for hiring of student affairs officers in STEM programs to promote and support STEM majors to graduation. The significance of this investigation highlights the potential explanatory effects of these funding shifts at comprehensive institutions on their STEM degree performance.

However, through a CRP-Ed and critical quantitative approach, some aspects of CSU policies came at the expense of addressing fundamental racism on campuses. For example, in response to the Great Recession, CSU campuses implemented a policy that capped the number of units a student can complete. On the surface, this policy created only minimal additional overhead for CSU campuses and initially seemed efficient. Yet, there is a mismatch between the goal of the policy (to address inefficiencies at the institutional level) and the measurement of the outcome (reductions in deficiencies in student behaviors and/characteristics). Often, URM students and URM STEM students violated this policy, causing many faculty and staff to assume URM students have a defect with STEM majors. Thus, URM STEM students were sought after in order to provide further support and guidance to complete the STEM degree, however many of these students were ushered into a non-STEM degree. This points to possible support of subtle institutional micro-aggressions against URM students' sense of belonging on campus and in the STEM field (Bensimon, 2005; Yosso, Smith, Ceja, & Solórzano, 2009). Therefore, a significant aspect of this investigation examines the impact of the Great Recession on comprehensive institutions' STEM graduation rates. This uncovers potential policy and funding consequences at CSU campuses that have racially biased aspects. The implications of this investigation could further inform policy and institutional behavior at comprehensive institutions for future recession and state cuts to higher education funding, while maintaining URM STEM success.

Although measuring outcomes and performance among comprehensive institutions can be difficult due to the varying mission, goals, and student compositions, most comprehensive institutions function under the oversight of state legislation or public constituencies (Doyle, 2015; Fryar, 2015; Henderson, 2007). Public institutions receive funding based on past performance and/or current enrollment. Yet, despite public policy initiatives (i.e. the College Promises) and federally funded resources (e.g. NIH Minority Access to Research Careers), there is little evidence connecting specific resource allocations to institutional STEM outcomes. Therefore, further research is needed in order to understanding existing trends in how comprehensive institutions allocate resources to develop their STEM graduation rates at their campuses.

This investigation is focused on the crucial role of comprehensive institutions in the STEM pipeline, where a majority of URM STEM students enroll. Diversity in the STEM pipeline leads to new solutions and perspectives to spark innovation for the next century. The STEM pipeline is currently stifling this creativity and possible expansion of new avenues of exploration. Examining the strategies campuses use to allocate resources to affect their STEM and URM STEM graduation rates brings together a number of previous bodies of literature regarding the STEM pipeline, institutional resource allocations, and graduation rates. Additionally, one of the aims of this investigation is to situate itself into the policy discussion and challenge the creation of colorblind and race-neutral polices to address STEM disparities. The important findings from this investigation will offer recommendations to help stop the gaps in the leaky STEM pipeline and provide insights into resource allocation strategies that improve effectiveness. Additionally in this tight financial time, improvements to programs and courses that help STEM students be successful will lead to a strong economic future.

CHAPTER 2

Literature Review: Empirical Research and Theoretical Framework

In order to examine the relationship between institutional resource allocations and six-year undergraduate STEM graduation rates at California State Universities (CSU), it is essential to first understand the nature of the STEM pipeline. Any efforts to do so would be remiss if they failed to include two key bodies of literature regarding theories of higher education (See Table B.1 in Appendix B for a list of STEM disciplines/majors).

Therefore, the literature review begins by presenting organizational and critical theories of higher education. These theories provide the foundation for this investigation and guide its efforts to examine the development of comprehensive institutions in the U.S. and their place in the national agenda (or lack thereof). Next, because this study focuses on STEM outcomes including graduation rates of URM students, the review highlights approaches to broadening diversity and participation in STEM, exploring important institutional characteristics related to positive STEM outcomes. Specific attention will be given to the effect of resource allocations on STEM programs and student outcomes with a review of the strategies that institutions use to disburse resources across allocation categories. The literature review concludes by describing the contribution this investigation makes to the body of research.

Theoretical Framework

This investigation aims to uncover patterns and relationships unique to comprehensive institutions and their role in the STEM pipeline. Using this goal, this investigation draws from two theoretical bodies to analyze literature and build a conceptual framework for data analysis. First, organizational theory in higher education utilizes an interdisciplinary lens to analyze campus-level aspects and their actions. Higher education scholars previously applied organizational theory to campuses and departments to assess contextual relationships to student outcomes and faculty productivity (Clark, 2004; Scott, 2014). The application of organizational theory in this investigation focuses on relationships between institutional outcomes and behavior.

However, the gaps identified in the literature suggest that organizational theory has limited applications to links between organizational behavior and institutional student outcomes, in particular with regard to STEM (Burke & Mattis, 2007). Although, some studies used organizational theory to connect causal relationships to student-level outcomes (Smith, Pender, & Howell, 2013), this investigation uses organizational theory to frame changes in organizational outcomes as a byproduct of decisions implemented at the organizational level.

The second theoretical body is Critical Race Praxis for Educational Research (CRP-Ed), developed by Jayakumar and Adamian (2015). Using fundamentals from critical race theory (CRT), the CRP-Ed framework challenges researchers to adopt counter-narratives and bridge the gap between policy and CRT research. Policy and CRT research seem to lack common ground, highlighted by tensions and contradictions in equity discussions and legal discourse (Manning, 2012; Parker, 2003). However, CRP-Ed aims to acknowledge such pitfalls and create a more synergistic approach to strengthen research by finding mutually beneficial leverage points (Jayakumar & Adamian, 2015). Research using CRT, and by extension CRP-Ed, in higher education includes both qualitative and quantitative work aimed at developing equity across racial and socioeconomic groups. However, such research that specifically considers comprehensive institutions is limited. The following sections outline each theoretical approach and their applications in higher education.

Organizational Theory

In forming a theoretical perspective for analyzing institutional STEM student outcomes, organizational theory provides an effective starting foundation. Organizational theory posits that individuals form social units and groups to accomplish a particular purpose (Birnbaum, 1991; Scott, 2014). As an organization, each unit is a social system aimed at attaining "specific objectives and goals, which contribute to a major function of a more comprehensive system…" (Parsons, 1956, p. 64). Organizational theory maintains that three main characteristics differentiate organizations from other social systems: (1) by producing a product, e.g. goods, services, products, or another output for another organization; (2) the product is centered around a common goal achieved through coordinated effort and internalized processes; and (3) the goals possesses external relationships that connect it to a larger institution (Clark, 1986; Parsons, 1960).

Drawing from a wide range of social science disciplines, organizational theory provides a lens to contextualize organizations and creates models to examine patterns and structures (Bolman & Deal, 2008; Manning, 2012). From this perspective, studies on organizations show how internal and external factors cause these social units learn (Cyert & March, 1963), adapt (Cameron, 1984), and change (Clark, 1998). As organizations change, each develop a specific culture and climate and as each organization evolves into their organizational culture and climate, applying knowledge learned from individuals within the organization, their behaviors and actions symbolize their internal values (Berger & Milem, 2000; Clark 1986; Manning, 2012). The research using organizational theory in higher education has developed campus-specific models to examine relationships and explain outcomes at colleges and universities, covering a broad range of topics (Bess & Dee, 2008).

Organizational theory enables the analysis of higher education in terms of organizational design and structure, relationships and behaviors of individuals or groups within and between institutions, and linkages with their external environments (Kezar, 2005; Manning, 2012; Scott, 2014). Broadly, colleges and universities are viewed as both open and closed systems, adapting and evolving to their environment (Bees & Dee, 2008). Most studies using a broad organizational theory lens within the field of higher education focus on governance, academic leadership, and institutional effectiveness (Berger & Milem, 2000). The vast majority of this research centers around three areas: (1) contextual factors of the campus culture and climate on faculty and student outcomes, (2) the effects of administrative leadership on policy and campuses level decisions; or (3) the effect of institutional policies and/or student success initiatives on individual student outcomes (Kuh, Kinzie, Schuh, Whitt, 2011). However, these studies tend to use traditional organizational theory, focusing on the rational and bounded control of the institution (Bastedo, 2012). This limits the types of innovations and structures that higher education institutions can adopt to accomplish goals and missions.

Blending traditional with contemporary organizational theory, higher education institutions stand to benefit from new models and concepts. In particular, organizational theory has lacked sufficient research on the conceptual relationships of organizational behaviors and institutional outcomes (Dee & Leisyte, 2016). The absence of organizational research on STEM outcomes neglects campuses that are critical to reaching and educating diverse student populations (Hurtado et al., 2010). Thus, the current study aims to connect organizational behavior to the institutional outcome of STEM six-year graduation rates, using critical quantitative theory to build on traditional organizational theory.

Organizational Behavior in Higher Education

Drawing roots from organizational theory, organizational behavior uses groundwork from a broad range of social science disciplines, sociology, psychology, political science, and others (Bess & Dee, 2008; Shafritz, Ott, & Jang, 2015). A unifying definition proposed by Berger and Milem (2000) states that organizational behavior can be seen as "the daily patterns of functioning and decision-making within an organization" (p. 274). Through this definition, organizational behaviors examine day-to-day processes and are a “function of what institutions do (and how they do it)” to accomplish their goals (Reason, 2009, p. 668). Therefore, they provide valuable insight into relationships that shape organizational outcomes.

Organizational behaviors encompass the specific internal organizational structures, practices and policies, and the types of student involvement and opportunities promoted, at a particular institution (Peterson & Spencer, 1990). That is, they refer to the actions of organizational agents within the institution, rather than ascribing action to the institution as a social actor itself (Berger, 2001). Yet, institutions adopt certain organizational behaviors (e.g. practices and goals) that respond to problems in the environment, which will differ by institution and change based on the intended goals aimed to accomplish (Leslie, Slaughter, Taylor, & Zhang, 2012). Therefore, these organizational behaviors are likely to have an impact on institutional student outcomes, beyond traditional institutional characteristics (Terenzini & Reason, 2005).

Organizational behaviors and decision-making patterns are tangible outcomes (Berger & Milem, 2000). They represent, in many respects, the development of organizational culture, climate, and learning (Berger, 2000; Titus, 2006). At this point, it is important to highlight how organizational behaviors embody these other organizational aspects. First, organizational culture is an entrenched, holistic aspect of the institution (Birbaum, 1991; Clark, 1980). Masland (1985) described organizational culture as "a 'bass clef' that conveys at a deep level what [the organization] really cares about" (p. 158). It is often described as the meaning and expectations that permeate throughout the organization while creating social cohesion (Pettigrew, 1979; Selznick, 1957; Tierney, 1998; Weerts, Freed, & Morphew, 2014). Although this is an abstract concept, higher education institutions may choose to incorporate practical curriculum that aims to train students for specific job markets. This example shows how organizational behavior, incorporating practical curriculum, serves to represent this institution's organizational culture (Birbaum, 1991; Masland, 1985). Thus, a campus with traditional liberal arts culture would choose theoretical pedagogies, whereas, this campus chooses a more practical approach and displays a culture that values more attentiveness to environmental workforce demands (Bastedo, 2012).

Second, organizational climate, referred to as campus climate in higher education, focuses on current patterns and individual perception toward the institution (Cabrera, Nora, Terenzini, Pascarella & Hagedorn, 1999; Hurtado, Clayton-Pederson, Allen, Milem, 1998). Campus climate is influenced by both personal experiences of individual students, faculty, and staff, but as also, the perceptions of the standing of their racial peers and mentors on campus (Rankin & Reason, 2005). The perceptions of individuals on campus can change over time and through campus initiates that prioritize planned, diverse interactions with diverse student populations (Berger, 2001; Rankin, 2014). Campus climate metrics provide insight into the evolution of institutional change and integration of diverse interactions into the fabric of campus life that develop and include marginalized students (Harper & Hurtado, 2007; Peterson & Spencer, 1990). Through concentrated effort, aspects of campus climate that are embraced by the institution are related to extensive positive educational outcomes when there is a high perceived level of respect between members and across diverse student, faculty and staff groups (Kuh, Kinzie, Buckley, Bridges, & Hayek, 2006; Pascarella & Terenzini, 2005).

Third, organizational learning occurs when subunits within the organization acquire new knowledge and apply the information to accomplish the mission and goals of the organization (Huber, 1991; Kezar, 2005). Organizational change rarely persists without the organization learning and applying important, beneficial knowledge into practice (Boyce, 2003). In higher education, organizational learning concepts foster leadership development of faculty and administrators, data management and usage, and implementation of initiatives to enhance institutional effectiveness (Dee & Leisyte, 2016). The key element to organizational learning in higher education institutions is that each college, department, and/or committee has the ability to influence organizational learning and aid in institutional change (Bensimon, 2005).

Studies that use organizational learning frameworks frequently apply functionalist perspectives. This aligns with policy research by seeking causal relationships and placing high value on generalizable results (Dee & Leisyte, 2016). In particular, the research focuses on financial aid practices and entrepreneurial strategies to gain more support from external constituencies (Bess, 2006; Slaughter & Rhodes, 2004). However, organizational learning is reflected in organizational behaviors, where practices and traditions adopted by the institutions are guided by the learning of new information and subsequently applied to the problems of the institution (Levitt & March, 1988).

Therefore, organizational behaviors are tangible demonstrations of organizational characteristics like culture, climate, and learning. They reflect the shared assumptions and cultural ideology that provide directions for individuals working toward the goals of the organization (Tierney, 1998). Both qualitative assessments and quantitative analyses have illustrated the observable outcomes of organizational behaviors and contextualized how higher education institutions approach problems both internally and externally, while theoretically acknowledging their multi-faceted nature (Berger, 2000; Birbaum, 1991; Scott, 2014). Thus, the current investigation strives to connect institutional characteristics, traditions, and organizational structures together through the analysis of organizational behaviors at comprehensive institutions.

Critical Race Praxis for Educational Research and Critical Quantitative Approach

Projections of higher education enrollments show increasing numbers of underrepresented minority students (URM), yet it remains consistent that these populations do not complete degrees at the same rates as majority students (Carnevale et al., 2011). However, policy and federal interventions focus mainly on economic outcomes that attempt "color-blind" analyses, missing differential effects of unique barriers faced by URM students (Teranishi, 2007). Further, the experiences of Latinx, Black, and Southeast Asian students are not homogenous (Harper & Newman, 2010). While these experiences limit URM student success in a variety of levels, CRT aids in understanding how policy and practices are impacted by decisions made at the institutional level, and in turn the resulting level of student success (Stage, 2007). Approaching this issue from a CRT perspective acknowledges the presence of race/racism and various forms of discrimination woven into the fabric of society (Ladson-Billings & Tate 1995).

CRT seeks to analyze and transform structural and cultural aspects of colleges and universities that maintain marginal positioning and practices of minoritized groups (Solorzano & Villalpando, 1998). The foundations of CRT developed from legal scholarship to challenge the dominant perspectives used to assess the "normal" standard, instead centering URM students' experiences (Crenshaw, 2011; Harper, Patton, & Wooden, 2009; Solorzano & Villalpando, 1998). CRT has expanded it applications beyond legal scholarship and been utilized to critically examine how race and racism influences access to education and student success outcomes (Ladson-Billings & Tate, 1995; Taylor, 1998). Delgado and Stefancic (2017) describe the fundamental tenets of CRT as:

1. Racism is ordinary, not aberrational. Society functions and perpetuates explicit and implicit discrimination.
2. Society views equity through a color-blindness lens, acting only when there is interest convergence for the dominant group and minority groups.
3. Race is a social construction. Behavior, intelligence, and other higher-order characteristics are not fixed by race, however society often views race and fixed and deterministic.
4. Depending on circumstance, society racializes different minority groups based on the needs or period. The context and the situation will shift the type of characteristics associated with the group.
5. Written expression of interactions with racism is encouraged, despite the dominant cultures ability to understand and accept those experiences. This expression gives voice and illumination to the dominant culture to be exposed to these occurrences.

In higher education, CRT provides a powerful means to view institutions and the campus context forged from practice, policies, and traditions perpetuating exclusion and marginalization. CRT places a spotlight on the effect of racial background in educational contexts, demonstrating how these factors are tightly linked with institutional environments as in the case with minority students in STEM (Manning, 2012).

CRP-Ed builds off CRT and extends the nature of race and racism into policy arenas. Building from Yamamoto (1997), the critical race praxis, and by extension CRP-Ed, "combines critical, pragmatic, socio-legal analysis with political lawyering and community organizing to practice justice by and for racialized communities" (p. 829), calling for social justice to be engrained into daily processing and practices (Jayakumar & Adamian, 2015; Museus, Ledesma, & Parker, 2015).

Additionally, CRP-Ed aims to bring together interdisciplinary approaches to combat systemic discrimination. Jayakumar & Adamian (2015) describe CRP-Ed in four detailed pillars: (1) relational advocacy toward mutual engagement, (2) redefining dominant and hegemonic systems, (3) research as a dialectical space, and (4) critical engagement with policy. These four basic tenets guide scholars in educational research to utilize a multilayered approach in analyzing problematic policies and practices, advocating for change within the institutional context. CRP-Ed pushes research to question facts that do not align with theory and dismantle symbolic artifacts that preserve subtle discrimination (Manning, 2012).

Another extension of CRT, the critical quantitative approach calls researchers to question the "traditional" models and methods used within higher education quantitative research and to offer competing perspectives that "better describe the experiences of those who have not been adequately represented" in the literature (Stage, 2007, p. 10). This approach seeks new models and ways of measuring higher education processes and practices, explicitly examining "equity concerns that can be highlighted through analysis of large datasets and…differences by race, class, and gender" (Briscoe, 2008).

Critical quantitative approaches acknowledge (1) quantitative research is not wholly objective and positivist with space to include autobiography and research together; (2) critical quantitative approaches identify discrepancies between theory and fact; and (3) there are positives and negatives for comparative group versus context-specific approaches to understanding group differences (Carter & Hurtado, 2007; Rios-Aguilar, 2014). Critical quantitative approaches allow for context specific analysis, utilizing the variability within a specified group as a point of leverage (Carter & Hurtado, 2007; Strayhorn, 2013a). From a policy perspective, the critical quantitative lens can "illuminate the limitations of current policies by illuminating resulting inequalities" (St. John, 2007, p. 70).

The critical lens from CRP-Ed and critical quantitative approaches brings to the forefront comprehensive institutions and their unique positioning in higher education (Wells & Stage, 2015). The reliance of quantitative outcomes in policy conversations requires a more in depth understanding of the relationships within institutional types, giving way to alternative quantitative methods using large datasets (Cheslock & Rios-Aguilar, 2011; Museus et al., 2015; Niehaus, Campbell, & Inkelas, 2014; Teranishi, 2007). With regard to the STEM pipeline, these critical approaches emphasize the importance of comprehensive institutions for educating URM students, providing the future STEM workforce with role models and examples, and diversification among STEM disciplines, and equity for STEM aspirants.

Summary of Organizational and Critical Theory in Higher Education

Together organizational theory and CRP-Ed create a unique lens to interpret patterns of organizational behavior within higher education institutions. Previous higher education research using organizational theory shows institutional behavior, through institutional characteristics and resource allocations, strongly predicts institutional student outcomes (Alon & Tienda, 2005; Hamrick, Schuh, Shelley, Mack, 2004; Horn, 2006; Oseguera, 2005; Titus, 2004). However, many of these studies restricted their findings to fit previous policy requirements that excluded or aggregated specific student groups and types of institutions. Additionally, studies focused on attainment of URM student groups, often viewed results through an economic lens weighing cost analysis (Perna & Jones, 2013). The inclusion of CRP-Ed and critical quantitative approaches allows this investigation to push against previous research findings and policy requirements, highlighting institutional and student groups that occupy a large proportion of the undergraduate population. The following sections review the literature on comprehensive institutions, institutional characteristics, and STEM pipeline, highlighting important disparities and contradictions in the literature.

Public Comprehensive Institutions

Traditionally, public comprehensive universities draw nearly 90% of their student body enrollments from local and regional areas (AASCU, 2013). Many students earning degrees from local, public colleges and universities remain in the area, becoming civil servants, economic developers, and educators (Henderson, 2009). For example in 2013, graduates of comprehensive institutions populated over 50% of all K-12 teachers and

55% of all STEM K-12 teachers in the U.S. (AASCU, 2013; NSF, 2015). Within this context, comprehensive institutions provide service and stability to local communities, while also remaining institutions "caught in the middle" of the higher education spectrum (Clark, 1987; Henderson, 2009; Henderson & Kane, 1991, pg. 393).

Since their inception, public comprehensive institutions evolved in numerous ways, reflecting the needs their local areas while balancing aspirations of contending as a full-fledged research university (Henderson, 2013). With this rich history and lack of clear breaking points between elite research universities and community colleges, comprehensive institutions encompass the gap between these two groups. As such, they play a pivotal role in accomplishing state and national STEM pipeline goals (Ogren, 2005; Schneider & Deane, 2015). For example, comprehensives enrolled 70% of the U.S. undergraduate and 60% of the graduate population, while awarding over 40% of all STEM baccalaureate degrees (NAS, 2016). Moreover, URM STEM students enroll more frequently at comprehensive institutions than other institutions (Stage & Hubbard, 2009).

Fryar (2015) found drawing lines to designate a college as a comprehensive institution will change based on the decisions made by the researcher. The author first used the Carnegie definition of comprehensive institutions. The result included campuses often considered research-intensive institutions (i.e. UCLA). However, the author employed another common definition of campuses awarding more than 20% baccalaureate degrees; this then included a number of community colleges (i.e. Wisconsin Community Colleges). It is important to note that definitions of comprehensive institutions continue to change. An extensive analysis of empirical and summary literature on comprehensives show scholarship spent little time delineating an accurate, common definition (Henderson, 2009). Additionally, as definitions change, perceptions of these institutions create unaligned views of their performance and quality.

For example, the NRC (2013) and the NSF (2015) conducted descriptive studies on overall degree completions. The NRC defined comprehensive institutions as “an institution that awards more than 25% of their degrees at the bachelor’s level,” finding that comprehensive institutions awarded approximately 41% of the baccalaureate degrees in the U.S. in Fall 2012. Many policy makers deemed this as successful institutional benchmarks and sought to use this as a national threshold for comprehensive institutional quality (Henderson, 2009). However, Yin (2015) defined comprehensives as the Carnegie defined sample of all baccalaureate and master’s granting institutions. The author used a breadth of institutional characteristics (student demographics, faculty composition, financial aspects) to predict the expected graduation rates of their student body. The findings lead to “high performing” institution performing lower than their expected rate (predicted graduation rates were higher than what is reported by the institution) with other institutions showing a higher than expected rate. This highlights the misalignment between perceived performance and an expected performance that many comprehensive institutions suffer.

A similar example is found for studies on STEM disciplines. The NSF (2015) study found that comprehensive institutions awarded approximately 48% of STEM degrees in the U.S. in Spring 2013 (NSF, 2015). This was used as example of successful

STEM pipeline development and an expansion of participation in STEM. However, Rine (2014) used a more narrowed classification of comprehensive institutions (Carnegie classified public baccalaureate granting institutions) and found mid-size comprehensive campuses produce 25% of all STEM degrees in AY 2014-2015. Although 25% of is lower than 48%, this indicates that a majority of the STEM degrees awarded by comprehensive institutions were centralized within only an elite group of institutions and highlights the differences in performance between comprehensive institutions. The vague definitions exacerbate the "undistinguished middle child of higher education" stigma associated with comprehensives (Selingo, 2015, para. 6).

Despite the vague definitions, one goal of comprehensive institutions is to provide a viable access point for higher education to the large majority of students, in particular for low-income, URM student populations, and non-traditional students (Ogren, 2005; Thelin, 2011). For example, in Fall 2011, comprehensive institutions enrolled over 80% of Black, 70% of Latinx, and 75% of Southeast Asian undergraduate students (Fryar, 2015). In addition, the Pell grant is awarded to approximately 45% of undergraduate students at comprehensive institutions (Yin, 2015). The enrollment patterns show comprehensive institutions provide URM students viable college competition pathways.

However, these institutions struggle with low retention and degree completion rates (Henderson, 2007; Scheneider & Deane, 2015; Skomsvold, Radford & Berkner, 2011; Yin, 2015). This pressures comprehensive institutions to increase degrees and student success, pushing institutions toward more cost efficient policies, often at the expense of mission drift and/or institutional isomorphism (Fryar, 2015; Henderson, 2013;

Titus, Vamosiu, McClure, 2017; Zumeta, 2001). For comprehensive institutions, this often compromises the target populations they enroll (Schneider & Deane, 2015). Additionally, as comprehensive institutions strive to improve quality, increase production of research, and build student success, they are pulled in multiple directions simultaneously (McMahon, 2009; Zumeta, Breneman, Callan, & Finney, 2012). As a result, comprehensives are constantly adapting to circumstances, however research fails to account for differences in strategies and resource allocation behaviors within this group of institutions (Scheneider & Deane, 2015).

Relationships of Institutional Characteristics as Organizational Behaviors

Institutional characteristics have been found to "have an influence on many different aspects of student gains" (Toutkoushian & Smart, 2001, p. 40). Fundamentally, institutional characteristics describe campus-level aspects that determine the campus's ability to provide education to students. Often, this centers on the type of preparation with which colleges or universities equip their students for the workforce (Astin & Oseguera, 2005; Braxton, 2000; Pascarella & Terenzini, 2005). These characteristics are the public image of the institution. Parents and students will use this information in their college choice process, while policy-makers use this information to determine institutions' rankings (Hazelkorn, 2015).

Additionally, previous research suggests that institutional characteristics provide static campus characteristics that rarely change (Pascarella & Terenzini, 2005). They include, more broadly, how the institution is controlled (public or private), the highest degree offered, and the composition of the student body (Astin, 2005; Kuh et al., 2006).

For example, studies have found a direct link between institutional characteristics' effect on student engagement on campus, completion of units and coursework, and campus climate of racial interactions, (Doyle, 2015; Mayhew et al., 2016; Oseguera, 2004; Pascarella & Terenzini, 2005; Wolf-Wendel, Ward, & Kinzie, 2009).

Institutional characteristics and their fluctuation reflect deep-rooted organizational culture, current environmental climates, and/or learned behavior from the application of new organizational knowledge (Bastedo, 2012). Through this lens, institutional change is possible through deliberate organizational behaviors that alter their disposition in the higher education landscape, not explicitly caused by environmental factors (Boyce, 2003; Kezar, 2005). As such, comprehensive institutions are likely to display prestige-seeking behavior due to their placement between community colleges and flagship universities (Goldman, Goldman, Gates, Brewer, & Brewer, 2004; Morphew, 2002).

Institutional Selectivity

Selectivity is one institutional characteristic that resembles a changing campus culture and/climate. Selectivity provides a measurement of institutional quality that shows the difficulty in achieving admission to an institution (Kuh & Pascarella, 2004; Alon & Tienda, 2005). It is defined by a composite variable that combines individual Scholastic Aptitude Test (SAT) (or other standardized tests) and Grade Point Average (GPA) scores as well as other categorical preparation markers (e.g. high school rank and percentage accepted) (Mayhew et al., 2016; Oseguera, 2005; Pascarella & Terenzini, 2005). As an educational quality measure, institutional selectivity has shown significant impact on institutional graduation, retention, and persistence rates across student populations (Kuh & Pascarella, 2004; Mayhew et al., 2016; Pascarella & Terenzini, 2005).

In addition to institutional quality, selectivity plays a significant role in institutions' undergraduate rankings (e.g. U.S. News and World Reports). Rankings give the public insight into college quality and simple comparisons between institutions (Bowen et al., 2009; Hazelkorn, 2015). Institutions that desire to elevate their campus rankings can adopt more stringent admissions policies to increase their selectivity. This behavior, called "striving" or "prestige-seeking" behavior (O'Meara, 2007), is fundamentally an attempt to gain higher prestige and results in an arms race between institutions to alter their status (Ehrenberg, 2003). Campuses' attempts to gain higher ranking and prestige often result in the acquisition of high quality students (based on SAT and GPA), nationally recognized research faculty, and subsequently improve rankings (Rodriguez, 2015). Therefore, increasing selectivity is a straightforward approach to improving rankings and overall public image, while also fulfilling the rising demands of accountability for higher education institutions.

Despite rankings showing little direct relationships to institutional quality (Pike, 2004; Pike, Smart, Kuh, & Hayek, 2006), selectivity is positively associated with institutional performance indicators, in addition to other factors such as faculty-student ratios and the gender composition of the entering cohort (Marchen, 2014; Pascarella & Trenzini, 2005; Titus, 2004). Selectivity also has been found to have positive effects on URM populations' outcomes across institutional types and contexts. Although the mismatch hypothesis assumes URM students will not be successful due to a lack of preparation for the environment surrounding them (Sander & Taylor, 2012), URM student graduation rates at highly selective institutions remain consistently higher than nonselective institutions (Alon & Tienda, 2005; Pascarella & Trenzini, 2005). In fact, this finding remains consistent across ethic groups (Kelly & Schneider, 2012). Consequently, comprehensive institutions choose to ignore their history and culture of accessibility for local students, instead accepting behaviors that restrict their enrollments in favor of more highly qualified students (Schneider & Deane, 2015).

The effect of striving behavior on comprehensive institutions may quell the short-term goals of cost effectiveness and accountability (Doyle, 2015). However, the long-term effect of increased selectivity homogenizes the definition of success for entering college students around obtaining high-test scores. Moreover, this definition of success further pushes marginalized groups away from comprehensive four-year institutions and into two-year community colleges or out of post-secondary education altogether (O'Meara, 2007). This contradicts the findings of diversity-focused research that shows increased educational gains through interactions with diverse student backgrounds, histories, experiences, and ideals (Hurtado, Engberg, Ponjuan, & Landreman, 2002).

Additionally, the pressures of striving behavior insert comprehensive institutions into a global reputation race (Hazelkorn, 2015). The competition for institutional "excellence" ignores the broader base of universities that fall outside of the Top 100 campuses; only 1% of institutions are represented within the Top 100. The effect of rankings and striving institutions on student outcomes may only affect a small percentage of the student body (O'Meara, 2007). Therefore, striving behavior and selectivity on campus initiated a complex conversation that carries political and economic motives and behooves more attention be given to the effects they have on comprehensive institutions and STEM students.

Cohort Size

Scholars have explored the effect of the size of the undergraduate population or the total full-time enrolled (FTE) units on student outcomes, although few significant relationships were found (Mayhew et al., 2016; Pascarella & Terenzini, 2005). However, in higher education, the cohort size has been shown to have an effect when a group on campus has reached critical mass. The concept of critical mass examines the size of a group or population of students or faculty on campus that allows for meaningful interactions between racial groups and develops sub-cultures to build within and across groups (Baber, 2015; Fries-Britt & Turner, 2002). It indicates a level of representation that promotes comfort and/or sustainability (Strayhorn, 2012). With a large enough critical mass, findings have found a "staying environment" is fostered at the institutional level for students and faculty, while counteracting institutional marginalization of minority student and faculty (Etzkowitz, Kemelgor, Neuschatz, Uzzi, & Alonzo, 1994; Garces & Jayakumar, 2014; Myers & Caruso, 1992). It appears that critical mass aids in "clear[ing] up blockages in the pipeline on the premise that a sufficient number of persons from a previously excluded social category will foster inclusion of others…" (Etzkowitz et al., 1994, p. 53), most commonly among URM students and faculty.

Without a large enough cohort size to create critical mass, students report feeling a sense of loneliness and isolation that pushes them to leave the institution (Fiske, 1988).

This can divert students towards other institutions or disciplines that enroll more students with similar backgrounds and experiences (Hagedorn, Chi, Cepeda, & McLain, 2007; Herzog, 2010). Additionally, studies on this concept have included faculty and staff; without a critical mass of faculty and staff to identify with, they feel isolated and tend to leave causing the institution instability (Carrigan, Quinn, & Riskin, 2011; Hendrickson et al., 2013; Lowe, 2005). Such instability often broadly affects outcomes across campus. Indeed, Hagedorn et al. (2007) found that reaching critical mass for community college faculty was a key predictor of URM student success because it provides an ample number of role models who share similar ethnic and background characteristics, creating a supportive campus climate.

URM students feel a stronger sense of belonging on campus at those that achieve critical mass for URM populations (Fries-Britt & Turner, 2002). With an increased sense of belonging, campuses with a larger cohort size minimize drop out risks and institutional barriers, while illuminating more pathways for achieving baccalaureate degrees for URM students (Colman & Palmer, 2006; Pascarella & Terenzini, 2005; Strayhorn, 2012; Wells & Horn, 2015). Reaching critical mass of URM groups allows for the development of sub-cultures within the institution where minority students can explore and identify connections with peers (Baber, 2012). Given the benefits of achieving critical mass coupled with the gains from campus diversity, critical mass creates a welcoming campus climate that often leads to positive institutional and student outcomes across disciplines.

The process of building critical mass for STEM students and for URM students requires participation from multiple decision-making bodies on campus (Manning, 2012).

It behooves stakeholders to embody cooperative behavior across departments to allow for transformative leadership among administrators that creates a more diverse and accepting campus climate (Hagedorn et al., 2007; Lowe, 2005). Although many of the previous studies regarding critical mass focused on overall institutional outcomes, Fries-Britt and Turner (2002) found campuses that adopted an active approach to recruit and graduate URM STEM students engrained the critical mass into the campus climate. Both students and faculty were given a voice to express their skills in STEM, instead of feeling like the token minority fighting against previous stereotypes. Despite these findings, comprehensive institutions remain understudied in terms of the effect and the magnitude of the relationship of cohort size on STEM institutional outcomes.

Summary of Institutional Characteristics as Organizational Behaviors

Comprehensive institutions have been called the ‘‘workhorses of American postsecondary education’’ and/or “the backbone of higher education” (Schneider & Deane, 2015, p. 4, 28). At the same time, comprehensives receive less attention from scholars and policy makers (Henderson, 2009), these campuses play a significant role STEM pipeline issues, especially for underrepresented groups (Zumeta et al., 2012). Despite the central location in the spectrum and critical role in accomplishing the national STEM educational goals, their organizational behaviors remain understudied.

Resource Allocations

Institutional spending and performance is a crucial concern in higher education (Titus, 2017). Resources come from a number of areas through state appropriations, registration/tuition fees, alumni donations, federal funding, and other areas (Winston, 1999). With increasing accountability, institutions are required to provide transparent decision-making processes that show the return of the investment to the public (McLendon, Hearn, & Deaton, 2006). Accordingly, the strategies and decisions that shape student outcomes at the institutional level, beyond individual student characteristics and preparation, help provide fundamental justification for allocating resources to specific categories within the institution.

In higher education, resource allocation strategies reflect institutional priorities and highlight practices that accomplish goals, remove barriers, and respond to environmental pressures (Berger & Melim, 2000; Pike et al., 2006). For example, devoting more resources to instructional support indicate that teaching and learning are a priority at the institution. As accountability and transparency become entrenched in policies and practices, expenditures tighten the types of goals that institutions can prioritize expenditure patterns that favor a specific category demonstrate commitment to accomplishing the intended goal and displays organizational culture, climate, and learning (Allen, 2004; Berger & Melim, 2000). For comprehensive institutions, the resources devoted toward STEM disciplines allow the institution to secure supplemental funding through external stakeholders, while also maintaining their focus on teaching and student support (Yin, 2015). However, as institutional characteristics evolve within the spectrum of comprehensive institutions, spending patterns towards STEM fields may neglect other aspects of student support, affecting STEM student outcomes.

Resource Allocations and Graduation Rates. Upon investigation, four themes emerged from the body of research examining resource allocations and their effect on graduation rates. First, general expenditures have significant effects across different categorical funding areas both positive and negative, after accounting for the differences between institutions and student populations. Many of the effects found maintain a strong effect size when dividing the population into different ethnic subgroups (Astin, 1993; Kuh, 2007). Additionally, general institutional expenditures affect student outcomes at three separate levels: state, institutional, and student (Abington, 2014; Douglass, 2013; Zhang, 2009). The results show positive relationships for student outcomes as spending per FTE increases, across all institutional types and shows robustness across demographic groups (Ryan, 2006; Kuh et al., 2008; Kuh, 2009; Titus, 2006).

Second, research on expenditures has incorporated examinations on separate categories of resource allocations. These categories focus on a targeted mission, goal, or area within the institution (Leslie, Slaughter, Taylor, & Zhang, 2012). Separate funding categories provide a deeper understanding of institutional priorities and the effect of limited resources on student and institutional outcomes (Leslie & Brinkman, 1988; McMahon, 2009). As such, it appears that instructional and student support allocations produce positive outcomes for individual student growth (Pike et al., 2011; Toutkoushian & Smart, 2001) and institutional graduation rates (Gansemer-Topf & Schuh, 2003; Hamrick, Schuh, & Shelley, 2004). Additionally, diverting resources from academic support to student services increases graduation rates for institutions with a high Pell grant population and low-income groups (Webber & Ehrenberg, 2010). This finding coincides with the demographic studies of comprehensive institutions, which enroll over 65% of Pell grant recipients (Yin, 2015).

Third, the effects of resource allocations vary by institutional characteristics and institutional types. Gansemer-Topf and Schuh (2006) analyzed institutional selectivity, various expenditures categories, and their relationship to institutional graduation rates at private institutions. This study focused on expenditures aimed at integrating students to academic life on campus, while accounting for institutional selectivity. Although the sample is limited to private colleges, findings indicate student services resources were not significant in predicting graduation rates for low selectivity institutions, but remained significant for moderate and high selectivity institutions. These findings corroborate previous research (Abington, 2014; Hamrick et al., 2004; Hayek, 2001; Ryan, 2004), but are theoretically contradictory to the expected outcome of integrating students early and often in their academic experience (Astin, 1993; Pascarella & Terenzini, 2005; Tinto, 2012). This contradiction from between theory and practice leads to investigation on the variation in comprehensive institutions' composition the relationships between graduation rates across resource allocation types.

Fourth, research conducted on organizational culture finds resource allocation behaviors mimic the history and values of the institution (Manning, 2012). However, Ogren (2005) described comprehensive institutions' behavior as a "tail of a snake…following along tirelessly…in a rush to catch up with the head of the snake" (p. 3-4), with the head of the snake in this metaphor representing flagship institutions. Comprehensive institutions then often ignore their history and culture to remain in line with flagship institutions and building accountability pressures, while also maintaining their deep-rooted mission for teaching, learning, and connecting to the regional needs (Schneider & Deane, 2015). In this way, comprehensives must cultivate multiple goals simultaneously and rely on disruptive innovation behavior (Horn, Wise, & Armstrong, 2015). Comprehensives are forced to develop creative practices and partnerships that disrupt the status quo and create new avenues to reach students, gain prestige, develop revenue streams, and keep pace with flagship institutions (Henderson & Buchanan, 2007; Lewin & Markoff, 2013).

This type organizational behavior is clearly demonstrated in the CSU system partnership with Udacity, a private online educational company, to aid students in completing college-preparatory coursework for major requirements prior to first semester enrollment (Horn, Wise, & Armstrong, 2015). Resources allocated towards student support added staff and faculty dedicated to guiding students enrolled in the program through the beginning stages of their college career. The goal of these resources was to facilitate this partnership and assist students in enrollment, participation, and completion, thus improving their institutional performance and overall graduation rates. The results of the three-year project indicate that increased resources allocated to student services had positive outcomes for student success and higher graduation rates for subsequent cohorts (CSU, 2016).

Although turning away from traditional educational methods to prepare students for college level coursework showed positive results for students, the organizational behavior also relieves faculty of teaching college preparatory courses and provides release time to conduct their research (Horn, Wise, & Armstrong, 2015). The resources allocated show an innovative practice to prepare a significant population at comprehensive institutions (Bahr, 2008), despite also signaling mission drift towards research production and prestige (Jaquette, 2013). With diminishing state appropriations toward higher education, comprehensive institutions have begun to choose disruptive innovation behaviors in order to secure funds and continue to be efficient with public support, while continuing to enroll the majority of the undergraduate population in the U.S. (Schneider & Deane, 2015).

Summary of Resource Allocations and Graduation Rates Literature

One key issue related to graduation rates and allocation categories is the definitions used to categorize comprehensive institutions in a national set. Fryar (2015) described the consequence of researchers' choices to include or exclude different campuses as a comprehensive institution. While most studies aggregate all Carnegie Classified Master's campuses together, this practice loses variability across comprehensive institutions and thus fails to recognize the important differences between campuses that exist (Stage & Wells, 2014). The aggregated findings provide a broad picture, but ignore the specifics of institutional behavior (Doyle, 2015; Yin, 2015). Further, studies exploring this relationship have focused on using a fixed-effects and/or OLS regression. These methods provide important causal relationships for the overall umbrella of comprehensive institutions (Titus, 2017), yet misrepresent the individual behaviors and characteristics that vary between institutions (Schneider & Deane, 2015).

Further, the relationships between resource allocation categories and STEM pipeline outcomes at the student and institutional level have received little scholarly attention (Hubbard & Stage, 2010). One notable exception is the work of Webber (2012), which used student level data from the Ohio State University System, finding that instructional support predicts STEM degree attainment, with student services and other resources showing no relationship. However, this analysis only included one (or two depending on the definition) comprehensive institution(s), and thus is not representative of a wide spectrum of comprehensive institutions that funnel students through the STEM pipeline.

It is also crucial to consider the strain that the Great Recession put on budgets at comprehensive institutions and the ways campuses adapted to circumstance (Barr & Turner, 2013). This national event affected all of higher education, but the impact was not the same across institutional types. Comprehensive institutions depend on state funding, yet were forced to negotiate their culture, climate, history, and strategies to accomplish their multifaceted goals. Through a number of different organizational behaviors and strategies, comprehensive institutions changed their behaviors to accommodate restricted funding and changing views of higher education (Zumeta, 2010). Many scholars have begun to examine the consequences of the Great Recession on financial aid practices, debt for undergraduates, and rising tuition costs (Brown & Hoxby, 2014). However, the focus remains on the two ends of the higher education spectrum, research universities and community colleges, again ignoring comprehensive institutions.

Therefore, the inclusion of the Great Recession in this investigation provides another layer of impact on the STEM pipeline at comprehensive institutions.

STEM Pipeline Literature

In 2010, President Obama and many state representatives set a national goal of increasing STEM degrees awarded by 30% (NAS, 2010; NSF, 2015). In order to meet this policy goal, several accountability measures were employed to address the leaks in America's STEM pipeline (Baum et al., 2013; Bertram & Forbes, 2014; Carnevale et al., 2011; Gonzalez & Kuenzi, 2012; Xie & Killewald, 2012). Indeed, approximately 50% of students who enter college as a STEM major will switch to a non-STEM major by the end of their second year of enrollment (Chang, Cerna, Han, & Saenz, 2008; NSF, 2015). Additionally, American students entering college ranked in the bottom third among Organization for Economic Cooperation and Development (OECD) members in science and math on the Program for International Student Assessment (PISA) evaluation in 2012 (Desilver, 2015).

In addition, in 2010, a group of scholars reimagined a research agenda for the STEM pipeline in higher education, considering STEM policies, institutional contexts, and URM students (Harper & Newman, 2010). Building on previous research regarding the STEM pipeline and URM student populations, the refocused agenda accelerated scholarship on the STEM pipeline broadly with an emphasis on the experiences of URM STEM students. Scholars studying the STEM pipeline analyzed state and institutional policies targeted towards increasing STEM student outcomes.

Overall, the STEM pipeline research highlights the need to critically examine policies and practices that promote the success of STEM students and URMs STEM students individually and together as groups/cohorts of students (Chang, Sharkness, Hurtado, & Newman, 2014; Xie, Fang, & Shauman, 2015). Research generated through the critical lens proposed by Harper & Newman (2010) acknowledged many of the previous pitfalls of research on the STEM pipeline. Specifically, four umbrella areas guiding this research and analysis of the pertinent literature regarding the students and institutions feeding the STEM pipeline:

1. Factors that promote individual STEM degree attainment;
2. URM student success in STEM, including experiences and interactions with faculty and students
3. Contextual factors at institutions related to STEM success; and
4. Institutional interventions aimed at removing STEM barriers.

Although these categories do not encompass an exhaustive list of issues within the STEM pipeline, extant literature indicates these are the most important aspects of the STEM pipeline that are directly related to comprehensive institutional context and their role in producing STEM degrees.

Factors promoting individual STEM Degree Attainment

Individual characteristics and pre-college preparation are the strongest factors that predict STEM degree attainment and capture the broadest results that are generalizable to the greater undergraduate population (Chen & Solder, 2013). Scholars have focused on key individual characteristics of STEM students, including gender, ethnicity, and students' previous experiences in STEM coursework (Eagan, Hurtado, & Chang, 2010). Studies find pre-college preparation in high school significantly predicts both STEM college persistence and degree attainment (Chang et al., 2014; Museus, Palmer, Davis, & Maramba, 2011; Villarejo, Barlow, Kogan, Veazey, & Sweeney, 2008). In particular, a strong high school curriculum, completing advanced placement courses, and earning high grades in high school play essential roles in the successful completion of a STEM degree (Tyson, Lee, Borman, Hanson, 2007). Further, rigorous STEM courses prior to college enrollment contribute to the development of the skills and aspirations to continue in STEM coursework (Tsui, 2007).

Indirect pathways to a STEM degree have also been considered (Museus et al., 2011). Using path analysis, research follows the development of STEM proficiencies and college preparation that are expected to lead to STEM degree attainment (National Academy of Engineering [NAE], 2005; NAS, 2007; President's Council of Advisors on Science and Technology [PCAST], 2012). Specifically, scholars examined course-taking patterns from high school through post-secondary education (Chang et al., 2014; Myers & Pavel, 2011; Tyson et al, 2007), transcript and GPA analysis in STEM coursework (Crisp, Nora, & Taggart, 2009; Ma, 2011), and the various pathways students take (instead of a pipeline metaphor) to obtain a STEM degree (Cannady et al., 2014). The findings from these studies recalibrated the understanding of individual characteristics as less static and more dynamic that the institution has a role in developing.

Underrepresented Minority Students (URMs) STEM Success

As the research on the STEM pipeline has expanded to recognize differences in individual developmental aspects, URM disparities in persistence and baccalaureate degree attainment were brought into the national spotlight (NSF, 2015). As previously noted, studies have highlighted the increasing numbers of STEM degrees awarded nationally. In 2014, the total amount of STEM degrees awarded in the U.S. was 603,992, marking a 31% increase from Fall 2008 to Spring 2014 (Cannady et al., 2014; NCES, 2015). A first glance, it appears as though the STEM pipeline in higher education improved. However, the share of STEM degrees awarded to URM students has not risen at or near the same rate that enrollment and significant gaps between ethnic populations remain consistent in attainment and success rates (NCES, 2015; NSF, 2015; Xie, Fang, & Shauman, 2015).

An examination of URM student populations shows that in 2014, Black students received only 7.2% of STEM degrees awarded that year (NCES, 2015). STEM degrees awarded to Latinx students increased by 77% from 2008 to 2014. However, this population only comprised 9.5% of STEM degrees awarded in 2014 and less than 5% of those degrees were in the physical sciences and mathematics (NSF, 2015). Additionally, Latinx students represent 37% of the undergraduate population in California, yet received less than 20% of the STEM degrees (NCES, 2015).

Another URM group oversimplified in the STEM pipeline literature is Asian American and Pacific Islander (AAPI) students. This racial group comprises over 40 different ethnic populations, yet often research aggregate AAPI students together to highlight successful STEM outcomes or positions AAPI students in a black-white racial framework (Museus et al., 2011; Teranishi, 2007). This argument depicts AAPI students as a homogenous group that represent the “model minority” or does not consider a minority group at all (Museus et al., 2015; Takagi, 1992). Although Southeast Asian students, comprised of Cambodian, Hmong, Laotian, and Vietnamese ethic groups, are more likely to enroll at a comprehensive institution than white students are, they attain STEM degrees at lower rates than Latinx students (Ngo & Lee, 2007). Yet, literature on this population receives less attention with regard to STEM pipeline issues. Consequently, it is essential that efforts are made to understand and remove barriers within the STEM pipeline.

The dynamic conceptualization of individual characteristics encouraged scholars to examine equity issues and key barriers unique to URMs in the STEM pipeline. This developed psychological factors that influence students’ academic grit, self-efficacy, sense of belonging on campus or within their major, and STEM aspirations (Harris & Newman, 2010). Academic grit and self-efficacy show a strong relationship to building a welcoming climate in STEM (Strayhorn, 2013a). This fosters community bonds within STEM disciplines and creates a family-like atmosphere with which URMs can identify (Museus et al., 2015; Strayhorn, 2014). Additionally, these bonds develop students’ sense of belonging and provide students with the knowledge that they have faculty and peer support in their STEM coursework and experiences (Hurtado et al., 2011). Sense of belonging leads to higher STEM aspirations and solidifies their goals throughout their academic career (Eagan et al., 2011).

At college entry, URM students show equal levels of STEM degree aspirations and self-efficacy as other student groups (Trujillo & Tanner, 2014; Wang, 2013). However, after experiencing negative experiences and “chilly” climates, students divert away from STEM, with URM students most likely to be advised into a non-STEM major (Cole & Espinoza, 2008). Though it may be difficult to reverse these experiences for students, campuses must recognize the importance of these factors in persisting beyond gateway courses and progressing through barriers in the STEM pipeline (Daempfle, 2002; Hutchinson, Follman, Sumpter, & Bodner, 2006; Hutchinson-Green, Follman, & Bodner, 2008; Maltese & Tai, 2010). These factors are integral for URM students to obtain a STEM degree and show disparities in their development in STEM experiences (Crisp et al., 2009; Eagan et al., 2011). As a result, it behooves universities and colleges to address the obstacles faced by URM students and work to offer equal opportunities and support for all students.

One type of barrier obstructing URM student pathways down the STEM pipeline is financial limitations. Although financial barriers impact all STEM students, URM students have shown higher rates than non-URMs of working part-time in order to pay for tuition costs and provide support their families (Chen, 2013). This practice depletes the additional time and energy needed to complete scientific laboratory and experimental assignments that are not normally required of non-STEM majors (Crisp et al., 2009). URM students are also more likely to commute to campus, provide childcare for children/siblings, and spending time with older family members, all of which t siphon time away from studying and laboratory skills development (Cole & Espinoza, 2008;

Nora, 2003). Given the extensive time needed to spend on STEM projects and developing skills, these challenges often push URM students to leave STEM majors in higher numbers than non-URM students (Blickenstaff, 2005; Espinosa, 2011).

Institutional Contextual Factors for STEM Success

Research within the STEM pipeline literature has connected institutional characteristics and/or the type of institution to STEM degree attainment (Greene, DeStefano, Burgon, & Hall, 2006; Griffith, 2010; Kanny, Sax, & Riggers-Piehl, 2014). These studies show a strong positive relationship between the type of institution students attend and their likelihood of obtaining a STEM degree (Chang et al., 2008). Findings suggest selectivity, size of the institution, and peer characteristics/quality have significant positive relationships in predicting STEM degree completion (Hurtado et al, 2010; Seymour & Hewitt, 1997; Strayhorn, 2013), following similar findings from overall graduation rates and institutional characteristics.

However, institutional contexts have an important role in influencing the factors that promote STEM success (Nunez & Elizondo, 2012; Crisp et al., 2009; Griffin, Perez, Holmes, & Mayo, 2010; Stage, Lundy-Wagner, & John, 2013). Perna et al. (2010) found institutional activities and interventions contributed to success in obtaining STEM bachelor degrees by URM women. Specifically, university and college behaviors can mitigate the negative effects of institutional barriers. Through positive educational experiences and engagement in smaller class sizes, students found role models and supportive faculty in STEM. These types of institutional policies and actions create supportive scientific experiences, leading to a stronger scientific identity for URM STEM students, which is critical for the STEM success of URM students (Ceci, Ginther & Khan, 2014; Herrera & Hurtado, 2011).

These findings parallel similar results at HSIs and AANIPISI campuses. HSIs and AANIPISIs have created curriculum to engage students in practical STEM coursework. The revised curriculum transforms theories and concepts into tangible knowledge and real-life applications (Allen-Ramdial & Campbell, 2014). This type of curriculum has advanced self-efficacy and STEM degree aspirations, leading to higher rates of STEM degree competition (Chang, 2014; Crisp et al., 2009). Although the history and development of HBCUs are different than HSIs and AANIPISIs, these findings guide successful practices and interventions at MSI campuses.

Institutional Interventions for STEM. Building from these findings, policy makers and administrators have developed STEM interventions and policies that aim to close equity gaps between student ethnic groups. Basic institutional actions rely on creating spaces and programs that require little time and funding (Manning, 2012). For example, many comprehensive institutions have actively provided spaces for commuting students to study on campus, as a large proportion of their student body drives in from the surrounding areas and do not reside on campus (PCAST, 2012; Tinto, 2012). Many of these spaces require little resources to build/upgrade, while being unsupervised during office hours without the need for additional staff to manage. This leads to students to remain on campus and participate in STEM events and workshops that further increase positive STEM experiences and a higher self-efficacy within their major (Crisp et al., 2009; Dagley, Georgiopoulos, Reece, & Young, 2016; Hurtado et al., 2009).

More disruptive institutional actions require broader investment from administration, faculty, staff, and external constituencies, an evinced by federally sponsored training STEM programs (NIH, 2015; NSF, 2015). Often found at HSIs and AANIPISIs, students participate in undergraduate research experiences (URE) aimed at integrating advising services, faculty research, and professional development experiences. These experiences are tied to student stipends and STEM degree attainment (Laursen, Hunter, Seymour, Thiry, & Melton, 2010). UREs teach STEM research skills and provide an active learning environment outside of traditional large lectures. Multiple studies have found that URE participants have positive effects on persistence for STEM students (Watkins & Mazur, 2013), particularly for URMs (Hurtado et al., 2009). Lopatto (2007) argues that for URM students in STEM, UREs not only promote interest in STEM careers but also provide financial support that allows them to maintain consistent full-time enrollment and additional advising through formal and informal support. UREs embody institutional action for broadening the STEM pipeline and reshape institutional culture to incorporate positive interactions with STEM students (Eagan et al., 2010; Hunter et al., 2007).

More broadly, UREs can have significant campus-wide and regional impact. One important feature of UREs is the integration of URM and non-URM students in STEM experiences. These interactions create networks of positive cross-racial cooperation in STEM fields, also developing URMs' sense of belonging within STEM and their campus (Brown, Henderson, Gray, Donovan, & Sullivan, 2013; Hathaway, Nagda, & Gregerman, 2002; Hunter, Laursen, Seymour, 2007). Additionally, faculty benefit from UREs by gaining awareness of barriers URM students face in the STEM pipeline that faculty may not have experienced or been aware of during their educational process (Schultz et al., 2011; Wilson et al., 2012). This changes faculty perceptions of equity-focused policies and encourages the development of supportive behavior toward URM advisees. Another important aspect is many UREs require partner institutions, where students and faculty meet across institutions within the same region to collaborate with experimental and social events. Together, these UREs training grants can help the STEM pipeline become more effective.

Summary of STEM Pipeline Issues

It is clear that the STEM pipeline has received significant attention with regard to student and institutional success. Students, faculty, and staff all require an investment of resources to be successful within the STEM pipeline. Similar to the resource allocation literature, an important gap persists regarding comprehensive institutions. Specifically understanding the effect of their STEM practices and policies on STEM graduation rates. Studies including comprehensive institutions continue to assume these campuses are monolithic in their approach to the STEM pipeline, yet many of these institutions continue to adopt innovative behaviors to advance their STEM performance (Horn, Weise, Armstrong, 2015).

Further, there is a clear need to analyze the broader impacts of organizational behavior. STEM pipeline research builds a wealth of knowledge on individual students and their outcomes or broad STEM degree completions across states (NSF, 2015). However, institutional level behaviors are neglected throughout the STEM literature

(Hurtado et al., 2010). Although students participating in federally funded UREs show higher levels of success across individual markers, are graduation rates at institutions increasing due to the impact of these practices and funding support? Are these federal dollars expanding the pipeline beyond their participants as the grant administrators suggest? Additionally, as previously stated, comprehensive institutions comprise the majority of STEM and URM STEM degree aspirants, yet remain understudied.

Contribution to Literature

Gaps in the research highlight two important contributions the current study makes to the literature - that is, it addresses the effect of resource allocations at comprehensive institutions on STEM graduation rates and the effect of URM STEM pipeline behaviors on URM graduation rates. It follows then that this study aims to examine the effect of resource allocation behaviors and the impact of the Great Recession at comprehensive institutions on STEM six-year graduation rates. Specifically, the current analysis seeks to answer two overarching research questions:

Primary Research Questions:

- ✓ To what extent did the Great Recession have an impact on STEM graduation rates at comprehensive institutions?
- ✓ To what extent are URM STEM graduation rates and various forms of resource allocations associated with STEM graduation rates at comprehensive institutions?

The CSU system represents a broad spectrum of comprehensive institutions. Many of the characteristics found in CSU institutions mimic those found in public comprehensive institutions across the U.S. These institutions cover wide variations in services, priorities, and policies similar to many public comprehensive institutions in the U.S. This investigation draws on previous research to guide analyses of the implications of institutional resource allocation strategies and uncover potential relationships unique to comprehensive institutions. Accordingly, this investigation seeks to expand three topics in the literature: (1) the relationship between organizational behavior and institutional level STEM outcomes, (2) overall and URM student success at comprehensive institutions, and (3) the role of comprehensive institutions in the STEM pipeline. While there is a considerable amount of research and literature on institutional characteristics on student outcomes, there is a general gap in understanding of how the organizational behaviors at comprehensive institutions shape the STEM pipeline. Such an understanding is essential to an informed policy discussion regarding institutional characteristics and STEM student outcomes.

The Complexity of the Pipeline

Although the analogy of a pipeline for STEM students highlights a direct pathway, this is far from a perfect description. There are layers of complexity within the STEM pipeline that accelerate and slow students from reaching the end of the STEM pipeline (see Figure 2.3), which in this case defined as earning a STEM degree. However, the pipeline analogy does match an important characteristic of a closed system. Studies find that due to the rigorous and sequential coursework for STEM degree requirements, students rarely enter college in non-STEM majors and eventually switch into STEM majors (Chen & Soldner, 2013; Chen & Weko, 2009; Maltese & Tai, 2011;

Wang, 2013). Therefore, it is important to understand the important relationships within the STEM pipeline and the types of mechanisms that offer students higher chances of going from college freshman to STEM graduation.

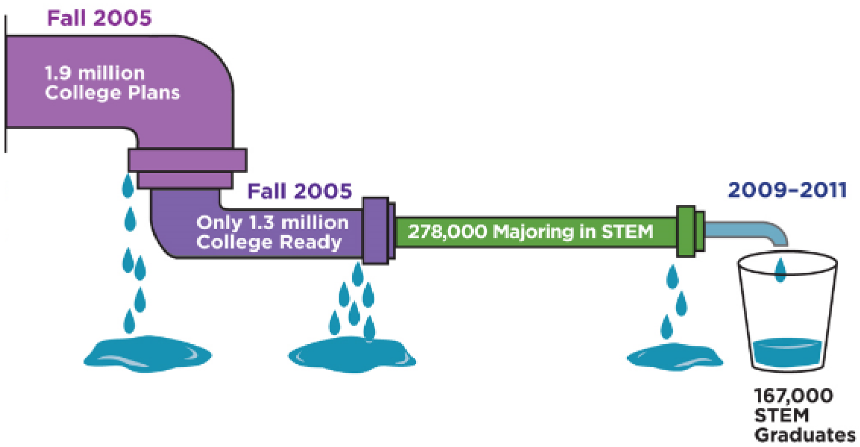

Figure 2.1.

The STEM pipeline from Fall 2005 to Spring 2011. Reprinted from "Rising Above the Gathers Storm, Revisited" by National Academy of Sciences.

Figure 2.1 provides a visual representation of the STEM pipeline in the U.S. from 2005 to 2011. It illustrates the specific holes where students fall out of the STEM system; the drips of water are groups of students lost through holes/joints in the pipeline (An alternative image in Figure B.1 in Appendix B shows the rates from the class of 2005 to STEM graduates in 2011). Pipe patches represent the priorities of institutions to cover these holes and keep students moving along the pipeline. The narrowing shapes of the pipeline represent different challenges for STEM students as well as the smaller cohort that remains moving forward. This highlights practices and priorities that target URM populations are, not only good for the specific population, but also for the overall STEM pipeline success.

The convergence of financial constraints and an increased focus on student outcomes has forced colleges and universities to re-evaluate how they allocate resources. With limited resources, administrators must determine the most effective resource allocation strategies to ensure a strong learning environment for students at their campus. There does appear to be a relationship between institutional expenditures and graduation rates. However, current research falls short of providing a comprehensive link between spending strategies and STEM graduation rates for comprehensive universities.

CHAPTER 3

Methodology

This investigation analyzes priorities in resource allocation strategies and the relationship with an institution's Science, Technology, Engineering and Mathematics (STEM) outcomes. To do so, a multilevel growth model (MLGM) is utilized to examine the relationship between institutional resource allocations and STEM graduation rates at California (CA) State Universities (CSU). Although there is scarce research directed towards comprehensive institutions, the overarching STEM pipeline literature was used to guide variables selection (Henderson, 2009; Fryar, 2015). Additionally, more detailed relationships will be explored that focus on support for STEM students and specifically for URM students at comprehensive institutions.

This chapter begins with a presentation of the overarching research question and specific sub-questions that will guide the investigation. This section describes characteristics of the sample, discusses the measures used, and outlines the timeframe of the investigation. Next, the analytic strategy is presented including a description of the models adopted, followed by a brief discussion of the limitations of this investigation. In the concluding section, the advantages of the MLGM used in this investigation are presented and are considered against other comparison models.

Research Questions

Although the introduction proposed one overarching research question, there are important secondary questions that target specific aspects of resource allocations in the

STEM pipeline and use the Great Recession to understand changing organizational behaviors. To reiterate, the primary research question is as follows:

Primary Research Questions:

- ✓ To what extent did the Great Recession have an impact on STEM graduation rates at comprehensive institutions?
- ✓ To what extent are URM STEM graduation rates and various forms of resource allocations associated with STEM graduation rates at comprehensive institutions?

The sub-questions explore different categories of resource allocations and their relationships with STEM graduation rates overall and for URM STEM students. Categories of resource allocations selected for analysis in this investigation are based on previous literature and conceptual frameworks in higher education, student services, and STEM pipeline studies. The variables are described in detail after the data sources and management are explained.

1. To what extent were there institutional differences in the rates of change for six-year STEM graduation rates between 2006 and 2016 at CSU campuses?
2. To what extent did STEM GRs differ before and after the Great Recession?
3. To what extent were black, Latinx, and Southeast Asian STEM GRs related to overall STEM GRs at CSU campuses?
4. Is there a relationship between resource allocations (Student Services, Instructional Support, and NIH/NSF Grants) and STEM GRs at CSU campuses and accounting for the Great Recession?

5. After controlling for institutional characteristics and accounting for the Great Recession, did the relationship between resource allocations and STEM graduation rates change between 2006 and 2016 at CSU campuses?
6. To what extent were the relationships between URM STEM graduation rates and resource allocation strategies different, after controlling for institutional characteristics and accounting for the Great Recession between 2006 and 2016 at CSU campuses?

Conceptual Framework

Drawing from organizational theory (Figure 3.1), Berger and Milem's (2000) organizational impact model (OIM) blends aspects of organization theory in higher education with other student frameworks. The OIM model draws on organizational behavior theory (Birnbaum, 1991; Bolman & Deal, 2008), peer group effects and peer climate (Astin, 1993), and student involvement theory (Pascarella & Terenzini, 2005; Tinto, 2012).

Fundamentally, their model posits organizational and student characteristics affect student outcomes both individually and institutionally. Their framework takes a comprehensive approach to connect institutional and student characteristics to examine student outcomes. The OIM sets the foundation for the conceptual framework used in this investigation, using two dimensions that separate institutional level characteristics from organizational behaviors. However, a more parsimonious model is proposed in the next section to target specific relationships in the STEM pipeline and weaving in CRP-Ed tenants.

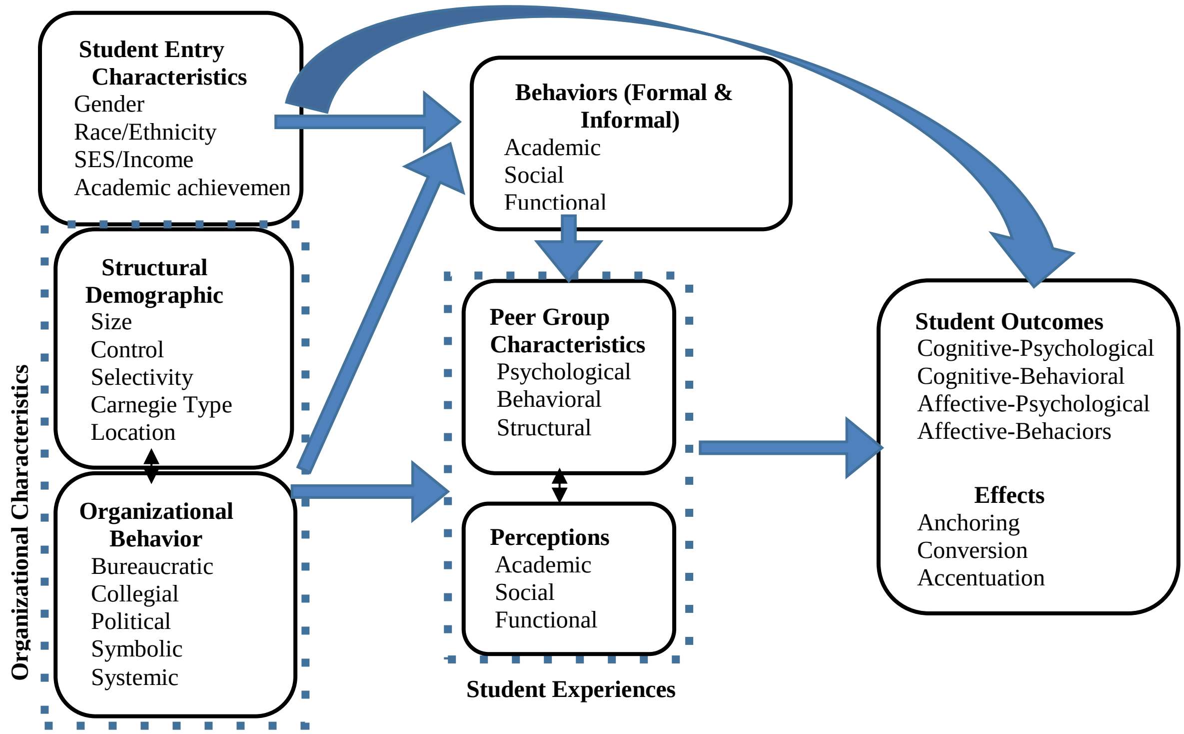

Figure 3.1.

Organization impact model diagram (Berger & Milem, 2000, p. 308)*

**Note*. From "Organizational Impact Model in Higher Education and Student Outcomes," by J. Berger and J. Milem, 2000, H*igher Education: Handbook of Theory and Research (15, p. 308)* Copyright 2000 by New York, NY: Agathon. Reprinted with permission.

Modified Organizational Impact Model

Previous literature using the OIM model focused on individual student outcomes, (e.g. students' STEM career interest and retention toward STEM degree attainment) (Reason, 2009). Applying this model to STEM institutional outcomes would tie together the STEM pipeline and organizational behaviors literature as well as expand the research on institutional outcomes for STEM students. Both literature bases have overlapping issues, findings, and perspectives that point to institutional outcomes as a possible avenue for analysis (Hurtado et al., 2010). In the modified OIM model (shown in Figure 3.2), the goal is to create a model to examine direct relationships of organizational behaviors and STEM graduation rates.

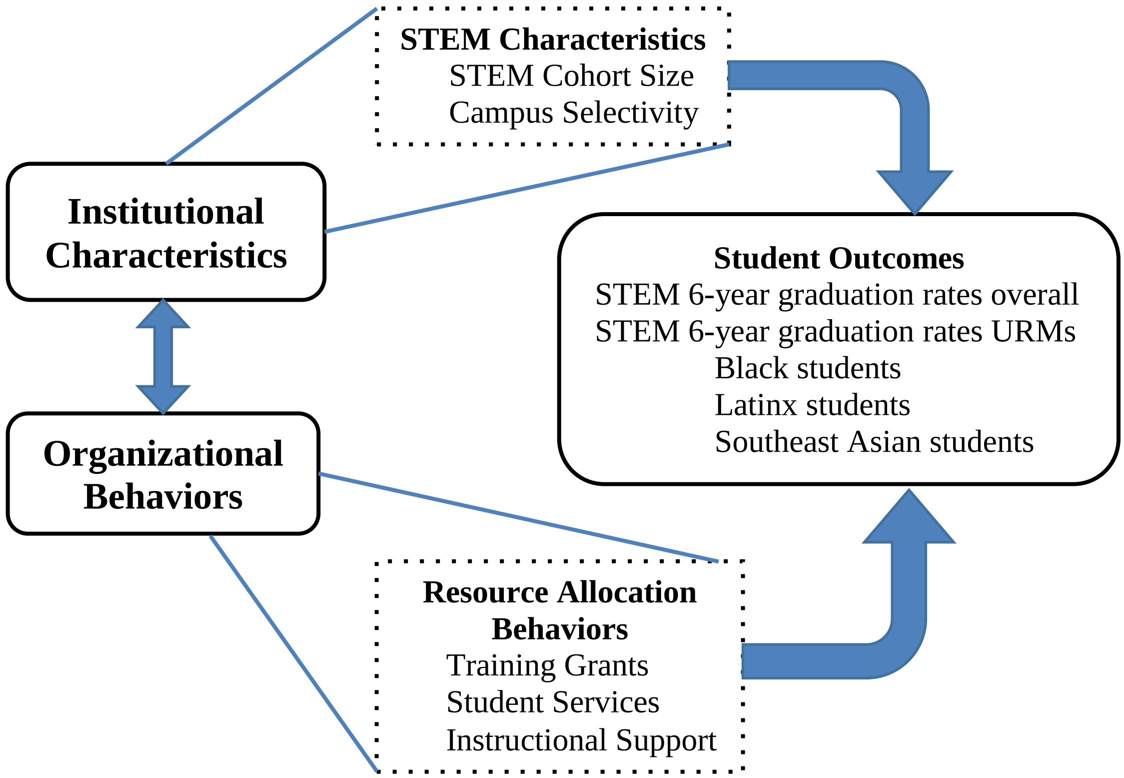

Figure 3.2.

Modified OIM Model Diagram

Institutional characteristics represent the structural-demographic frame. The framework narrows the type of characteristics to the STEM cohort size and campus selectivity. In the previous model, the location and Carnegie Classification type were included; however, this sample restricts the selected institutions to the California State University (CSU) system. These institutions are all considered comprehensive institutions, governed by one overarching affiliation. The advantage of limiting the sample to CSU system leverages the differences between related institutions that broadly cover the middle of the California higher education spectrum.

The OIM framework includes a wide range of organizational behaviors, resource allocations that represent the broad culture, the changing campus climate, and organizational learning through new practices implemented. This provides an avenue to assess organizational behaviors in the CSU system and their effect on impacts on the STEM pipeline.

CRP-Ed pushes this investigation further against previous literature and policies in two unique ways. First, while most studies situate predominantly white institutions as the reference group, this investigation highlights the diversity among comprehensive institutions. This captures the differences between institutions as well as understanding the unique behaviors within institutions. Second, despite previous research identifying disparities that are masked by aggregating Asian American students as one homogenous group, many STEM pipeline studies have continued to use this practice. The CSU enrolls a significant number of Southeast Asian (SEA) students, with a sizeable portion enrolled in STEM majors across campuses (CSU, 2016). Adding this group to the analysis, the current study addresses the impact of on a growing population within STEM that has been otherwise overlooked and provides a broader representation of STEM students.

Sample

The CSU system serves as the population from which the sample will be drawn for purposes of this investigation. The sample includes a set of 23 comprehensive colleges and universities that are located across the state of California. The CSU system's mission seeks out students with collegiate potential who face cultural, financial, or broad personal barriers, while providing high-quality instructional and scholarly support to develop career aspirations (CSU, 2016). It is a diverse set of campuses that vary across institutional and student characteristics, as well as research and grant production, and resource expenditures per full-time enrolled students (FTE), among other characteristics (CSU, 2015). Some CSU campuses are categorized as doctoral institutions with a high level of selectivity, similar to research-focused universities and colleges (e.g. University of California [UC]). Other campuses enroll large numbers of students that require developmental writing and mathematics education, representing characteristics similar to community college campuses.

This dataset includes 22 out of the 23 CSU campuses. The CSU Maritime Academy is removed from this analysis as it functions similar to a military academy, which fundamentally differs from a traditional comprehensive campus experience. Thus, the study is left with a remaining sample of 22 campuses (see Table A.1 and Figure A.3 in Appendix A). One key advantage of the CSU system is the diversity among the campuses. The system covers a broad range of institutional characteristics and behaviors within the comprehensive institution segment and each campus develops, facilitates, and administrates their budget, policies, and community outreach. Therefore, this dataset provides a unique reference point in order to connect resource allocations to institutional STEM outcomes at comprehensive institutions, both overall and for URMs that also acknowledges the differences among these institutions.

Additionally, this dataset captures recent allocation strategies from the CSU as points of emphasis. For example, since 2010 the CSU devoted over ten million dollars to support STEM initiatives at each campus as well as developing K-12 partnerships with community school districts (Arcidiacono et al., 2016). Much of this funding and priority shifts occurred before, during, and after the Great Recession in 2008 where the CSU system was forced to reprioritized resource allocations to better align with the "new normal" of budgets (Barr & Turner, 2013). Including priority shifts and campus initiatives for STEM education, this dataset provides a new lens to view resource allocations at comprehensive institutions.

Lastly, the demographic population in CA already reflects the demographic shift projected to occur throughout the U.S., standing as one of four majority minority states, along with Hawaii, New Mexico, and Texas (Census, 2015). For many scholars addressing the effects of the STEM crisis, this demographic shift (as well as the adjustments made from the Great Recession) is the key to the development of future STEM workers and future economic prosperity in the U.S. (Alfred et al., 2005; Hurtado et al., 2009; NSF, 2015). Therefore, the CSU system provides an important example of comprehensive institutions and how their resource allocation strategies relate to institutional STEM outcomes.

Data Sources and Management

This study utilizes quantitative data from public access national datasets and state-level research centers. Raw data was downloaded in STATA format or converted into STATA format. The following three data sources combined to create a master dataset for analysis: (1) Consortium for Student Retention Data Exchange; (2) Delta Cost Project; and (3) National Science Foundation and National Institutions of Health. All data sources provide campus-level information that is each a campus-level characteristic or an aggregated mean from student level data provided by one of the data sources. Institutions are matched using institutional identifiers from IPEDS that allow combining variables to match across campuses as well as over time, providing a unique opportunity to tie organizational behavior to institutional STEM outcomes over time.

First, the CSU maintains a database that provides detailed data in their CSU STEM Graduation Rates; Consortium for Student Retention Data Exchange (CSRDE). The CSRDE is a collection of institutional research directors and faculty from about 400 campuses that compile retention and graduation rates for a number of different student populations. Data are available on the website and aggregate the data into the publically available set used in this investigation (http://asd.calstate.edu/csrde/index.shtml).

The principal purpose of the CSU participating in the CSRDE is to provide the public with information on each campus' ability to graduate students in a timely fashion. Although mainly a tool for quick non-research assessments, the data provides a window into campus-level outcomes. CSRDE began collecting data for the CSU starting in 1990 and continues collection for all CSU campuses at the institutional level. The CSRDE calculates this measurement in conjunction with another national survey as part of their STEM report that is released annually to the public. In 2010, the CSU system adjusted their major labels to match national NSF data dating back to 2000. Additionally, other large public datasets can be paired with CSRDE for statistical modeling.

Second, data was collected from the National Center for Education Statistics (NCES) Integrated Postsecondary Education Data System (IPEDS) Delta Cost Project (DCP). IPEDS is a system of interrelated surveys conducted annually by NCES that gathers information from every college, university, and technical and vocational institution that participates in federal student financial aid programs; a more detailed description of the DCP data is presented in the next section. Institutions that receive federal funding are required to report data on student and faculty/staff outcomes, finances and expenditures, and other institutional characteristics. Although the IPEDS data includes over 7,500 institutions, this investigation will utilize the detailed data provided for the 22 CSU campuses in the sample.

Within the IPEDS framework, the DCP is an independent, non-profit organization whose mission aims to improve cost management within higher education and documents trends in institutional spending. The organization translated technical accounting information from the IPEDS into spending and revenues by full-time equivalent (FTE) student. The longitudinal nature of this database allows examination of changes in institutional behavior over time that is specific to this investigation. Campuses that participate in data collection from IPEDS provide information on the variables included in this dataset.

Although the DCP dataset provides data from 1987-2013, data from 2013-2016 was retrieved from the individual CSU campuses public financial forums, published as part of the CSU accountability report. As part of accountability policies set by the CSU system, each campus maintains reporting of DCP categories on publicly available campus websites (CSU, 2016). Again, only information regarding CSU campuses from 2000 to 2016 is included for this study. Data include institutional characteristics, institutional finances and categorical resource allocations, enrollment for full- and part-time students, student financial aid, completions, staffing salaries, and student unduplicated-headcounts.

Third, this study collected data from the National Science Foundation (NSF) WebCaspar System and National Institutes of Health (NIH) RePORTER. These publically available datasets both provide institutional level data in year-by-year federal allocations to individual campuses, including awards related to student training programs (i.e. Maximizing Access to Research Careers). Specifically, the NSF Survey of Federal Science and Engineering Support to Universities, Colleges, and Nonprofit Institutions and the NIH RePORTER, federal training grants provide data on STEM training grants, research training & activities, and grants/scholarships for STEM training programs.

These data were matched using the IPEDS institutional identifiers and specific academic years (AY) across the investigation time-period: AY2000 thru AY2016. AYs 2000-2003 are included from DCP and NSF/NIH in this dataset in order to create variables and averages for individual campus-level spending patterns. Additionally, the NSF produces an annual report describing the state of the STEM pipeline and uses a consistent definition for the majors that were included in STEM graduation rates.

Variables and Analytical Steps

Variables included in the model were chosen based on the conceptual framework, prior empirical research, and the objectives of this investigation. All dollar values will be CPI-adjusted to 2016 and expressed as per full-time equivalent student unless noted otherwise. Data grooming, missing data imputation, checking of statistical assumptions of the MLGM, descriptive statistics, and testing for mean differences will be conducted using STATA version 14. Lastly, all modeling and statistical procedures will be conducted using the same STATA platform (Statacorp, 2015a). Table 3.1 outlines the dependent and independent variables used in this investigation. The table provides the theoretical perspective associated as well as the research question(s) aimed at answering.

Table 3.1.

Variable Outline and Research Questions

Variable Name	Theoretical Connection	Research Question
Dependent Variable		
STEM Graduation Rate	STEM Pipeline Impact; Organizational Behaviors	Were there differences in the change for six-year STEM graduation rates at CSUS?
Ethnic Graduation Rates		
Black	CRP-Ed; URM STEM Success	Were there differences in the change for STEM graduation rates for URM students?
Latinx	CRP-Ed; URM STEM Success; HSIs*	
Southeast Asian	CRP-Ed; URM STEM Success; AANIPISIs*	Did URM STEM rates differ during this timeframe?
Resource Allocations		
Instructional Support	Organizational Behaviors	Is there a relationship between resource allocations and STEM graduation rates?
Student Services	Organizational Behaviors	
Federal Training Grants	Organizational Behaviors; CRP-Ed	
Institutional Characteristics		
Selectivity	Control Variables	
STEM Cohort Size	Control Variables	

*There are no HBCUs in the CSU and are not examined in this investigation.

All dollar values will be CPI-adjusted to 2016 and expressed as per full-time equivalent student unless noted otherwise. Data grooming, missing data imputation, checking of statistical assumptions of the MLGM, descriptive statistics, and testing for mean differences will be conducted using STATA version 14. Lastly, all modeling and statistical procedures will be conducted using the same STATA platform (Statacorp, 2015a). Table 3.1 outlines the dependent and independent variables used in this investigation. The table provides the theoretical perspective associated as well as the research question(s) aimed at answering.

Dependent Variables

This study utilizes two dependent variable from the CSU-CSRDE dataset – STEM six-year graduation rates and URM STEM six-year graduation rates. The dependent variables represents the percentage of the total number of first-time, full-time declared STEM majors at initial enrollment (referred to as: graduation cohort), against the total number of that entry cohort (total number of students that enrolled in a STEM major six years earlier) graduating in four, five, and six years with a STEM degree by the spring semester of that AY. Thus, this variable serves to measure institutional success in graduating students along the STEM pipeline after six years of enrollment within STEM majors (CSU-CSRDE, 2016).

Additionally, the dependent variables will be transformed into a logit function. The logit transformation is the log of the odds ratio, meaning, the log of the proportion divided by one minus the proportion -- $p/(1 - p)$. Conducting this transformation, this technique allows data that are proportions (between 0 and 1) to be modeled in longitudinal data (Rabe-Hesketh & Skrondal, 2008; Singer & Willett, 2003). After the transformation, very small and very large values are treated symmetrically, extending the tails outward and compressing the middle around 0.5 or 50% (Acock, 2008; Hosmer, Lemeshow, Sturdivant, 2013). The plot of p against logit-p shows a flattened S-shape (See Figure 3.1).

There are three main advantages of using this transformation: (1) it is robust and protects against possible violations in the data; (2) the dependent variable and error terms are not required to have equal variances for each group; (3) the terms and coefficients can be reverse transformed in order to provide a working interpretation for the results (Heck, Thomas, Tabata, 2014; Rabe-Hesketh & Skrondal, 2008). Once the dependent variable is transformed, it is treated as a continuous variable for the log odds of STEM six-year graduation rates and URM STEM six-year graduation rates at CSU campuses.

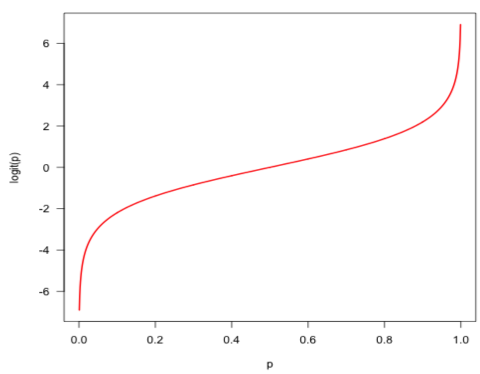

Figure 3.1.

Example of Logit function p v. Logit-p.

STEM graduation rates. Prior to describing STEM graduation rates (GR) for the STEM population, a description of general graduation rates needs to be defined. GRs are a cohort-based measure that tracks the percentage of first-time, full-time freshmen that graduate within four-, five-, or six-years. These include all majors and degree programs during enrollment, allowing for students to switch majors during enrollment. Students that change majors, but obtain a degree are included in the measurement. GRs are calculated by IPEDS and derived for each individual institution. The six-year marker is considered 150% time, as compared to the expected graduation time to degree of four-years after initial enrollment (NCES, 2016). For federal financial aid participating institutions, the GR survey collected by IPEDS is required annually. IPEDS provides the criteria to each institution to establish their initial cohort, pinpoint exclusions from the initial cohort, and calculate four, five, and six-year GR for cohorts. Lastly, the six-year GR includes students that graduated in four and five years.

Specifically, STEM GRs are limited to majors within the NSF defined disciplines (NSF, 2015). Therefore, six-year STEM GRs are more restrictive than overall GRs and give STEM policy more targeted feedback on institutional performance. First, only NSF defined majors are included: Agricultural Sciences, Chemistry, Computer Science, Engineering, Environmental Science, Geosciences, Life Sciences, Mathematics, and Physics/Astronomy (NSF, 2015). Second, students cannot switch to another major outside of these STEM disciplines to be considered for this metric. Students that switch majors are considered in a different graduation rate.

However, STEM students can switch within the STEM fields (listed above), graduate with a degree, and still be included for this measurement. This makes this measurement highly restrictive to STEM fields and shows an institution's success specifically for the STEM pipeline. For this investigation, the STEM GRs are obtained for each individual CSU campus for AY 2006 to AY 2016 from the CSU-CSRDE database. For example, the entry cohort of AY 2006 is the graduation cohort of AY 2012. This dependent variable continues the prior work on STEM pipeline issues and the institutional role in encouraging STEM students to graduate (Gayles & Ampaw, 2014; Hurtado, Egan, & Chang, 2010; Strayhorn, 2013; Toven-Lindsey, 2015; Whalen & Shelley, 2010). Table 3.2 shows CSU campus STEM six-GR averages and the ranges between AY 2006 to AY 2016.

Table 3.2.

CSU Campus STEM GR Rates AY2006-AY2016 (N=22 campuses)

Campus	***STEM 6-year Grad Rate***		
	10yr Ave	Hi	Lo
Bakersfield	18.29%	26.40%	12.60%
Channel Islands	38.21%	48.10%	31.30%
Chico	33.41%	43.80%	21.30%
Dominguez Hills	8.46%	14.60%	3.10%
East Bay	20.20%	32.10%	15.20%
Fresno	23.74%	32.70%	19.10%
Fullerton	20.20%	29.40%	15.90%
Humboldt	26.90%	35.70%	22.50%
Long Beach	26.35%	38.60%	14.30%
Los Angeles	19.00%	35.40%	11.90%
Monterey Bay	24.83%	40.10%	15.80%
Northridge	21.19%	25.20%	16.20%
Pomona	34.99%	51.70%	27.30%
Sacramento	16.57%	21.80%	12.80%
San Bernardino	18.62%	29.30%	11.10%
San Diego	33.25%	46.50%	23.40%
San Francisco	19.56%	30.10%	10.70%
San Jose	22.74%	33.10%	15.70%
San Luis Obispo	56.15%	65.80%	47.30%
San Marcos	10.53%	19.20%	4.10%
Sonoma	27.68%	36.70%	17.60%
Stanislaus	25.75%	32.10%	19.80%
System (All Campuses)	**31.17%**	**38.90%**	**25.00%**

URM STEM graduation rates. Similar to the overall STEM graduation rates described above, URM student graduation rates are a cohort based measurement that tracks the percentage of first-time, full-time freshmen that graduate six-years after enrollment in a STEM major. However, this measurement only includes URM student populations. The URM populations included in this investigation are the traditional racial/ethnic categories identified by the NSF. Populations included in this measurement are: black, Latinx, and Southeast Asian students. Success within URM student populations has direct implications to the STEM pipeline (National Academies of Sciences, Engineering, and Medicine, 2016). Separating URM students into a combined depending variable, this investigation can tease apart relationships specific to these populations and compare potential statistical models to the overall STEM six-year graduation rates (Wells & Stage, 2015). Previous literature and findings highlight the necessity to explore relationships among these populations in further detail within the comprehensive institutional context (Schneider & Deane, 2015).

Independent Variables of Interest

The independent variables of interest at the institutional level were selected through the conceptual framework displayed in Chapter 2 and guided by prior (Anstine, 2013; Leslie, Slaughter, Taylor, & Zhang, 2012; Webber, 2012; Webber and Ehrenberg, 2010). Specific resource allocation categories will be retrieved from the Delta Cost Project IPEDS database. URM STEM GRs are retrieved via CSU-CSRDE database similar to the dependent variable. Three specific resource allocation categories were selected as primary interest for this investigation. Below are descriptions of these a priori determined variables. Important literature supporting the expected relationship to graduation rates and/or the STEM pipeline is also included.

Black, Latinx, and Southeast Asian STEM GR. Three populations were selected for analysis from the overall URM population: (1) Black; (2) Latinx; and (3) Southeast Asian (SEA); the enrollment patterns of American Indians/Alaska Natives were not included as their enrollments at CSU campuses are extremely low (in some cases no enrollments) during the investigation timeframe. The URM STEM GRs variable is measured through the same technique as overall STEM GRs. Each population are a cohort-based measure that tracks the percentage of first-time, full-time freshmen that graduate within four-, five-, or six-years within the designated STEM disciplines (CSU, 2016). These include STEM majors and degree programs during enrollment, while restricting major switches to disciplines outside of STEM during enrollment.

The SEA population includes Cambodian, Hmong, Laotian, and Vietnamese groups (Pang, Han, & Pang, 2011). These populations are identified as URM populations within the traditional racial/ethnic categories identified by the CSRDE and NSF (NSF, 2014) and are target populations to many federal agencies. Additionally, the NSF, NIH, and U.S. Department of Education identify all three populations as populations of need for future STEM development (DOE, 2016).

This investigation uses each population separately as part of comparison analysis to the general STEM population. Additionally, these three populations will be used to analyze the time-varying educational gaps between ethnic groups and the overall STEM population. Although in some years the included populations have low enrollments in STEM majors, each population shows consistent enrollment patterns at each CSU campus that will not hinder the analysis from drawing effective conclusions (Fields &

Miles, 2010; Foster, Diamond, & Jefferies, 2014). The CSRDE calculated percentages for all variables. The populations of Black, Latinx, and SEA students vary in both size and performance across CSU campuses (see Table 3.2 – also see Table C.1, C.2, and C.3 in Appendix C for further detail by campus). Additionally, including these STEM GRs as independent variables provides unique comparisons of these ethnic categories and institutional STEM performance trends (Shadish, Cook, & Campbell, 2002).

Table 3.3.

Black, Latinx, and Southeast Asian Populations STEM Performance in AY2006-AY2016 (N=22 campuses)

	Black	Latinx	Southeast Asian
Average GR	13%	19%	16%
High GR	100%	55%	72%
Low GR	0%	0%	0%
Average Head Count	22.13	104.90	96.43
High Head Count	71	499	379
Low Head Count	0	0	12

Separating the three URM populations into categorical variables allows this investigation to tease apart relationships specific to these populations and compare potential relationships to the overall STEM six-year graduation rate. Success within URM student populations has direct implications to the STEM pipeline (National Academies of Sciences, Engineering, and Medicine, 2016). This investigation also will identify unique relationships (if any) for this population and institutional behaviors that target this population more effectively than the general population, particularly in terms of federal training grants. Half of CSU campuses are designated HSI and eight are eligible for AANIPISI status, however none are listed as an HBCU as of 2016 (CSU, 2016). Although spending and allocation strategies are different between PWIs, HSIs, and AANIPISIs, this invitation is targeting broader impacts from federal funding towards URM students. This investigation also will identify unique relationships (if any) for these populations and institutional behaviors that target URMs more effectively than the general population, in particular federal training grants and scholarships.

Resource allocation categories. As discussed in Chapter 2, there are a number of ways universities and colleges choose to allocate their financial resources to accomplish various institutional goals. Such decisions and strategies impact both institutional-level and student-level outcomes. Consequently, this investigation considers three main resource allocation categories associated with student success to consider their involvement in STEM institutional outcomes, particularly those of URM students. All financial variables are calculated as the share and/or percentage of the budget dedicated to the specific resource allocation (Desrochers & Sun, 2015).

Instructional support. Data regarding instructional support is available in the NCES IPEDS dataset and includes expenditures for all schools, departments, and other instructional practices including campus activities, research, and full-time faculty salaries. This variable was calculated as the percentage of educational and other related spending for instruction. This category includes all allocations for general academic instruction, community education, developmental and basic skills education, and regular, special, supplemental sessions, and for both credit and non-credit activities. This allocation mainly deals with funds related to support within the classroom for training, technology, and other in-class support for faculty (Desrochers & Sun, 2015). Specifically, this variable was selected because it excludes operations and maintenance allocations within the institution that has been found to be unrelated to student success outcomes (Webber, 2012). Additionally, the share of the expenses dedicated to instructional support allows analyses to control for the broad diversity of the budgets in this sample.

Student services. Based on existing research, student services is included in the current analysis and is operationalized as a functional expense category that includes expenses for admissions, student life, and registrar activities (Abington, 2014; Webber, 2012; Webber & Ehrenberg, 2010). This variable was calculated as the percentage of the budget allocated for student services from educationally related expenditures. It is mainly comprised of funding for administration and staff that deal directly with students and includes areas that impact the students' academic and social development outside of the classroom setting. This variable measures the level of investment that the institution has committed to developing student belonging, support programs, and opportunities to build relationships with peers (Crisp et al., 2009; Espinosa, 2011).

NIH and NSF funding for student training. The third expenditure variable involved in analyses measures NIH and NSF funding for student training based on data from the NIH RePORTER and the NSF WebCasper. This category includes all allocations for undergraduate research, staffing salaries, and faculty hours dedicated to training undergraduates in STEM programs that are awarded through a federal program, excluding all student related spending and stipends. All of the federal training monies included in this dataset expect the practices and training to broadly impact the institution and the STEM pipeline (NIH, 2015; NSF, 2015). However, the previous research conducted on these training grants focused on individual student development and their STEM career aspirations (Hurtado et al., 2011; Schultz et al., 2011; Strayhorn, 2010b). Thus, this investigation aims to expand on those findings and assessing the broader impacts of these training grants.

Resource allocations and expenditures from federal agencies like NIH and NSF, are annually award a specific amount of a grant total. Therefore, each year of funding is values associated by the yearly allocation, not the total grant amount to the institution (e.g., CSU-San Jose receives $1 million over five years or approximately $200,000 per year, although these values are not exactly symmetrical as this example because each year changes based on changing staff and benefits provided). These allocations will be combined together to form one composite variable that varies across the timeframe of the study. Therefore, this variable will indicate the percentage of the yearly total amount dedicated towards staff, faculty, and administrative costs.

Control Variables

There will be a total of two institutional level variables averaged across the study time frame. Other institutional variables that were included were considered time-varying and changed during each year of the study time frame.

Selectivity. The selectivity of the institution will be controlled for using a variable that indicates the average or median score of entering/enrolled students on standardized tests, see Table 3.4. This is often used as a proxy for undergraduate educational quality in different aspects of the university (Astin, 1993; Pascarella & Terenzini, 2005). Students with higher standardized test scores will compose a well-prepared student body, which in turn will allow faculty to increase educational rigor and place higher demands on students (Oseguera, 2005). This leads to an enhanced academic program for this institution and greater success overall. Additionally, this fits into the theoretical model through STEM characteristics as research shows that students who have more well-prepared peers in STEM prior to college enrollment are more likely to persist and graduate with a STEM degree (Titus, 2004; Winston & Zimmerman, 2004). In previous studies, this accounts for a significant portion of variance within graduation and retention rates (Pascarella & Trenezini, 2005).

Table 3.4.

CSU Cohort Size and Campus Selectivity (N = 242; 22 campuses & 11 years)

Campus	Cohort Size			Campus Selectivity		
	Ave 10	Hi	Lo	Ave 10	Hi	Lo
Bakersfield	119.18	197	72	969.82	1030	916
Channel Islands	70.73	94	52	1042.64	1063	1008
Chico	443.64	608	343	1055.55	1074	1039
Dominguez Hills	85.36	131	54	863.64	888	825
East Bay	150.82	222	100	953.55	971	918
Fresno	497.27	696	363	987.64	1003	971
Fullerton	557.27	745	385	999.55	1027	984
Humboldt	328.27	504	234	1069.18	1081	1046
Long Beach	713.00	1024	475	1035.82	1057	1002
Los Angeles	251.18	407	160	918.45	964	894
Monterey Bay	130.18	220	78	1010.18	1029	980
Northridge	556.73	921	409	972.82	986	960
Pomona	1189.64	1449	917	1067.55	1126	1046
Sacramento	475.27	665	398	996.27	1010	984
San Bernardino	254.18	388	132	932.73	957	908
San Diego	643.82	808	461	1096.27	1122	1061
San Francisco	411.27	627	261	995.73	1014	969
San Jose	727.36	916	537	1035.55	1089	1012
San Luis Obispo	1796.27	2583	1366	1215.55	1242	1181
San Marcos	112.73	176	55	1021.00	1050	984
Sonoma	150.64	247	97	1067.27	1090	1037
Stanislaus	112.45	207	56	993.09	1036	942
System	9813.82	11857	7940	1060.45	1073	1049

STEM cohort size. Another institutional characteristic that is essential to control for is the size of the STEM cohort. This variable measures the levels of STEM enrollment at individual CSU institutions. Within the CSRDE database, it is labeled as the STEM enrollment cohort. Table 3.4 presents information regarding the size of the STEM population at CSU institutions and indicates system-wide growth during the years between 2000 and 2016 (NSF, 2013). For this investigation, the STEM enrollment of a campus is viewed as a peer-effect variable (Berger & Milem, 2000; Winston, 1999) that directly impacts the STEM student community population and more broadly to the STEM pipeline (Luppino & Sander, 2015). The STEM cohort size will also be restricted to the URM population as well, including only the head counts from URM students.

Statistical Technique – Multilevel Modeling

In order to address the research question and secondary questions, the current investigation adopts a multilevel growth modeling (MLGM) approach. Data within education fields are often nested within levels (i.e., schools, districts, etc.), where subjects and groups share similar characteristics in a systematic fashion (Cheslock & Rios-Aguilar, 2011) (see Figure 3.3). This type of data, referred to as multilevel data, poses unique issues to answering research questions (Raudenbush & Bryk, 2002). Using a MLGM, an extension of multilevel modeling (MLM) and a preferred technique over ordinary least squares (OLS) regression models, accounts for the nested nature of the data and provides the flexibility to analyze shared characteristics and experiences within a parsimonious model (Raudenbush & Bryk, 2002; Singer & Willett, 2003; Snijders & Bosker, 2012).

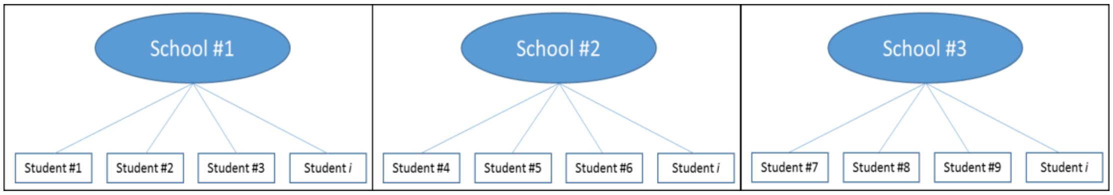

Figure 3.3.

Traditional Example of a Multilevel Data Structure

This investigation uses the explanatory example of Raudenbush and Bryk (2002) to describe the MLM technique and the additional extensions to a MLGM and piecewise terms. Although the statistical model can be represented as a single equation (e.g. the combined model), Raudenbush and Bryk (2002) display the equations for level-1 and level-2 in separate expressions; this improves clarity and explanation for each level of the model. Using this technique highlights relationships between the selected institutional variables and the six-year STEM graduation rates among the CSU campuses and expands the research around STEM students in comprehensive institutions.

Multilevel Growth Modeling – The Appropriate Technique

The ability to analyze the complexity of the data simultaneously is a distinct advantage of MLM (Raudenbush & Bryk, 2002). One special class of MLM models collects observations of the same individual -- student, school, and/or institution -- over multiple time periods, called multilevel growth models (MLGM). This class of MLMs uses repeated measurements over time to model trends (Raudenbush & Bryk, 2002; Singer & Willett, 2003). Although the term “growth” may seem to infer increases in the dependent variable, this approach tracks the directional nature of the outcome for both directions (Singer & Willett, 2003). MLGM refers to level-1 rates of change as the individual's trajectory over time and the level-2 characteristics consist of stable characteristics that change little over the duration of the study (O'Connell & McCoach, 2008; Raudenbush & Bryk, 2002).

MLGM is a common longitudinal analysis technique in education, higher education, and social sciences (Heck & Thomas, 2001; Titus, 2004). In MLGM, level-1 observations of an individual are nested within the level-2 subjects (e.g. individual or institutions – see Figure 3.4). The adaptability and accuracy of MLGM analysis explain changes in phenomena over time and between cases/subjects (O'Connell & McCoach, 2008; Rabe-Hesketh & Skrondal, 2012; Raudenbush & Bryk, 2002). MLGM accounts for the random variation of the intercept (the starting point), the slope (the rate of change), and the shape of that change (a straight line, a curve, or a wavy pathway), through a parsimonious, efficient approach (Cheslock & Rios-Aguilar, 2011; Curran, Obeidat, & Losardo, 2011; Raudenbush & Bryk, 2002).

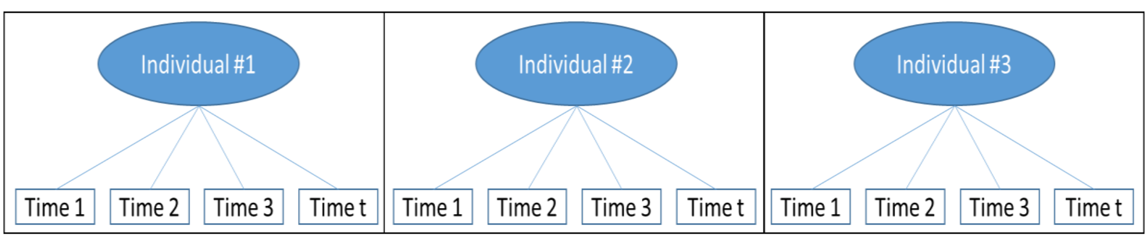

Figure 3.4.

Example of Basic Multilevel Model Structure

The MLGM approach is appropriate for this investigation as the research questions concern institutional characteristics and STEM performance. The growth trajectories of STEM graduation rates and the relationships with resource allocations across CSU campuses are the main aim of this investigation. Institutional performance measured in annual increments will represent the dependent variable with stable and time-varying institutional characteristics providing additional depth to the relationship examined. Similar to previous research in higher education that analyzes the impact important institutional characteristics on retention and graduation rates over time (Chen, 2012; Heck, Lam, & Thomas, 2014; Webber & Ehrenberg, 2010), this investigation uses longitudinal data to examine the institutional outcomes of colleges and universities across time. Chen (2012) and Heck, Lam, and Thomas (2014) specifically used a version of MLGM to analyze the relationships in institutional outcomes that provide a foundation for this investigation.

In addition, MLGM is appropriate for IPEDS data. The use of a multi-stage sampling with a broad sample of colleges and universities allows this study to employ MLGM with sufficient statistical power to detect significant relationships within and across institutions (Raudentbush & Bryk, 2002). Since IPEDS has been used in various studies and collected data points across more than 10 years including institutional resources, financial aid, and spending patterns the data provide a comprehensive portrait on how individual characteristics, resource allocations, and STEM training are related to STEM pipeline outcomes. However, this investigation expands on the use of IPEDS by including the CSRDE data for CSU campuses. The STEM performance measure is calculated in a similar fashion as the IPEDS overall graduation rate for campuses and provides a unique perspective for research into the STEM pipeline.

Lastly, the assumption inherent in MLGM is that change is linear over time (Singer & Willett, 2003). Adding a piecewise term, the relationships of nonlinear change and variations in the outcome is assessed during specific time periods and/or phases (Raudenbush & Bryk, 2002); also called a discontinuous term (Singer & Willett, 2003) and/or spline models (Hoffman, 2015). Each phase corresponds to a unique trajectory with a hypothesized meaning for the break in trend. Accordingly, deviations in trajectory are attributed to the correct variability and main effects are appropriately estimated (Bauer & Cai, 2009; Palardy, 2010). For example, high school students who earn a bachelor's degree while they are working would sharply increase their annual salary after their achievement. Since "*why*" and "*when*" the student increased their wages occurred is known, the change should be modeled (Singer & Willett, 2003). If this characteristic is ignored, it could potentially lead to incorrect conclusions (Raudenbush & Bryk, 2002).

MLGM can account for the nonlinearity in the growth trajectory and utilize piecewise analysis. One advantage of using MLGM is the ability to gain statistical power with limited observations (Raudenbush & Bryk, 2002). Although this investigation examines the timeframe from 2006 to 2016, an eleven-year window, the Great Recession in 2008 shocked the CSU system and created two distinct phases. Due to the limited observations before and after the Great Recession, the MLGM technique allows for limited observations in each phase as well as unbalanced observation numbers (Rabe-Hesketh & Skrondal, 2012; Raudenbush & Bryk, 2002; Singer & Willett, 2003).

MLGM Steps and Procedure

The validity of inferences derived from MLGM is contingent on satisfying specific model assumptions. Each model in this investigation will test the following assumptions of MLGM modeling and ensure each are met: (1) the residuals at the institutional-level to satisfy distributional assumptions of independence of observations, (2) normality of distribution, and (3) homogeneity of variance (Raudenbush & Bryk, 2002; Snijders & Bosker, 2012). Additionally, the association between the outcome variable and continuous independent variables is assumed to be approximately linear and will be checked during the model building process (Rabe-Hesketh & Skrondal, 2012). The residuals for the final models for each research question in this study will be examined to test whether the assumptions are tenable.

Independent variables will be standardized in order to properly interpret and analyze effect size estimates. In this step, all continuous variables in this investigation will be standardized across all years and variables before the model will be completely built. Although the unstandardized variables will also be checked in a secondary analysis, the standardization of independent variables allows the variable coefficients to reflect standardized measurements that are interpreted separately from raw data (Raudenbush & Bryk, 2002). This step also includes creating six-year averages for campuses of their resource allocations that match the cohort graduate rate (e.g. student services expenditures are averaged from 2010-2016 for the 2010 entry cohort) and is important to this investigation to compare the variables of interests to one another in a standardized approach and match with the entry cohort timeframe.

All independent variables used in this investigation had low rates of missing values and in some cases none had missing values. IPEDS data has annual requirements for institutions to report their information, therefore most cases do not have missing data; follow up data was recovered from individual campuses websites. The result was less than 1% of the data was missing in three resource allocation categories: (1) student services, (2) institutional support, and (3) NIH/NSF training grants. IPEDS acknowledged the missing values for 2007 at certain campuses, however, individual campus archive data was obtained in place of missing values (NRC, 2013). Many of the allocations did not change significantly in that year and this procedure has been used in other research; although the concern is that the report values on campus websites might differ from the actual value reported in IPEDS (Webber & Ehrenberg, 2010). For NIH/NSF training grants, missing values are important to investigation because they indicate that there was no funding allocated to that campuses for STEM training during that academic year and could impact the cohort during their time at the campus.

Lastly, important continuous variables will be centered to enable interpretation of the coefficients of centered independent variables. Variable centering is described by Raudenbush and Bryk (2002) and Singer and Willett (2003) to aid in interpretation and creates an approach to understand the context in which these relationships function. Therefore, following their suggestions, this investigation will grand-mean center all continuous institutional-level variables, although in some cases group-mean centering will occur in order to answer a specific research question. Those cases will be explained in the section for the research question. Grand-mean centering allows for the interpretation of model parameters in relation to the “average” institutional spending and other characteristics on those parameters. Dummy-coded variables were not centered.

Statistical Models Used to Address Research Questions

This investigation will follow a traditional growth modeling procedure, building models and complexity based on model fit and focused research questions. The steps in the procedure will follow the steps Raudenbush & Bryk (2002) presented in their seminal work on MLGM. Although this technique has been widely used in K-12 school effectiveness studies (Bryk & Raudenbush, 1992; Lee, 2000), MLGMs, also referred to as hierarchical linear models (HLM), mixed models (MM), and random effects models, are utilized in higher education research and building growth models to analysis hierarchical data. The MLGM technique allows the research to reap the benefits of multilevel data while also focusing on specific relationships within the research (Cheslock & Rios-Aguilar, 2011; Niehaus, Campbell, & Inkelas, 2014).

As Raudenbush & Bryk (2002) describe, the first step in the modeling building process will be to assess basic plots and visual representations of change for the individual campuses. This step visually assesses linear, quadratic, and piecewise change in STEM six-year GRs without any predictors in the growth model, providing a rough outline of the variability that exists in STEM GRs between CSU institutions. Since this investigation is contextualizing graduation rates as nested within the institution, starting with the unconditional means model provides beneficial information by partitioning the variation in the outcome (Singer & Willett, 2003; Snijders & Bosker, 2012). The first research question begins this process of assessing the variation in STEM GRs between

2006 and 2016 between institutions as base to move forward with more models to account for added variability.

The basic examination of the slopes and intercepts in Figure 3.5 shows variation between the performances of institutions for STEM GRs in 2006, four years before the Great Recession affected the CSU system, the directional growth rates between 2006 and 2016, and the trajectory of the change during this timeframe. A secondary plot of a fitted quadratic line (see Figure C.1 in Appendix C for this plot). However, examining a quadratic growth for each of the CSU campuses, from the visual examination, the quadratic function does not seem to provide much information to the change in growth rates as the initial plot of trajectories.

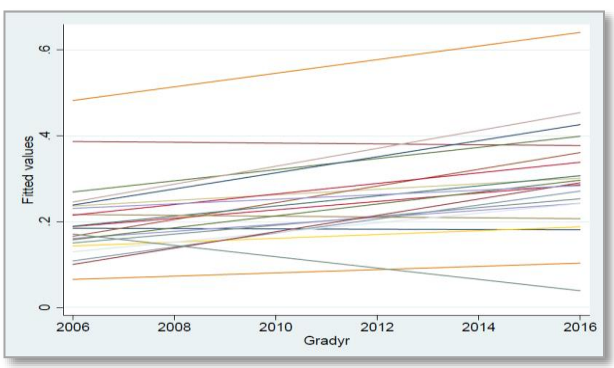

Figure 3.5.

STEM GRs by CSU Campus from 2006 to 2016

In the piecewise plot, the break between pre-Great Recession (2006 to 2010) and post-Great Recession (2011 to 2016) provides insight into the different trajectories during these phases (see Figure 3.6). Figure 3.6 shows the trajectories for campuses before and after the Great Recession vary widely, with some showing a change in direction, while others have increased their performance post-Great Recession. The piecewise analysis allows for the analysis of resource allocation priorities shifting after the Great Recession.

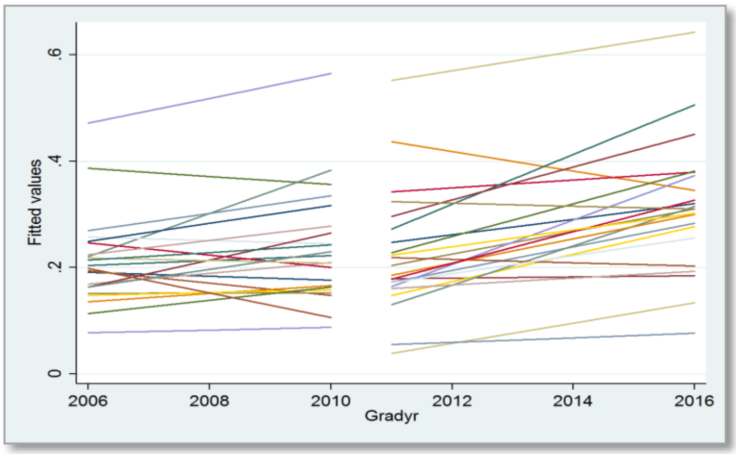

Figure 3.6.

STEM GRs by CSU Campus from 2006 to 2016 with Piecewise Term

In addition, this investigation is interested in the STEM GRs of Latinx, Southeast Asian (SEA), and Black students at CSU campuses. These populations are subgroups within the overall GRs measurement (CSRDE, 2016). The GRs of these student populations represent the percentage of students graduating with a STEM degree after six year from the total number of STEM declared majors at initial enrollment, including students that graduate in four and five years (NCES, 2016). Figure 3.7 provides the fitted line and piecewise fitted plots for Latinx STEM GRs.

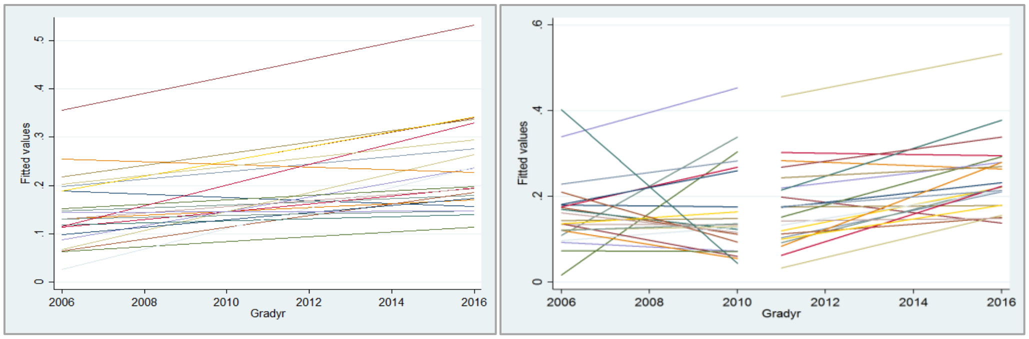

Figure 3.7.

STEM GRs by CSU Campus for Latinx Students

From the visual examination, Figure 3.7 shows consistent improvement from 2006 to 2016. However, Figure 3.7b shows prior to the pre-Great Recession performance varied for both trajectory and overall performance with some campuses showing strong improvements after the Great Recession.

Figure 3.8, presents both fitted line and piecewise plots for Black STEM GRs. Black students show consistent improvement from 2006 to 2016. However, the performance pre-Great Recession highlights the differences in trajectories and performance by CSU campus.

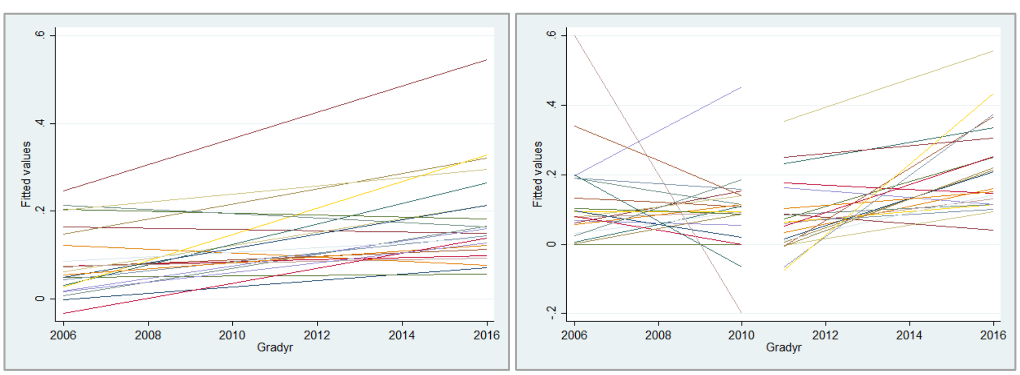

Figure 3.8.

STEM GRs by CSU Campus for Black Students

Finally, Figure 3.9 illustrates STEM GRs for SEA students. SEA students show patterns similar to the Latinx populations, with some improvement and losses from 2006 to 2016. However, the performance pre-Great Recession highlights the differences in trajectories and performance by CSU campus in particular the significant differences between campuses.

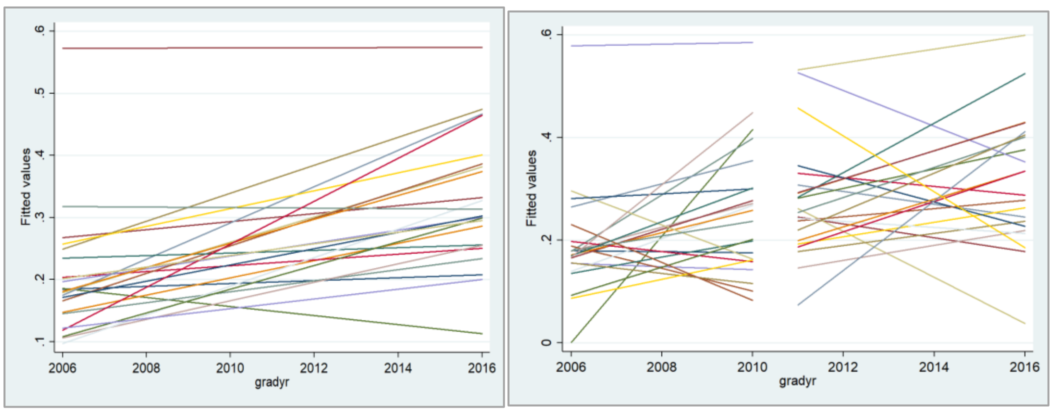

Figure 3.9.

STEM GRs by CSU Campus for SEA Students

These visual plots show the variation in graduation rates across campuses at CSU campuses. It is important to assess the differences within the data and gain understanding of the important relationships for these populations in the STEM pipeline. This provides justification for further research into the types of resource allocations that are associated with these GRs both overall and for URMs populations.

Research Sub-Questions: The next section outlines the specific sub-questions aimed at building models to answer the two research questions introduced in Chapter 1. Interpretations of the equation terms and visual representations (where appropriate) are provided.

Sub-questions 1 (unconditional model):

1. To what extent were there institutional differences in the rates of change for six-year STEM graduation rates between 2006 and 2016 at CSU campuses?

The research sub-question 1 is the starting point for this investigation. It begins by building the unconditional growth model (null model) highlighting the change of STEM GRs between 2006 and 2016. From this question, there will be three models built to answer all of the sub-questions. The null model consists only of the repeated measurements of the outcome variable and a time related growth parameter (Raudenbush & Bryk, 2002). Level-1 of the null model contains four parameters, (1) the outcome at time 1, (2) the intercept of each institution at 2006, (3) the growth rate of each CSU institution from 2006 to 2016, and (4) the residual or the random variations around the linear change trajectory; see equation below following the conventions provided by Raudenbush & Bryk, (2002):

Model 1: Unconditional Model

Level 1 CSU Campus: $Y_{ti} = \pi_{0i} + \pi_{1i}(time)_{ti} + e_{ti}$

Level 2 intercept: $\pi_{0i} = \beta_{00} + r_{0i}$

Level 2 Growth: $\pi_{1(time)i} = \beta_{10} + r_{1i}$

In the equation above, level 1 terms are defined as: Y_{ti} is the value for the overall STEM six-year GRs for CSU campus *i* measured at time *t*; the treatment of time in this investigation will follow a year-to-year change as IPEDS, the DCP, and the CSRDE provide yearly information on performance, student body, and funding for CSU campuses. In this case, the starting value of time is 2006. Therefore, π_{0i} represents the intercept and the true performance of overall STEM GRs at CSU institution *i* in 2006 (when $a_{ti} = 0$; where a_{ti} is coded 0, 1, 2….10 for the time variable in this initial model and centered at 2006, time will be coded differently for subsequent models and will be noted where applicable). π_{1i} represents the linear growth rate of overall STEM GRs at CSU institution, *i*, between 2006 and 2016. e_{ti} is the within CSU institution effect not accounted for by the specified growth parameters, which is assumed to be normally distributed and around a mean of 0 (Raudenbush & Bryk, 2002, pp. 163).

The level-2 equations describe between institution variability in the two growth parameters; the intercepts of CSU institutions, π_{0i} and the linear change rates for CSU institutions from 2006 to 2016, $\pi_{1.}$ Both growth parameters represent the outcomes for level-2 equations from the level-1 equation. Therefore, the residual effects, r_{0i} & r_{1i}, represent the random, between-institution differences in the growth parameters π_{0i} and π_{1i} and are assumed to have normal distributions and mean of 0 with a variance of $\tau_{00.}$ The two fixed effects, β_{00} and β_{10}, represent the average performance of CSU institutions in 2006 and the average rate of change for CSU institutions from 2006 to 2016. The inclusion of the level-2 equations allows the analysis to examine the variability in both growth parameters across CSU institutions (Singer & Willet, 2003).

Sub-question 2:

2. How did the change in overall six-year STEM GRs differ before and after the Great Recession?

In sub-question 2, Model 2 adds a piecewise term ($\pi_{2i}(time2)_{2ti}$) and an elevation change term ($\pi_{3i}(PoGR)_{3ti}$). Conceptually, this creates the phases between pre-Great Recession and post-Great Recession for overall graduation rates and adds an elevation change in the slope at the onset of the Great Recession. Below are equations that follow the conventions of Raudenbush & Bryk (2002) for a piecewise linear change model that accounts for both intercept and slope change for each phase.

Model 2: Great Recession Impact on Graduation Rates

Level 1:	$Y_{ti} = \pi_{0i} + \pi_{1i}(time1)_{1ti} + \pi_{2i}(time2)_{2ti} + \pi_{3i}(PoGR)_{3ti} + e_{ti}$
L2 intercept:	$\pi_{0i} = \beta_{00} + r_{0i}$
L2 GradRate Slope:	$\pi_{1i} = \beta_{10} + r_{1i}$
L2 Post-GR Slope:	$\pi_{2i} = \beta_{20} + r_{2i}$
L2 Post-GR Intercept:	$\pi_{3i} = \beta_{30} + r_{3i}$

Since the Great Recession caused CSU institutions to adjust to financial changed to their budgets and the introduction of performance metrics, funding decisions made the administration resulted in an abrupt change in the growth trajectory before and after the Great Recession occurred. In more detail, the equation for the piecewise model describes the CSU institutional STEM graduation rates (*i*'s) differ in both intercept and slope. The two new terms in the equation from Model 1, (1) π_{2i}(time2) & (2) π_{3i}(PoGR). $\pi_{2i}(time2)$ represents the incremental growth rate of the post-Great Recession timeframe, defined as 2012 to 2016 and the onset of the post-Great Recession impact; the slope differential between the overall growth rate and the post-Great Recession growth rate. $\pi_{3i}(PoGR)$ captures how much higher or lower STEM graduation rates for CSU campuses were immediately the onset of the Great Recession (See Figure 3.10 for a visual representation of the piecewise model for Model 3). Piecewise terms allows this investigation to explicitly model growth rates and the impact of the Great Recession on CSU campuses (Raudenbush & Bryk, 2002; Singer & Willett, 2003).

The terms from the unconditional model are each broken into two terms, describing growth parameters for phase 1 and phase 2. β_{10} and β_{20} represent the average rate of change in the overall growth rate and the difference between post-Great Recession growth rate, respectively. This investigation hypothesizes both an elevation and slope change in STEM GRs. Thus, the coding for time will represent an incremental growth change between phases (Raudenbush & Bryk, 2002; see Table D.1 Appendix D for coding year-to-year incremental change between phases). The terms r_{0i}, r_{1i}, and r_{2i} represent the random effects of the initial status of institutional STEM GRs in 2006, the overall growth rate and after the Great Recession (Singer & Willett, 2003). Figure 3.10 is an adaptation from Singer & Willett (2003) that provides a visual representation of these conceptual models.

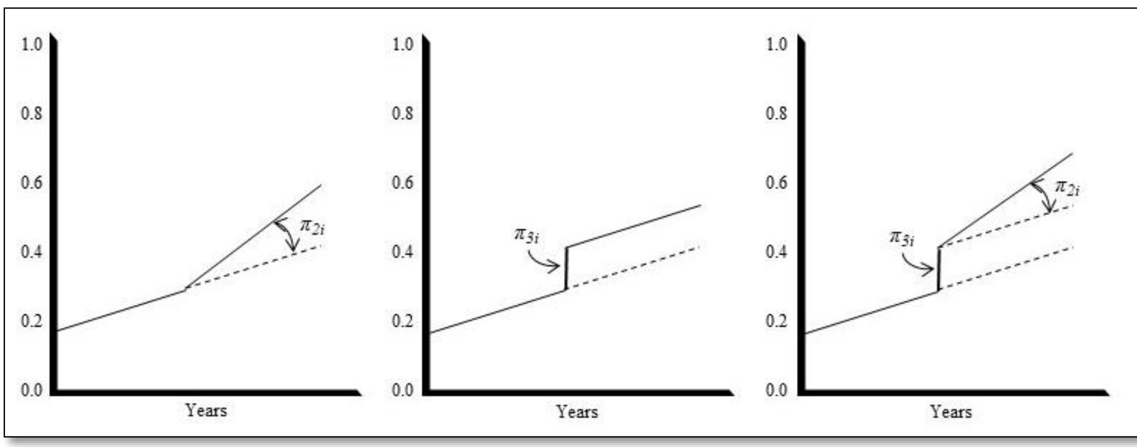

Figure 3.10.

Singer & Willett (2003) Visual diagram of Piecewise Model (pg. 196)

The left panel highlights the differential slope after the Great Recession π_{2i}(time2). This is considered a slope change unique to phase two of the model. The middle panel shows the elevation change measured by π_{3i}(PoGR). In this case, there is a break in the linear trajectory, but no change in the slope or growth rate. The right panel shows both an elevation and slope change, this investigation, it represents the impact of the Great Recession on both trajectory and slope (Singer & Willett, 2003).

Although the Great Recession affected the U.S. population during 2009 and 2010 fiscal years (DOL, 2014), the CSU implemented financial budget decisions during the AY 2010-2011, specifically regarding faculty and staff furloughs, reallocating resources for student development centers, and reassigning faculty and staff time to cross-coordinated job duties as well as cutting courses for the fall and spring terms (CSU, 2010). The reduction in budgets did not fully impact CSU campuses until the AY 2011-2012 fiscal year (CSU 2016). Therefore, one intercept and growth factor describes the institutional STEM GRs in AY 2006 to AY 2016, the first phase. The second intercept and growth factor describes the post-Great Recession trend, the second phase (AY 2012-2016). The inclusions of a second intercept in the model allows for the possibility that CSU campuses could experience dramatic changes in STEM GRs during the transition of the Great Recession. As explained previously, an additional benefit of piecewise growth modeling is its ability to capture nonlinear growth, which is hypothesized in this investigation for GRs across the Great Recession.

Sub-question 3:

3. To what extent were black, Latinx, and Southeast Asian STEM GRs related to overall STEM GRs at CSU campuses?

To answer sub-question 3, the model includes all three URM populations at level-2. These were measured as the six-year STEM graduation rates for each population at each CSU campus. Entering these three populations into the model at level-2, the analysis examines the relationship between STEM six-year graduation rates growth rates at CSU campuses with black, Latinx, and Southeast Asian populations' STEM six-year graduation rates before and after the Great Recession.

Model 3: URM Graduation Rates Piecewise Model

Level 1: $Y_{ti} = \pi_{0i} + \pi_{1i}(time)_{1ti} + \pi_{2i}(time2)_{2ti} + \pi_{3i}(PoGR)_{3ti} + e_{ti}$

L2 intercept: $\pi_{0i} = \beta_{00} + \beta(Blk)_{01} + \beta(Lax)_{02} + \beta(SEA)_{03} + r_{0i}$

L2 Slope Pre-GR: $\pi_{1i} = \beta_{10} + \beta(Blk)_{11} + \beta(Lax)_{12} + \beta(SEA)_{13} + r_{1i}$

L2 Slope Post-GR: $\pi_{2i} = \beta_{20} + \beta(Blk)_{21} + \beta(Lax)_{22} + \beta(SEA)_{23} + r_{2i}$

L2 Post-GR Intercept: $\pi_{2i} = \beta_{30}$

Terms added from the unconditional model are described in the same conventions used by Raudenbush and Bryk (2002). Model 3 aims to analyze the difference between URM STEM performance growth rates (black, Latinx, and SEA) and the average growth rate of overall STEM graduation rates at CSU campuses. *β(Blk)* the relationship of black STEM GRs with the expected initial status and growth rates (pre- and post-Great Recession) of overall STEM graduation rates at CSU campuses that have average Latinx and Southeast Asian STEM GRs. *β(Lax)* the relationship of Latinx STEM GRs with the expected initial status and growth rates of overall STEM graduation rates at CSU campuses that have average black and Southeast Asian STEM GRs; and *β(SEA)* the relationship of Southeast Asian STEM GRs with the expected initial status and growth rates of overall STEM graduation rates at CSU campuses that have average black and Latinx STEM GRs. The final term, Post-Great Recession Intercept, is fixed across campuses and denotes the elevation change from the onset of the Great Recession was expected to be the same across CSU campuses and occurred in the same fiscal year.

Adding the ethnic GRs in the level-2 equations, the URM STEM GRs represent the first block of fixed effects of interest. These variables examine systemic institutional differences in the initial status and growth rates of STEM GRs between CSU campus from AY 2006 to 2016 (Raudenbush & Bryk, 2002). The URM STEM GRs are measured as six-year STEM graduation rates and in annual percentages of the graduating cohort of STEM students six years after entry (See pg. 85 for description of variable).

Sub-questions 4 & 5:

4. Is there a relationship between resource allocations (*Student Services, Instructional Support, and NIH/NSF Grants*) and STEM GRs at CSU campuses and accounting for the Great Recession?
5. After controlling for institutional characteristics and accounting for the Great Recession, did the relationship between resource allocations and STEM graduation rates change between 2006 and 2016 at CSU campuses?

The research questions above build from the initial null model, but adds complexity at level-2 to assess the relationship between resource allocations and STEM GRs at CSU campuses. From these questions, there were two additional models built to the sub-questions. Model 4 begins by adding resource allocation categories to the unconditional growth model: Student Support, Instructional Support, and NIH and NSF training grant funds by campus, removing the ethnic STEM graduation rates. Model 4 examines the effect of resource allocation strategies, independent of URM STEM graduation rates.

Model 4: Resource Allocations

Level 1: $Y_{ti} = \pi_{0i} + \pi_{1i}(time1)_{1ti} + \pi_{2i}(time2)_{2ti} + \pi_{3i}(PoGR)_{3ti} + e_{ti}$

L2 intercept Pre-GR: $\pi_{0i} = \beta_{00} + \beta(StudSer)_{01} + \beta(Intrusup)_{02} + \beta(NIHNSF)_{03} + r_{0i}$

L2 Slope Pre-GR: $\pi_{1i} = \beta_{10} + \beta(StudSer)_{11} + \beta(Intrusup)_{12} + \beta(NIHNSF)_{13} + r_{1i}$

L2 Slope Post-GR: $\pi_{2i} = \beta_{20} + \beta(StudSer)_{21} + \beta(Intrusup)_{22} + \beta(NIHNSF)_{23} + r_{2i}$

L2 Post-GR Intercept: $\pi_{3i} = \beta_{30}$

The new terms added into Model 4 are described using Raudenbush & Bryk (2002) conventions. $\beta(Studser)$ the relationship of student services support with the expected initial status and growth rates (pre- and post-Great Recession) of overall STEM graduation rates at CSU campuses that have average instructional and NIH/NSF training grants. *β(Intrusup)* the relationship of instructional support with the expected initial status and growth rates of overall STEM graduation rates at CSU campuses that have average student services support and NIH/NSF training grants; and *β(NIHNSF)* the relationship of NIH/NSF training grants with the expected initial status and growth rates of overall STEM graduation rates at CSU campuses that have average student services and instructional support. The Post-Great Recession Intercept is again fixed across CSU campuses, denoting the elevation change from the onset of the Great Recession.

This second block of fixed effects of interest added into level-2 equations. The resource allocation strategies represent the relationship to overall STEM GR separate from ethnic GRs (Model 3). The independent relationships of research allocations strategies provide important answers to the research questions posed in Chapter 1 by highlighting the unique relationships resource allocations provide to the STEM pipeline. These resource allocation strategies were 6-year averages across the enrollment timeframe of the graduating cohort (See pg. 85 for full description of variable).

Model 5 adds two institutional characteristic to the resource allocation categories: campuses selectivity and STEM cohort size. Model 5 examines the effect of resource allocation strategies, controlling for the effect of institutional characteristics on STEM graduation rates.

Model 5: Resource Allocations & Institutional Characteristics

Level 1: $Y_{ti} = \pi_{0i} + \pi_{1i}(time1)_{1ti} + \pi_{2i}(time2)_{2ti} + \pi_{3i}(PoGR)_{3ti} + e_{ti}$

L2 intercept Pre-GR: $\pi_{0i} = \beta_{00} + \beta(StudSer)_{01} + \beta(Intrusup)_{02} + \beta(NIHNSF)_{03} + \beta(Select)_{04} + \beta(STEMsize)_{05} + r_{0i}$

L2 Slope Pre-GR: $\pi_{1i} = \beta_{10} + \beta(StudSer)_{11} + \beta(Intrusup)_{12} + \beta(NIHNSF)_{13} + \beta(Select)_{14} + \beta(STEMsize)_{15} + r_{1i}$

L2 Slope Post-GR: $\pi_{2i} = \beta_{20} + \beta(StudSer)_{21} + \beta(Intrusup)_{22} + \beta(NIHNSF)_{23} + \beta(Select)_{24} + \beta(STEMsize)_{25} + r_{2i}$

L2 Post-GR Intercept: $\pi_{3i} = \beta_{30}$

Two new terms added into Model 5. Each are described using Raudenbush & Bryk (2002) conventions. $\beta(Select)$ the relationship between campus selectivity with the expected initial status and growth rates (pre- and post-Great Recession) of overall STEM graduation rates at CSU campuses that have average resource allocations and STEM cohort size. $\beta(STEMsize)$ the relationship of the STEM cohort size with the expected initial status and growth rates of overall STEM graduation rates at CSU campuses that have average resource allocations and campus selectivity. Institutional characteristics, such as selectivity and cohort size, has well-documented implications for institution success (see Chapter 2 pg. 43). However, these characteristics are not the focus of this investigation, yet need to be accounted for in the modeling process.

Sub-questions 6:

6. To what extent were the relationships between URM STEM graduation rates and resource allocation strategies different, after controlling for institutional characteristics and accounting for the Great Recession between 2006 and 2016 at CSU campuses?

The research question creates a counter-narrative model for URM STEM graduation rates. This model builds from the original piecewise model, replaces the overall STEM graduation rates variable with URM STEM graduation rates, and adds complexity at level-2 to assess the relationship between resource allocations and institutional characteristics with URM STEM GRs at CSU campuses. Model 6 uses resource allocation and institutional characteristics variables into the model: Student Support, Instructional Support, NIH and NSF training grant funds by campus, and institutional characteristics. The goal of Model 6 was to examine the relationship unique to URM STEM graduation rates to examine differences and similarities to overall STEM graduation rates. Model 6 presents the final projected models for analysis, tying together the previous models proposed for this investigation and examining the URM STEM graduation rates separately from the overall population. Although, model building is an iterative process and alternative models are developed based on the data and results. (Raudenbush & Bryk, 2002; Singer & Willett, 2003).

Methodological Limitations of the Investigation

Comparison of Alternative Modeling Techniques

Although MLGM extensions are used regularly in higher education, Difference-in-Difference (DD) and Interrupted Time Series (ITS) models are also frequently used. Application of these models aim to control for unobserved variables that are excluded from the model, acknowledging that unmeasured variables may affect estimates and cause omitted variable bias (Angrist & Pischke, 2008; Rabe-Hesketh & Skrondal, 2012; Shadish et al., 2002). Each has its own unique adjustment to control for additional variance associated with error terms, dependent, and independent variables (Kennedy, 2008; Somers, Zhu, Jacob, & Bloom, 2013). Generally, these statistical techniques aim to understand and evaluate the causal relationship between the dependent variable and independent variables of interest while controlling for other factors that are not directly observable or collected by the researcher (Angrist & Pischke, 2014; Kennedy, 2008; Woolridge, 2013). The advantage of these models is that they control for between-subject unobserved effects and limit the analysis to within-subject change over time (Angrist & Pischke, 2014).

A fundamental aspect of the DD models is the estimation of effects based on the variation within a group or individual (Angrist & Pischke, 2008; Murnane & Willett, 2010). DD models enable the research to account for the commonalities within groups of observations while analyzing individual-level variance, negating the assumption that the errors are independent (Rabe-Hesketh & Skrondal, 2012; Snijders & Bosker, 2012). This leverages the structure of the data to reduce bias created by omitted variables and accounting for unobserved group-level characteristics, primarily using only within group variation to estimate coefficients (Angrist & Pischke, 2014; Cheslock & Rios-Aguilar, 2011). This eliminates observed and unobserved variability between subjects leaving the analysis to focus solely on within-subject effects; at its core, this approach compares the individual to itself (Cellini, 2008).

Similar to DD models, ITS models use measurements of the same variable over consecutive years and evaluate group performance means, as well as the differences in the slopes between groups (Shadish et al., 2002). Both the mean group performance and the slope/trend of the group pre- and post-treatment together assess the counterfactual group against the control group. As such, it evaluates post-intervention differences rather than just a simple difference between-mean performance (Somers et al., 2013; St. Clair, Cook, & Hallberg, 2014). Additionally, this technique has the flexibility to add a no-treatment time series to the treatment (Rabe-Hesketh & Skrondal, 2012; Shadish et al., 2002).

The review of these models is important, since these account for potentially unobserved variables at the campuses or regional level that are immeasurable (Angrist & Pischke, 2014). These additional models are not the focus on this investigation, however provide an additional considerations regarding the cross-sectional nature of the dependent variable (O'Connell & McCoach, 2008; Shadish et al., 2002; Snijders & Bosker, 2012). Although these models are typically found in economic and political science literature, previous research in higher education have used DD and ITS regression models. Studies in HE have targeted causal links spanning HE access (Toutkoushian & Hillman, 2012), state appropriations (Archibald & Freeman, 2006; McLendon, Hearn & Moker, 2009), financial aid policies (Chen & DesJardins, 2010; Cellini, 2008; Ewell & Kelly, 2009; Heck, Lam, & Thomas, 2012; Hillman, 2012), degree production (Doyle, 2015; Titus, 2009), and student success outcomes (Domina, 2013; Hickman, 2009; Webber & Ehrenberg, 2010; Zhang, 2008). This is not an exhaustive list, but the breadth of topics provides evidence for these models provides a useful perspectives that develop the MLGM used in this investigation.

Other Considerations

Although the MLGM constructed aims to accurately assess the relationship between the selected institutional variables and the STEM six-year graduation rates both overall and for URM students, there are some important limitations to the investigation. First, six-year graduation rates only reflect first-time, full-time enrolled students.

Therefore, this analysis is unable to effectively measure institutional success with regard to transfer and part-time students. These populations of students tend to enroll at comprehensive universities and are often targeted students for special programs (Bowen et al., 2009; Evans, 2002; Hurtado, 2010; Monaghan & Attewell, 2015; Sullivan, 2008; Velez, 1985). A report from the American Council on Education (ACE) (2010) found that approximately 20-25% of the students enrolling at baccalaureate granting institutions overall are excluded based on the current definition. Although in California, the STEM college enrollment for part-time and transfer students is much lower than the national average, between 6-10% (CSU, 2016). Although this measure leaves out a percentage of students, it is a commonly used measure of completion for institutions and an effective measure to gain part of the whole picture of productivity in comprehensive universities (Bowen et al., 2009; NRC, 2013).

Second, because this investigation utilized aggregate data at the institutional level, inferences cannot be made regarding the impact of specific institutional-level aspects on individual students. Specifically, data are analyzing institutional level relationships and thus, unable to provide student conditions and characteristics highlighting patterns of student behavior within the institution. Additionally, since this data are not making connections directly with student behavior, this investigation is limited in predicting whether receiving these services are associated with an increased probability of individual STEM degree attainment. Aggregated data limits the understanding of access and services provided to URM students, only the average outcomes. This limitation can create what is known as “aggregation bias”, or “the ecological fallacy”, which ascribes inferences about the individual from findings of the group to which those individuals belong (Robinson, 1950; Robson & Pevalin, 2015). As such, policy implications based on aggregate data have shown contrary effects at the individual level. Therefore, the currently investigation did not model individual because individual STEM degree attainment data was not available. This investigation highlights the need for more research on this topic to ascertain the associations between specific campus services and practices and individual STEM student outcomes, specifically developing accessible databases that provide individual level STEM data.

Third, this investigation does not make causal inferences. The basis of this investigation develops a relational analysis with a parsimonious model. This narrows the generalizability of the results to a limited population of comprehensive colleges and universities. Extending this limitation, the MLGM framework attempts to keep flexibility of the model provides the opportunity to compare differences between institutions and their characteristics. However, this limitation costs internal validity, where the potential to omit important variables lurks in the background (Angrist & Pischke, 2014; Kennedy, 2008; Rabe-Hesketh & Skrondal, 2008). This limitation is a choice made in order to effectively compare across the institutions and assess potential future avenues of research for comprehensive universities. The complexity of the model aims at understanding the many different complicated relationships that higher education institutions develop with their students, faculty, and staff.

CHAPTER 4

Results

The purpose of this investigation is to analyze the relationship of resource allocation behaviors and California State Universities' (CSU) Science, Technology, Engineering, and Mathematics (STEM) six-year graduation rates. Debate over institutional spending and institutional performance raised valid concerns about providing qualified workers for the STEM pipeline (Carnevale et al., 2011). However, comprehensive institutions continue to educate the majority of the U.S. undergraduate STEM population and yet, remain understudied (Schneider & Deane, 2015).

Although the literature regarding the STEM pipeline and resource allocations focuses on the two ends of higher education (flagship universities and community colleges), there is little empirical research into the relationships among comprehensive institutions within the STEM pipeline. Thus, the present research explores the link between resource allocation strategies and institutional graduation rates, accounting for the differences between institutions during the academic year (AY). Further, the nature of the relationship unique among underrepresented minority (URM) STEM students with overall STEM graduation rates is also considered. To accommodate the differences in resource allocation and institutional characteristics among institutions, as well as the influence of ethnic STEM graduation rates on overall STEM graduation rates, this longitudinal study incorporated 11 years of institutional level data. Multilevel Growth Modeling (MLGM) is used to examine the relationship between institutional resource allocations and STEM graduation rates.

Summary of Data Analysis Plan

The analysis was conducted for the STEM graduation rate outcome following the data analysis plan outlined in Chapter 3 (Raudenbush & Bryk, 2002). Data were examined for compliance with statistical assumptions and the outcome measures assessed for outliers. Model fitting for the outcome variable was conducted in an iterative process using the maximum likelihood (ML) estimation method to facilitate comparison of each subsequent model. The ML goodness-of-fit and deviance statistics are used to compare between models and subsequent models (Singer & Willett, 2003).

Additionally, STEM graduation rates were transformed into a logit function prior to analysis and subsequently treated as a continuous variable (Heck, Thomas, & Tabata, 2014; Singer & Willett, 2003). To aid in interpretation, coefficients associated with STEM graduation rates will be transformed back into percentages. In order to achieve a balance between complexity and accuracy, model selection was based on comparison of the Akaike information criterion (AIC) and the Bayesian Information Criterion (BIC). The deviance of the fitted model was also calculated to highlight significant differences between models. The findings for each research sub-question are discussed in separate sections and are grouped based on the addition of specific independent variables.

Descriptive Results

Table 4.1a, 4.1b, 4.1c, and 4.1d present baseline descriptive statistics for CSU campuses during the investigation timeframe. According the 2016 National Science Foundation (NSF) report, the national average of STEM graduation rates from 2010 to 2015 was 20.4% across all four-year, public institutions. By comparison (Table 4.1a), the

CSU system is overall performing above the national average, yet disparities remain between ethnic groups. SEA students had the highest average graduation rate (26.3%) and Black students had the lowest average graduation rate (12.8%) of the URM populations during the timeframe of the investigation. The Latinx student populations performed just below the average STEM graduation rate during the timeframe (18.9%). In comparison, both White and non-Southeast Asian student populations performed above the national average and consistently retained at least a fifth of students from their entering STEM cohort.

Table 4.1a

Basic CSU Campus Descriptive Statistics (N = 242; 22 campuses & 11 years)

Graduation Rates (GR)	Mean	Std. Dev.	Min	Max
STEM GR	24.8%	11.2%	3.1%	65.8%
Black GR	12.8%	14.4%	0%	100%
Latinx GR	18.9%	10.1%	0%	55.3%
Southeast Asian GR	26.3%	13.7%	0%	75%
White GR	42.4%	12.5%	19.7%	79.4%
Asian (Non-Southeast Asian) GR	39.6%	15.8%	21.2%	82.1%

Table 4.1b displays the campus resource allocations. Each was calculated using the Full-Time Enrolled (FTE) measurement and rounded to the nearest cent. This allows the analysis to determine how much financial support the campus allocated for each full-time enrolled student and their association to STEM graduation rates. The federal training grants provided the highest average amount of support during the timeframe of the investigation, while the least came from student services.

Table 4.1b

CSU Resource Allocations by FTE and Share of Salaries (N = 242; 22 campuses)

Resource Allocations by FTE	Mean	Std. Dev.	Min	Max
Instructional Support	$891.30	$477.46	$98.45	$1,788.98
Student Services	$223.25	$127.06	$25.72	$686.94
Federal Training Grants	$790.81	$364.27	$50.64	$1,286.46

Yet, the highest amount spent by a campus in one of these categories was instructional support (CSU-Fullerton, AY 2013), showing variation in spending for the allocation categories. Overall, CSU campuses allocated over three times as much resources toward instructional support and federal training grants than student services.

Further analysis of the proportion of educational expenditures dedicated to resource allocation categories showed a change in strategy pre- and post-Great Recession. Table 4.1c highlights the average proportional spending of campus resource allocations before and after the Great Recession for the CSU system. Values included in the table represent the percentage of a particular category dedicated to the specific category (not FTE calculation) for the annual budget and fiscal year. This allowed the analysis to determine the percent difference between pre- and post-Great Recession spending on staff, faculty, personnel, and other institutional aspects dedicated to the students and the success at the institution within each of the resource allocation categories.

Using the percent spending, this aspect negates some of the variation between large and small campus budgets, which vary based on size and status (Zumeta et al., 2012). Despite spending less per FTE on student services, the pattern showed that more proportion of the budget was dedicated to student services support. Additionally, prior to the Great Recession, CSU campuses were spending more on instructional support than after, showing a redirection away from instructional support. However after the Great Recession, the trend switched with CSU campuses spending more proportionally on student services and becoming a priority for CSU campuses over instructional support (Note: Overall spending and by campus spending tables are found in Appendix E).

Table 4.1c

CSU Pre- and Post-Great Recession Spending (N = 242; 22 campuses)

Resource Allocations by Salary Share of Budget	Ave AY 2006-2011	Ave AY 2012-2016	Difference
Instructional Support	49.14%	48.71%	-0.44%
Student Services	52.24%	60.39%	+8.15%
Federal Training Grants	12.22%	14.47%	+2.25%

Table 4.1d shows the descriptive statistics of CSU campuses' institutional characteristics during the timeframe of the investigation. Selectivity showed a broad range, with the high end close to flagship universities and the low end representing an open admissions policy, closely representing community colleges. The highest selectivity score for a CSU campus was 1242 by California Polytechnic, San Luis Obispo in AY 2014. In comparison, UC San Diego (1256) and UC Santa Barbara (1241) had similar scores using the same formula in AY 2013 (Doyle, 2015). This comparison shows a higher level of competition that mimics characteristics at research-intensive institutions. On the other end of the spectrum, the lowest selectivity score by a CSU campus was 825 by CSU Dominguez Hills. Translating the score into average entrance SAT scores, CSU Dominguez Hills accepts students with two-standard deviations below

the national average in SAT scores (CSU, 2016). This marker shows a dramatic range in institutional quality and highlights the significant institutional differences among comprehensive institutions.

Table 4.1d

Basic CSU Campus Descriptive Statistics (N = 242; 22 campuses & 11 years)

Institutional Characteristics	Mean	Std. Dev.	Min	Max	% of STEM
Selectivity	1013.63	72.22	825	1242	--
STEM Cohort Size (CS)	444.62	418.80	52	2583	--
STEM CS – Black	22.13	16.27	0	71	6.8%
STEM CS – Latinx	104.90	94.22	0	499	23.9%
STEM CS – SEA	119.15	118.91	2	568	18.6%
Full-Time Enrolled (FTE)	15265.96	8590.67	474.73	32079.53	--

STEM cohort size is another important institutional characteristic of CSU campuses. On average, there were approximately 445 students enrolled in STEM programs at CSU campuses, yet, three campuses (San Luis Obispo, Pomona, and Long Beach) enrolled a STEM cohort with over 1,000 students on average. In contrast, two campuses never reached over 100 students in any academic year (Dominguez Hills and Channel Islands). By ethnic groups, campuses enrolled Black students in STEM majors at the lowest levels while Latinx and SEA student performance displayed considerably larger levels of enrollments, with SEA students slightly higher in comparison. Additionally, the last column of Table 4.1c shows the percentage of URM students within that, on average, comprise STEM majors at CSU campuses. This comparison shows the total URM enrollment in STEM majors is just below half, however also highlighting

Asian and white students comprise the remaining half of STEM majors at CSU campuses. One difference shows the SEA population with the highest total STEM majors (Long Beach, AY 2014), yet the Latinx population having the highest average percent of STEM cohorts. The last row in Table 4.1c shows the Full-Time Enrolled (FTE) calculation, showing the overall enrollment of full-time students at CSU campuses (however, not used in the analysis).

Correlations

The correlation matrix shown in Tables 4.2 and 4.3 presents the Pearson correlation coefficient of the variables of interest. These highlight the pairwise relationships between the dependent variable and the independent variables of interest. Included are the overall STEM six-year graduation rates and the ethnic population graduation rates, as well as the covariates specifically related to resource allocations. Additionally, selectivity for CSU campuses is included in the table. Table 4.2 demonstrates a pattern of association among the overall graduation rates with all three ethnic groups. The strongest correlation with overall STEM graduation rate was Latinx graduation rates r = 0.64 ($p < 0.01$), which is considered a strong correlation relationship and the weakest relationship was with Black student STEM graduation rates r = 0.53 ($p < 0.01$), which is considered a moderate relationship (Shadish, et al., 2002).

Additionally, Table 4.2 suggests that student support is especially crucial for STEM graduation rates. Specifically, the pairwise relationship show that student support is significantly and positively related to overall, Black (r = 0.328, $p < 0.01$), and Latinx STEM (r = 0.262, $p < 0.01$) STEM graduation rates, despite being a weak relationship.

Table 4.2

Pairwise Correlations – STEM Graduation Rates (GR) and Resource Allocations (N = 242; 22 campuses & 11 years)

	STEM GR	Black GR	Latinx GR	SEA GR	Instructional Support	Student Support	NSF NIH	Selectivity
STEM GR	1.000							
Black GR	0.528*	1.000						
Latinx GR	0.644*	0.497*	1.000					
SEA GR	0.528*	0.464*	0.446*	1.000				
Instructional Support	0.189	0.235	0.177	-0.035	1.000			
Student Support	0.228*	0.328*	0.262*	0.167	0.699*	1.000		
NSF NIH	-0.072	0.140	0.021	-0.008	0.032	0.192	1.000	
Selectivity	0.739*	0.541*	0.595*	0.432*	0.158	0.173	-0.05	1.000

Note. Asterisk(s) next to variable name indicate(s) statistically significant pairwise relationship in Pearson correlation coefficient *$p < 0.01$. STEM = Science, Technology, Engineering, and Mathematics. GR = STEM six-year Graduation Rates. NSF & NIH = Federal Sponsored STEM Training Grant funding.

Table 4.3

Pairwise Correlations – STEM Graduation Rates (GR) and STEM Cohort Size (CS) (N = 242; 22 campuses & 11 years)

	STEM GR	Black GR	Latinx GR	SEA GR	Cohort Size (CS)	Black CS	Latinx CS	SEA CS
STEM GR	1.000							
Black GR	0.528*	1.000						
Latinx GR	0.644*	0.497*	1.000					
SEA GR	0.528*	0.464*	0.446*	1.000				
Cohort Size	0.564*	0.366*	0.439*	0.420*	1.000			
Black CS	-0.093	-0.339*	-0.153	-0.018	0.433*	1.000		
Latinx CS	0.357*	0.220*	0.269*	0.292*	0.743*	0.641*	1.000	
SEA CS	0.336*	0.149	0.178*	0.249*	0.766*	0.554*	0.704*	1.000

Note. Asterisk(s) next to variable name indicate(s) statistically significant pairwise relationship in Pearson correlation coefficient *$p < 0.01$. STEM = Science, Technology, Engineering, and Mathematics. GR = STEM six-year Graduation Rates. NSF & NIH = Federal Sponsored STEM Training Grant funding. CS = The size of the entering first-time, full-time STEM declared majors.

However, analyses found a non-significant relationship with Southeast Asian (r = 0.167, $p > 0.01$) STEM graduation rates. Selectivity shows strong relationships across all the graduation rates, yet not with the resource allocation strategies. Lastly, NIH and NSF training grant support is not significantly correlated with any of the STEM graduation rates or resource allocation strategies. Table 4.3 shows the pairwise correlations of the STEM cohort sizes with the various STEM graduation rates, including the overall rate and the rates among ethnic groups. The relationships between the ethnic graduation rates and the associated ethnic cohort sizes all appear significant and positive. Black student cohort size was the one exception, showing a significant, negative correlation (r = -0.339, $p < 0.01$).

Growth Modeling Results

Graduation rates – Model 1: Unconditional Model. Each set of research sub-questions build complexity to the unconditional growth model (Raudenbush & Bryk, 2002). The results for each set of questions are presented in their own table and an interpretation of the fixed- and random-effects follows. The first set of research questions pose a series of growth models to evaluate changes in overall STEM six-year graduation rates taking into account the relationships unique to Black, Latinx, and Southeast Asian STEM graduation rates with regards to overall STEM graduation rates. Table 4.4 shows the maximum likelihood (ML) results for the model building process for the unconditional growth model and piecewise growth models.

Model 1 (unconditional linear growth model) analyzes the rate of change or the average annual growth (or decline) in STEM graduation rates of the sample of CSU campuses. The AIC and BIC estimates indicate the baseline of the model fit (AIC = 136.33; BIC = 153.78), which will compare future models. The average STEM graduation rate of CSU campuses in 2006 was 19.2% (b = -1.44; SE = 0.11, $p < 0.001$), STEM graduation rates improved during the timeframe of the investigation, AY 2006 to AY 2016 (b = 0.05; SE = 0.01, $p < 0.001$). (Note: In the following section, initial status, intercept, average STEM graduation rate, and average STEM performance are used interchangeably).

Table 4.4

Piecewise Model Building - Graduation Rates & Great Recession (GR) 2006 to 2016 (N = 242)

Effects	Model 1 *b* (SE)	Model 2a *b* (SE)	Model 2b *b* (SE)	Model 2c *b* (SE)	Model 2d *b* (SE)
Initial Status					
Intercept	-1.438*** (0.11)	-1.465*** (0.11)	-1.345*** (0.11)	-1.373*** (0.11)	-1.373*** (0.11)
Intercept Post-GR		-0.118^ (0.06)		-0.220*** (0.06)	-0.220*** (0.06)
Rate of Change					
Time 1	0.047***	0.063***	0.007	0.027^	0.027^
Time 2: Pt-GtRc			0.080***	0.101***	0.101***
Random Effects					
Within	0.060***	0.059***	0.053**	0.049***	0.049***
Initial Status	0.258**	0.260**	0.255**	0.254**	0.254**
Time 1	0.002**	0.002**	0.002*	0.002**	0.002**
Status Pt-GtRc		0.000		0.000	
Time 2: Pt-GtRc			0.001*	0.001**	0.001**
Goodness-of-fit					
AIC	136.33	134.77	122.54	111.81	111.81
BIC	153.78	155.70	146.96	139.72	139.72
Deviance	126.33	122.77	108.54	95.81	95.81

AIC = Akaike information criterion; BIC = Bayesian information criterion. Full sample of all CSU Campuses, excluding CSU Maritime Academy. Likelihood ratio test (with scaling correction) based on comparison with previous model. Standard Errors (SE). Deviance tests an alternative model fit measurement.

^$p < 0.10$; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Converting the coefficient from log-odds ratio to a percentage, the resulting value facilitates interpretation for STEM graduation rates at CSU campuses. The initial status of -1.438 is in the log-odds metric (i.e., the natural logarithm (ln) of the odds ratio), which can be written as:

$$\textit{Log odds} = \ln(p/1\text{-}p)$$

However, to facilitate the interpretability of that value, it is converted back to the proportion/percentage metric, and value of 19.2%, using the following equation:

$$\textit{Percentage STEM graduation rate} = Exp(^{a+bX}) \,/\, [1 + Exp(^{a+bX})]$$

For the Model 1 growth, results indicate an expected average increase in STEM graduation rates from one academic year to the next (for example, AY 2006 to AY 2007) of approximately 0.8% and an overall increase of 9.3% during the course of the 11-year period of the investigation. Figure 4.1 provides a visual representation of the results.

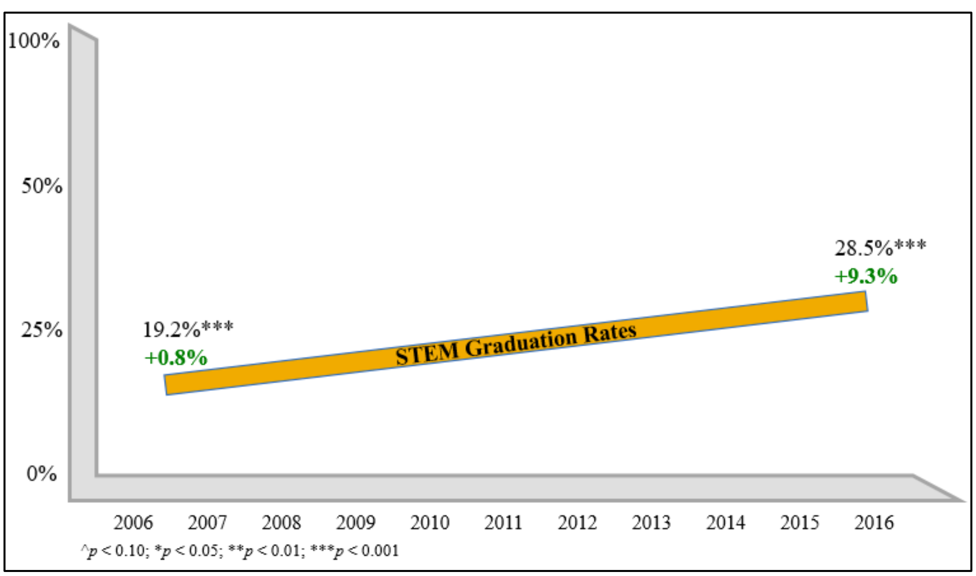

Figure 4.1.

Visual Representation of Model 1 Results

Specifically, the AY 2007 average performance is calculated as follows: -1.44 + 0.05 = -1.39, which converts to a rate of 19.9% in AY 2007. Additionally, the overall change is calculated by the formula: -1.44 + (0.05*11) = -0.92. This converts to a GR of 28.5% for AY 2016, with the difference between 19.2% in AY 2006 and 28.5% in AY 2016 equal to 9.3% increase. Following analyses will describe the percentage after the log odds ratio has been transformed using the above transformation and formulas. Examination of the variance components in Model 1 reveals that the variation in average STEM graduation rate in AY 2006 (the random intercept or the initial status) and growth rates of overall STEM performance between CSU campuses remain large, while the rates of change tend to be positive across CSU campuses.

Piecewise model with STEM graduation rates. The next research sub-questions are addressed using a series of growth models to evaluate changes in overall STEM six-year graduation rates broken into two separate phases, pre-Great Recession growth rate and incremental growth rate after the Great Recession (GtRc) occurred. Table 4.4 shows the results for the model building process and Figure 4.2 provides a visual representation of the piecewise growth models that were tested separately in each step of the modeling building process. Each subsequent model adds complexity from the unconditional growth model with piecewise terms, adding elevation, slope, and both parameters into the model to determine the approximate model fit to the data. Included in Table 4.4 are the results from each model estimated with ML and independent covariance structure (Raudenbush & Bryk, 2002; Singer & Willett, 2003).

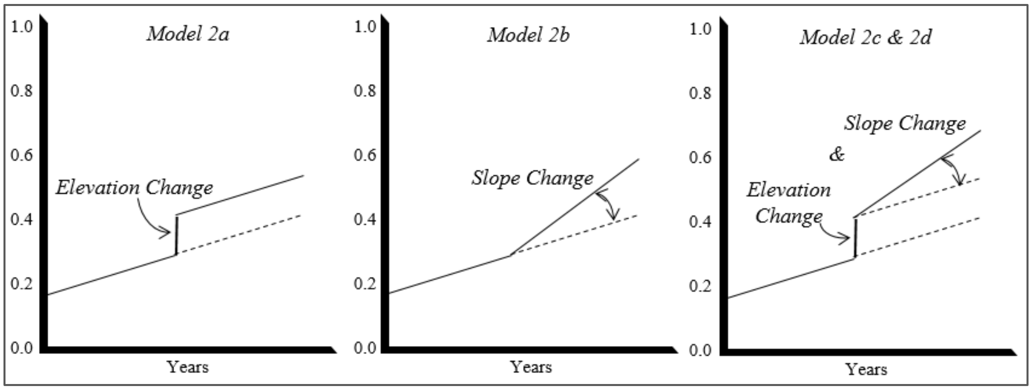

Figure 4.2.

Visual Representation of Model 2a, 2b, 2c, and 2d

Model 2a in examines the linear change for AY 2006 to AY 2016 with an elevation change at AY 2012, which represents the graduation year (see Figure 4.2, Model 2a). For most CSU campuses, the fiscal AY 2011 marks the year that the Great Recession impacted CSU budgets and therefore also the STEM graduation rates for AY 2011-2012. This model demonstrated a significantly improved model fit compared to the nested unconditional growth model with the addition of the elevation change in the slope ($\chi 2 = 21.73$, $p < .01$; AIC = 134.77; BIC = 155.70; Deviance = 122.77).

Although the unconditional model showed the average performance in AY 2006 at 19.2%, Model 2a showed overall STEM performance rates in AY 2006 was 18.8% ($b = -1.46$, SE = 0.11, $p > 0.001$) for an average CSU campus and remained statistically significant. Additionally, this model showed a higher growth rate for CSU campuses from AY 2006 to AY 2016 ($b = 0.06$, SE = 0.01, $p > 0.001$). Based on the formulas used for Model 1, results indicated 0.99% growth from year-to-year and an overall improvement of 12.95% from AY 2006 to AY 2011. The additional term of the intercept for the Great Recession was significant (b = -0.12, SE = 0.06, $p < 0.10$), indicating a significant decrease to 17.04% (-1.47 + -0.16 = -1.63), on average, in overall STEM graduation rates after the Great Recession (AY 2012). This indicates a negative impact of the Great Recession on CSU campuses on average.

Examination of the variance components between Model 2a and Model 1 showed the proportion of variance captured by adding the post-Great Recession intercept (see Table 4.5). The results indicated there was less than 0.01% more variance accounted for in the initial status in AY 2006 of CSU institutions than the unconditional growth model (Model 1). In the growth rates, Model 2a lost some variability when compared to Model 1, although this is common when adding an additional term into the model (Singer & Willett, 2003). Model 2a explained 1.8% more within-institutional variance. However, there still remains a significant amount of unaccounted for variance in the initial status of STEM graduation rates in AY 2006 as well as the growth rates of CSU institutions across the timeframe, whereas there was not as much variability between CSU campuses in the elevation change (see Table 4.4 – Random Effects).

Table 4.5

Proportion of Variance Explained: Unconditional Model to Model 2a

Effects	Initial Status[1]	Growth Rate[1]	Within CSU Institution
Unconditional Model	0.260	0.002	0.060
Model 2a	0.260	0.002	0.059
Variance Explained	>0.001%	-0.004%	1.8%

[1]Rounding of decimals causes estimates to look similar

Model 2b examines the linear change of STEM graduation rates in two phases, (1) AY 2006 to AY 2011 – which is the pre-Great Recession timeframe of the investigation and (2) AY 2012 to AY 2016 – which examines the incremental (or decremental) growth rate post-Great Recession of STEM graduation rates. Switching to the incremental growth model and excluding the elevation change at the onset of the Great Recession, Model 2b improved the model fit compared to the unconditional model ($\chi 2 = 29.27$, $p < .01$; AIC = 122.54; BIC = 146.96, Deviance = 108.54). Based on the addition of the piecewise growth parameter in Model 2b to the unconditional model, the initial status of overall STEM graduation rates in AY 2006 for CSU campuses increased to 20.6% and remains statistically significant ($b = -1.35$, SE = 0.11, $p < 0.001$). However, the growth rate for STEM graduation rates from AY 2006 to 2011 became non-significant; the rates only increased 1.1% over the six-year period and 0.1% per year ($b = 0.01$, SE = 0.02, $p > 0.05$); ($-1.34 + (0.007*6) = -1.81$). After the onset of the Great Recession, CSU campuses, on average, improved their overall STEM graduation rates by 8% ($-1.34 + ((0.01 + 0.08)*5) = -0.91$) from AY 2012 to AY 2016 and 1.6% per year. This displays a steeper slope after the Great Recession occurred rather than prior to the Great Recession for CSU campuses.

Examining the variance components (see Table 4.6), Model 2b accounted for more variability in both the initial status in AY 2006 (10.8%) and the within-institutional variability (1.6%). However, the growth rates of STEM graduation rates lost variability (-4.6%), indicating there is unexplained variability in the growth rates after accounting for the slope change in the trajectory after the Great Recession (Singer & Willett, 2003). The results demonstrated there was a break in the linear trajectory after the Great Recession by CSU institutions in STEM graduation rates. Despite improvement, some variability in AY 2006 STEM graduation rates remains unaccounted for, as is also the case for the variability in the growth rates of STEM graduation rates.

Table 4.6

Proportion of Variance Explained: Unconditional Model to Model 2b

Effects	Initial Status	Growth Rate*	Within CSU Institution
Unconditional Model	0.260	0.002	0.060
Model 2b	0.255	0.002	0.053
Variance Explained	10.8%	-4.6%	1.6%

*Rounding of decimals causes estimates to look similar

Model 2c added both slope and elevation change. Results indicated that the model fit is significantly better than the previous model ($\chi 2 = 41.10$, $p < .01$; AIC = 111.81; BIC = 139.72, Deviance = 95.81). The model examined the growth rate for AY 2006 to AY 2011 (pre-Great Recession), the growth rate for AY 2012 to AY 2016 (post-Great Recession), and the elevation change in AY 2012. Model 2c shows that the initial status of overall STEM graduation rates in AY 2006 for the CSU campuses remains similar to Model 2b at 20.2% and remains statistically significant ($b = -1.37$, SE = 0.11, $p < 0.001$). The growth rate from AY 2006 to AY 2011 was significant ($b = 0.03$, SE = 0.02, $p < 0.10$), with STEM graduation rates increasing 5.2% across the six-year period and 0.4% per year. In AY 2012, the overall STEM graduation rates at the onset of the Great Recession decreased, on average, at CSU campuses to 16.9% marking a 3.3% decline from AY 2006 ($b = -0.22$, SE = 0.06, $p < 0.001$), and remained statistically significant. The post-Great Recession growth rate continued to show a steeper and significant increase in STEM graduation rates ($b = 0.10$, SE = 0.02, $p < 0.001$). This showed the difference between the pre- and post-Great Recession growth rates;

graduation rates increased by 2.4% annually and 12.2% in the five years after the Great Recession (-1.37 + (0.10+0.03)*5) = -0.73; -0.73*exponent/1 + (-0.73*exponent) = 0.32; 0.32-0.20=0.12; 0.12/5 = 0.02). Although an improvement from Model 2b, the random effect for the post-Great Recession intercept did not show reason for inclusion.

Thus, Model 2d incorporated aspects from the previous models to complete the parsimonious model to examine the impact of the Great Recession on STEM graduation rates ($\chi 2 = 41.10$, $p < .01$; AIC = 111.81; BIC = 139.72, Deviance = 95.81). Figure 4.3 provides a visual representation of the results for Model 2d.

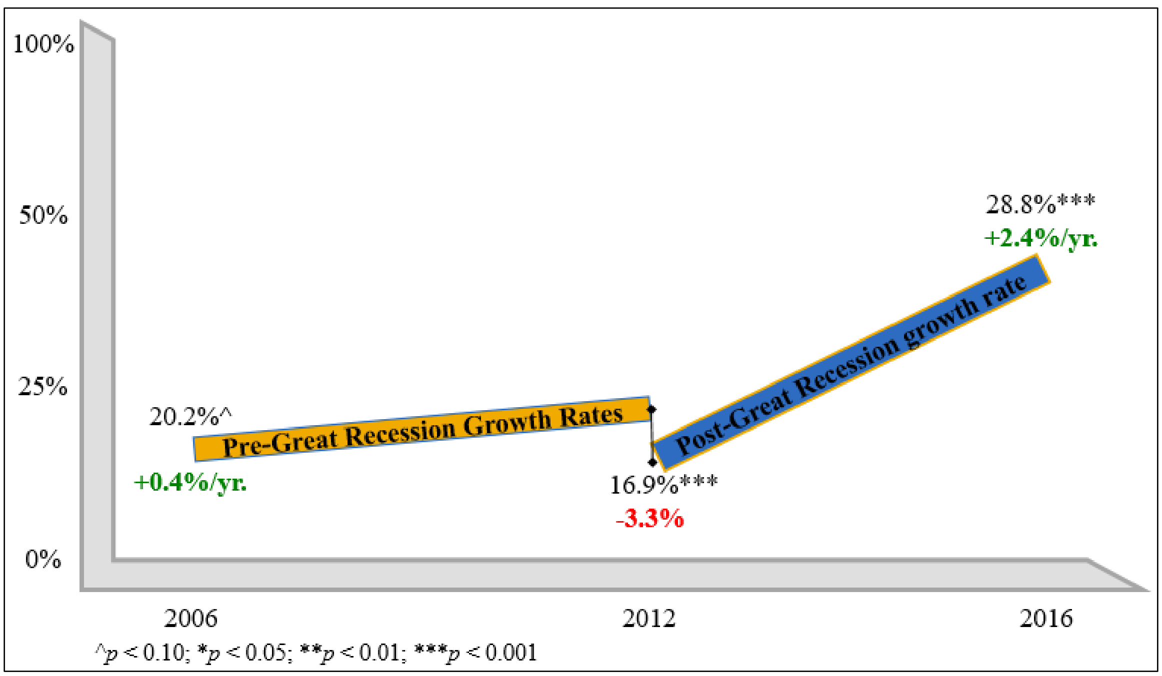

Figure 4.3.

Visual Representation of Model 2d Results

The coefficient estimates for Model 2d included the growth rate for AY 2006 to AY 2011 and AY 2012 to AY 2016, with an elevation change in AY 2012. In this model, the elevation change was fixed across CSU campuses, while the growth rates were allowed to vary randomly across CSU institutions. Such an approach facilitated examination of the growth rates across CSU campuses (Raudenbush & Bryk, 2002; Singer & Willett, 2003).

The coefficient estimates remained the same as in Model 2c. Therefore, an examination of the variance components from Model 2b and Model 2d showed that adding in a fixed post-Great Recession intercept resulted in a slight improvement in the amount of variance explained (see Table 4.7). Using Model 2b variance components, the comparisons showed losses of variability in growth rates from the same variance components and improvements to both the initial status in AY 2006 and within CSU institutional variability.

Model 2d accounted for more variability in both the initial status in AY 2006 (0.6%) and the within-institutional variability (7.2%). However, the pre-Great Recession growth rate showed losses in overall (-4.4%) and post-Great Recession (-36.1%). Although Model 2d showed losses in variability in both growth rates, both terms were significant. This improved the model fit overall justifying Model 2d as the base model to build additional complexity at level-2.

Table 4.7

Proportion of Variance Explained: Model 2b to Model 2d

Effects	Initial Status	Growth Rate Pre-GtRc[1]	Growth Rate Post-GtRc[2]	Within Institution
Model 2b	0.255	0.002	0.001	0.053
Model 2d	0.254	0.002	0.001	0.049
Variance Explained	0.6%	-4.4%	-36.1%	7.2%

[1]Rounding of decimals causes estimates to look similar
[2]Great Recession (GtRc)

Piecewise model with URM STEM Graduation Rates. The next research sub-question aims to address the extent to which URM STEM graduation rates were associated with overall STEM graduation rates. Model 3 included URM STEM graduation rates in the level-2 portion of the model. Initially, these variables were measured as the six-year STEM graduation rates for each population at each CSU campus for a particular academic year. To effectively answer the question, the URM graduation rates variable for the growth rate from AY 2006 to 2016 was the campus 11-year average for a specific URM population at a specific campus. In the post-Great Recession growth rate, the URM graduation rate variable was the campus five-year average for a specific URM population at a specific campus. This technique is used in other higher education literature to form a counterfactual representation of institutional success (Cheslock & Rio-Aguilar, 2011; Webber & Ehrenberg, 2010). Each URM population was entered into the model as grand mean centered.

For example, the Latinx student population for San Jose State University was averaged over 11-years and showed a 13.6% STEM graduation rate. This variable was entered into the model to examine the association of Latinx STEM graduation rates with the growth rate of overall STEM graduation rates (AY 2006-2011). For the post-Great Recession growth rate (AY 2012-2016), again using San Jose State, the six-year STEM graduation rate for Latinx students was 14.3%. The post-Great Recession Latinx STEM graduation rate variable was entered into the model to examine the association of URM STEM graduation rates with the post-Great Recession growth rates of overall STEM graduation rates after the Great Recession. Therefore, these variables were included into the level-2 portion of the model to examine the association between the various URM groups and their STEM graduation rates with the growth rates of overall STEM graduation rates across CSU campuses.

Conceptually, the aim of Model 3 was to examine the campus-level relationships of URM STEM performance on the growth rates in overall STEM graduation rates. This assessed the relationship between the overall STEM performance and URM STEM performance pre- and post-Great Recession. Results indicated differences in the directional relationships between the STEM performance of URM populations and the growth rates of overall STEM graduation rates before and after the Great Recession. The relationships between URM STEM populations with the growth rates of STEM performance revealed the extenuation and/or reduction of attainment gaps in the STEM pipeline brought on by the Great Recession (Singer & Willett, 2003).

Model 3 slightly improved the fit from Model 2d ($\chi2 = 120.61$, $p < .01$; AIC = 90.46; BIC = 149.77, Deviance = 56.46), with an improvement in the AIC and deviance measurement, but an increase in the BIC. In this model, the pre- and post-Great Recession performance were allowed to vary randomly across CSU institutions, with the elevation change in AY 2012 fixed across institutions. As described above, each of the URM STEM graduation rates were included as institutional-level variables to examine their unique relationships the initial AY 2006 status and pre- and post-Great Recession performance rates. Table 4.8 presents the results of Model 3, using a ML test for the estimates of the coefficients and a maximum likelihood test for model fit between previous growth models (Raudenbush & Bryk, 2002; Singer & Willett, 2003).

Table 4.8

Model 3 – Ethnic Graduation Rates & Great Recession (GR) 2006 to 2016 (N = 242)

Effects	*b*	SE	t-Ratio
Initial Status			
Intercept	-1.373***	0.06	-22.64
Black Grad Rate	-0.958	1.38	-0.70
Latinx Grad Rate	2.539	1.61	1.58
SEA Grad Rate	3.261^	1.69	1.93
Time 1 – AY2006-2016			
Time 1	0.027^	0.01	1.89
Black Grad Rate	-0.492^	0.28	-1.75
Latinx Grad Rate	0.181	0.33	0.54
SEA Grad Rate	0.475	0.34	1.39
Time 2 – Post-GrRc: AY2011-2016			
Intercept	-0.220***	0.06	-3.66
Time 2	0.101***	0.02	4.99
Black Grad Rate	0.307	0.36	0.86
Latinx Grad Rate	-0.944*	0.45	-2.09
SEA Grad Rate	0.285	0.40	0.72
Goodness-of-fit			
AIC	90.46		
BIC	149.77		
Deviance	56.46		

AIC = Akaike information criterion; BIC = Bayesian information criterion. Full sample of all CSU Campuses, excluding CSU Maritime Academy. Likelihood ratio test (with scaling correction) based on comparison with previous model. Standard Errors (SE). Deviance tests an alternative model fit measurement.
^$p < 0.10$; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

The inclusion of the institutional URM STEM graduation rates for both the initial status and the piecewise growth reveals the initial status of average STEM graduation rates in AY 2006 is 20.2% and statistically significant ($b = -1.37$, SE = 0.06, $p < 0.001$). The results indicate that in AY 2006, the black student population showed a negative, albeit non-significant, relationship ($b = -0.96$, SE = 1.38, $p > 0.05$). This means that for each 0.11% increase in average STEM graduation rates, there would be a decrease of 1% in the black STEM graduation rates in AY 2006. The Latinx STEM graduation rates (b = 2.54, SE = 1.61, $p > 0.05$) had a positive, non-significant relationship with overall STEM graduation rates. Accordingly, a 1% increase in Latinx STEM graduation rates translates into a 0.56% increase in the average STEM graduation rates in AY 2006. The Southeast Asian population showed a significant, positive relationship (b = 3.26, SE = 1.69, $p <$ 0.10) with overall STEM graduation rates. As such, a 1% increase in Southeast Asian STEM graduation rates would show an increase of 0.66% in the average STEM graduation rates in AY 2006.

The pre-Great Recession growth rate (b = 0.03, SE = 0.01, $p < 0.10$) was 5.2% overall and an annual 0.4% increase. During the six-year period, only black students showed a significant relationship with overall STEM graduation rates. Black students showed a negative trend such that, as overall STEM graduation rates increased by 0.07%, the black student STEM graduation rates declined by 1% (b = -0.49, SE = 0.28, $p < 0.10$), at a campus with average STEM performance of Latinx and Southeast Asian students. Two non-significant relationships between overall STEM graduation rates and URM population are important to note. First, Latinx students showed a positive trend; STEM graduation rates were expected to increase 0.03% with an increase of 1% in Latinx STEM graduation rates (b = 0.18, SE = 0.33, $p > 0.05$) at a campus with average STEM performance of black and Southeast Asian students. Second, Southeast Asian students showed a positive trend, where STEM graduation rates were expected to increase 0.09% with an increase of 1% in Southeast Asian students STEM graduation rates (b = 0.48, SE = 0.34, $p > 0.05$) at a campus with average STEM performance of black and Latinx students. Notably, the black student population was the only statistically significant relationship any of the URM STEM populations before the Great Recession.

After the Great Recession, the average STEM graduation rate in AY 2012 (the elevation change) showed a significant reduction to 16.9% (b = -0.22, SE = 0.06, $p <$ 0.001). This marks a 3.3% drop in the average STEM graduation rates at CSU campuses at the onset of the Great Recession. However, after the Great Recession, the growth rates at CSU campuses showed a steeper overall trajectory of STEM performance. STEM graduation rates increased by 12.2% from AY 2012 to AY 2016 and 2.4% per year in the five years after the Great Recession (b = 0.10, SE = 0.02, $p <$ 0.001).

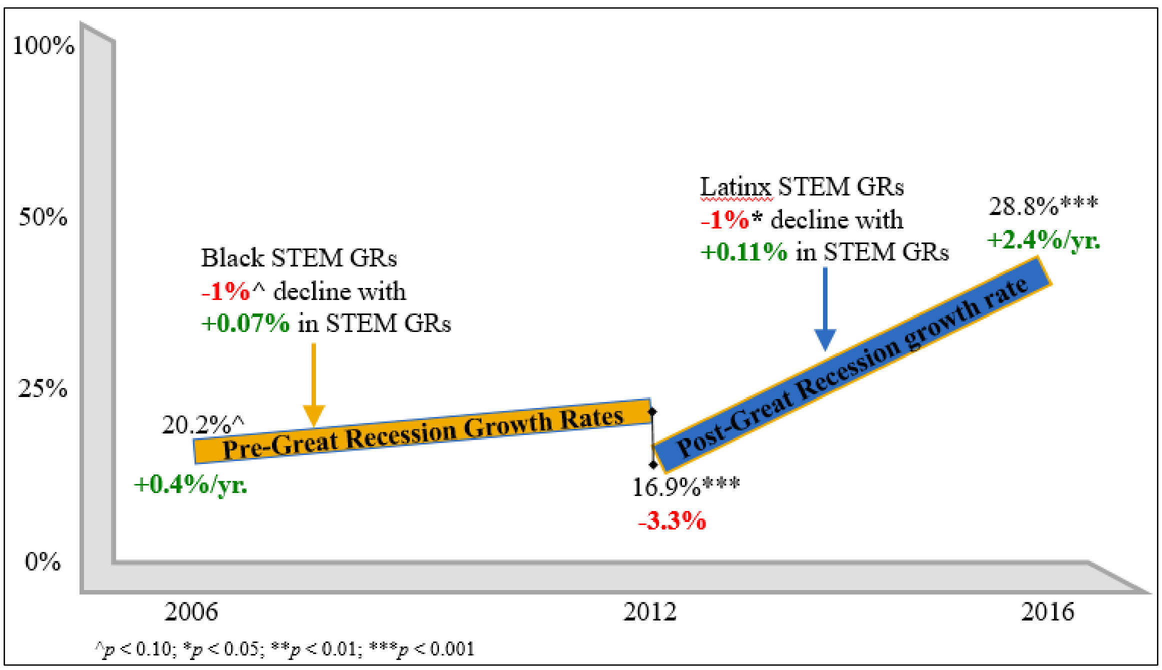

Figure 4.4.

Visual Representation of Model 3 Results

Only one of the URM STEM graduation rates after the Great Recession was significantly related to overall graduation rates. During the five-year period after the Great Recession, Latinx students showed a negative, significant trend, such that, the Latinx STEM graduation rates declined by 1% (b = -0.944, SE = 0.45, $p <$ 0.05) as overall STEM graduation rates increased by 0.11% at a campus with average STEM performance of black and Southeast Asian students. In contrast, the relationships between overall STEM graduation rates and the graduation rates of both black and Southeast Asian students were not significantly related to overall STEM graduation rates. Black students showed a positive relationship with overall STEM graduation rates after the Great Recession. Accordingly, STEM graduation rates were expected to increase 0.05% with an increase of 1% in black STEM graduation rates (b = 0.31, SE = 0.36, p > 0.05) at a campus with average STEM performance of Latinx and Southeast Asian students. The graduation rates of Southeast Asian students showed a positive relationship with overall STEM graduation rates, where overall STEM graduation rates were expected to increase 0.05% for a 1% increase in Southeast Asian students STEM graduation rates (b = 0.28, SE = 0.40, p > 0.05) after controlling for Latinx students and black students.

Comparison of the variance components from Model 2d to Model 3 (see Table 4.9) showed that the inclusion of the Great Recession and URM STEM graduation rates in the model explained a significant amount of variability in overall STEM graduation rates at CSU campuses.

Table 4.9

Model 3 – Variance Explained in Initial Status and Growth Rates (N = 242)

Effects	Initial Status	Growth Rate Pre-Great Recession*	Growth Rate Post-Great Recession*
Great Recession Model (2d)	0.254	0.0024	0.001
Conditional (Model 3)	0.055	0.0016	0.001
Proportion of Variance Explained	78.2%	31.9%	9.5%

*Rounding of decimals causes estimates to look similar

Specifically, the addition of URM STEM graduation rates into Model 3 accounted for 31.9% of the growth rate from AY 2006 to AY 2011 and 9.5% of the growth rate in overall STEM graduation rates after the Great Recession. The overall STEM performance in AY 2006 accounted for the most amount of variability (78.2%) in Model 3 in comparison to Model 2d.

Piecewise model with institutional variables. The next research sub-questions aimed to address the extent to which resource allocations and institutional characteristics were associated with STEM graduation rates. Model 4 included the resource allocation strategies in the level-2 portion of the model without institutional characteristics. Model 5 adds two institutional characteristics variables to Model 4. The aim of Model 4 was to examine the campus-level relationships of resource allocation strategies on the growth rates in overall STEM graduation rates.

Model 4 included student services, institutional support, and NIH and NSF training grant funding for each academic year. The variables are measured using the same approach as the URM STEM graduation rates; the variables associated with pre-Great Recession performance were averaged across the investigation and, for post-Great Recession, variables are averaged across the five-year period after the financial retention. These variables were calculated in terms of full-time enrolled (FTE) according to the Delta Cost Project formulas (Desrochers & Sun, 2015). Each variable was grand mean centered and entered into the model at level-2. Examination of the relationships between the overall STEM performance and resource allocations from (1) AY 2006 to 2011 and (2) after the Great Recession (AY 2012-2016) tied important funding mechanisms to

STEM performance at comprehensive institutions. Table 4.10 shows the results from Model 4 and Model 5.

Table 4.10

Model 4 & 5 – Resource Allocations, Institutional Characteristics, and Great Recession (GtRc) (N = 242)

Effects	Model 4		Model 5	
	b	SE	*b*	SE
Initial Status				
Intercept	-1.373***	0.11	-1.373***	0.07
Instructional Support	-7.147^	4.20	-0.252	3.08
Student Services Support	5.662	3.46	0.859	2.65
NIH/NSF Grants	0.695	5.88	-1.776	3.90
Campus Selectivity			0.006***	0.00
STEM Cohort Size			-0.001	0.00
Time 1: AY 2006-2016				
Growth Rate	0.027	0.02	0.027	0.02
Instructional Support	0.009	0.59	0.471	0.68
Student Services Support	0.595	0.46	0.090	0.55
NIH/NSF Grants	0.284	0.84	0.391	0.88
Campus Selectivity			0.000	0.00
STEM Cohort Size			0.000	0.00
Time 2: Post-GtRc: AY2011-2016				
Intercept	-0.220***	0.06	-0.220***	0.06
Post-GtRc Growth Rate	0.101***	0.02	0.101***	0.02
Instructional Support	0.034	0.75	-0.472	0.81
Student Services Support	-0.171	0.47	-0.062	0.50
NIH/NSF Grants	-0.251	1.14	-0.321	1.16
Campus Selectivity			-0.001^	0.00
STEM Cohort Size			0.000	0.00
Goodness-of-fit				
AIC	122.34		101.95	
BIC	181.66		182.19	
Deviance	88.34		55.95	

^$p < 0.10$; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Using the piecewise technique developed, the research sub-questions aimed to examine the relationships of resource allocation strategies and institutional characteristics with overall STEM graduation rates, before and after the Great Recession. Results for the model estimates in Table 4.10 report the restricted maximum likelihood (REML) coefficients and standard errors and ML for model fit. Model 4 included the resource allocation categories and piecewise term. The model showed no improvement in model fit compared to the nested model ($\chi 2 = 48.17$, $p < .001$; AIC = 122.34; BIC = 181.66, Deviance = 88.34). Additionally, results showed only one statistically significant relationship between the resource allocation strategies and the overall STEM graduation rates, while the remaining variables showed no significant relationships.

Model 4 results indicated the average STEM graduation rates was 20.2% for AY 2006 for an average CSU campus ($b = -1.37$, SE = 0.11, $p < 0.001$). Instructional support showed a negative, significant relationship ($b = -7.15$, SE = 4.20, $p < 0.10$), where an increase of 1% in instructional spending is expected to result in a decline of 0.2% in the initial status of AY 2006 when a campus spends average amounts on student services and training grant allocations. Neither student services support ($b = 5.66$, SE = 3.46, $p > 0.05$) nor NIH/NSF training grant funding ($b = 0.70$, SE = 5.88, $p > 0.05$) were significantly related to overall STEM graduation rates in AY 2006.

The growth rate from AY 2006 to AY 2011 ($b = 0.03$, SE = 0.02, $p > 0.05$) showed an annual increase of 0.4% per year and a 5.2% expected increase with average spending resource allocations. However, this relationship turned nonsignificant with the inclusion of resource allocations in the model from the previous unconditional growth model. Additionally, none of the resource allocation strategies showed a significant relationship to overall STEM performance growth rates. After the Great Recession, STEM graduation rates in AY 2012 again showed a significant decrease in the average STEM graduation rates to 16.9% ($b = -0.22$, SE = 0.06, $p < 0.001$). Similar to the previous model, this marks a 3.3% decline in the average STEM graduation rates at CSU campuses at the onset of the Great Recession. However, after the Great Recession, CSU campuses improved their overall STEM graduation rates more rapidly as indicated by the steeper slope of the growth rates after the Great Recession. STEM graduation rates increased by 2.4% per year from AY 2012 to AY 2016 and 12.2% increase across the five years after the Great Recession (b = 0.10, SE = 0.02, p < 0.001). However, Model 4 showed that none of the resource allocation strategies contributed to this trend. Figure 4.5 provides a visual representation of Model 4 results.

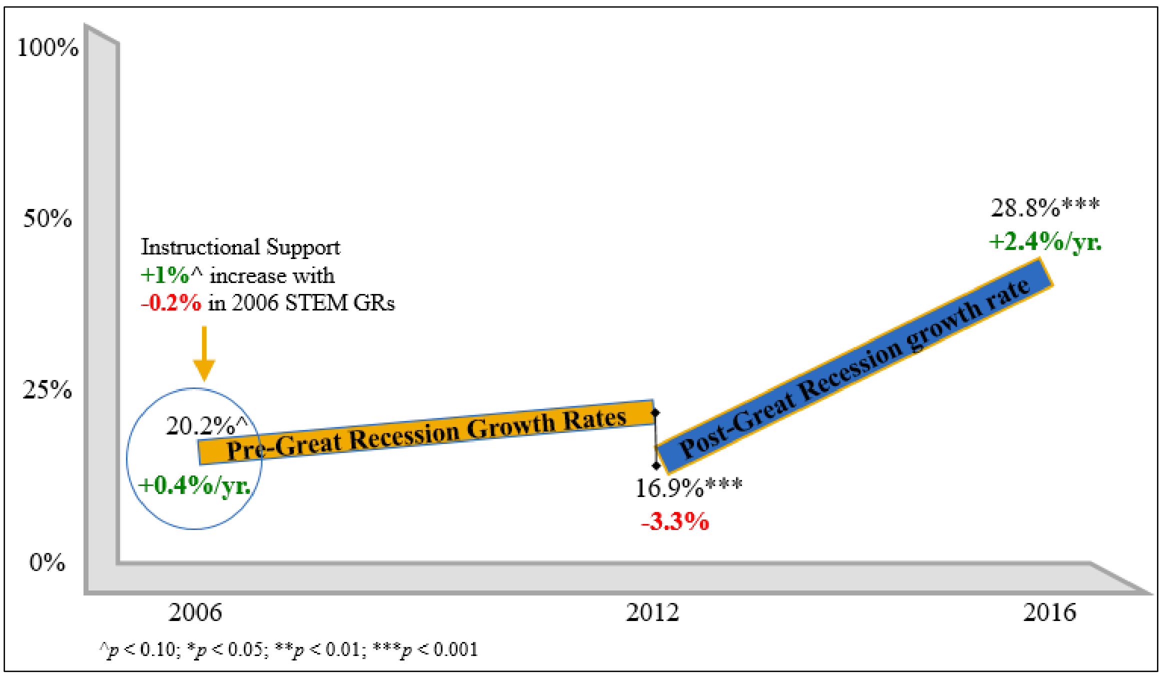

Figure 4.5.

Visual Representation of Model 4 Results

Model 5 addressed the research sub-questions regarding the relationship between resource allocation strategies and overall STEM graduation rates, while controlling for two institutional characteristics: (1) selectivity and (2) STEM cohort size. Model 5 showed an improved model fit compared to Model 4 based on the AIC and deviance statistics. However, it still did not improve the BIC nor show an improvement from Model 3 with URM graduation rates in the model ($\chi2$ = 130.19, p < .001; AIC = 101.95; BIC = 182.19, Deviance = 55.95). Importantly, the inclusion of institutional characteristics (mainly selectivity) negated the negative effect of instructional support from Model 4. Figure 4.6 provides a visual representation of Model 5 results.

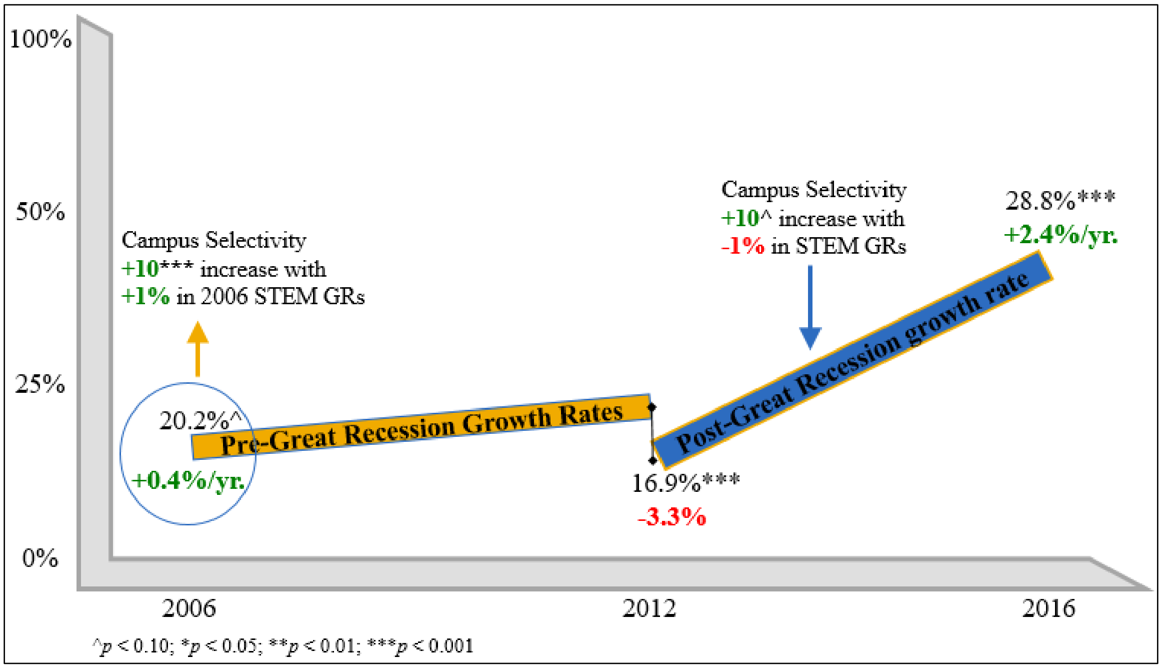

Figure 4.6.

Visual Representation of Model 5 Results

Results indicated the average STEM graduation rates for AY 2006 for an average CSU campus was 20.2% (b = -1.37, SE = 0.11, p < 0.001). After controlling for institutional characteristics, none of the resource allocation strategies were significantly related to overall STEM graduation rates in AY 2006, growth rates from AY 2006 to 2016, nor after the great Recession growth rates. However, selectivity showed a positive, significant relationship with overall STEM graduation rates in AY 2006 (b = 0.01, SE =

0.00, $p < 0.001$), with an expected increase of 0.11% in 2006 in cases where there was an increase in 10 point campus selectivity score at a campus with average institutional characteristics and spending. The STEM cohort size displayed a small, negative relationship with overall STEM graduation rates (b = -0.00, SE = 0.00, $p > 0.05$). Hence, a slight decrease of less than 0.1% would be accompanied by an increase of 10 students in the STEM cohort at a campus with average institutional characteristics and spending, but this was also non-significant.

The pre-Great Recession growth rate from AY 2006 to AY 2011 (b = 0.03, SE = 0.02, $p > 0.05$) showed a similar annual increase of 0.4% and a 5.2% expected increase with average spending resource allocations, but this relationship remained non-significant. Additionally, none of the resource allocation strategies nor the institutional characteristics showed a significant relationship with overall STEM performance growth rates. At the onset of the Great Recession, STEM graduation rates in AY 2012 again showed a significant decrease in the average STEM graduation rates to 16.6% (b = -0.22, SE = 0.06, $p < 0.001$). Similar to the previous model, this marks a 3.3% decline in the average STEM graduation rates at CSU campuses at the onset of the Great Recession.

Similar to trends observed in previous models, CSU campuses improved their overall STEM graduation rates more rapidly after the Great Recession, with growth rates showing a steeper slope. STEM graduation rates increased by 2.4% per year from AY 2012 to AY 2016 and by 12.2% across the five years after the Great Recession (b = 0.10, SE = 0.02, $p < 0.001$). Despite none of the resource allocation strategies nor the STEM cohort size showing a significant relationship, campus selectivity showed a significant, negative relationship that contributed to this steeper trend in STEM growth rates. Selectivity, after the Great Recession, showed that a 10-point selectivity increase would result in a decline of less than 0.01% per year and a 0.07% decline from AY 2012 to 2016.

Model 6 - Counter-narrative model: The final research sub-question aims to create and uncover patterns specifically among URM STEM graduation rates. To do so, URM STEM graduation rates are treated as the dependent variable. The model building process examines association of resource allocations with URM STEM graduation rates as a separate populations from the overall population. Building a model that represents the overall STEM population, the relationships examined capture only part of the context in which URM students engage in the STEM pipeline. Previous literature found that URM STEM students experience unique institutional barriers and roadblocks not faced by the overall STEM population (Chang et al., 2014; Museus, et al 2011). Using a critical quantitative and CRP-Ed approach, this counter-narrative model building aims to examine how the relationship between the URM STEM population and resource allocations is distinct from that with the overall STEM population (Carter & Hurtado, 2007; Rios-Aguilar, 2014; Stage, 2007).

Model 6 creates the counter-narrative model with the piecewise term for the Great Recession as well as the previous level-2 variables: (1) resource allocation strategies and (2) institutional characteristics. This is the final model and examines the URM STEM graduation rates separately from the overall STEM performance. The variables are measured using the same approach as the previous models. STEM performance growth rates were broken into two pieces in Model 6a, similar to the previous piecewise models: pre- and post-Great Recession. Table 4.12 uses Model 6a to compare the URM unconditional growth model. This developed a rebuilt model of the piecewise growth model with URM STEM graduation rates as the dependent variable.

Table 4.12

Piecewise Model Building – URM Graduation Rates & Great Recession (GR) 2006 to 2016 (N = 242)

Effects	Model 6 *b* (SE)	Model 6a *b* (SE)
Initial Status		
Intercept	-1.908*** (0.13)	-1.727*** (0.13)
Intercept Post-GR		0.153* (0.07)
Rate of Change		
Time 1	0.071***	-0.014
Time 2: Pt-GtRc		0.128***
Random Effects		
Within	0.095***	0.063**
Initial Status	0.317*	0.331**
Time 1	0.001**	0.005**
Status Pt-GtRc		
Time 2: Pt-GtRc		0.009**
Goodness-of-fit		
AIC	228.80	192.54
BIC	246.24	220.45
Deviance	218.80	176.54

AIC = Akaike information criterion; BIC = Bayesian information criterion. Full sample of all CSU Campuses, excluding CSU Maritime Academy. Likelihood ratio test (with scaling correction) based on comparison with previous model. Standard Errors (SE). Deviance tests an alternative model fit measurement.
^p < 0.10; *p < 0.05; **p < 0.01; ***p < 0.001

Model 6 follows the same interpretation as the unconditional linear growth model (Model 1) and analyzes the average annual growth (or decline) in URM STEM graduation rates within the sample of CSU campuses. The coefficients, AIC, BIC, deviance estimates indicate the baseline of the model fit (AIC = 228.80; BIC = 246.24;

Deviance = 218.80), which will compare future models, using a ML approach. The average URM STEM graduation rate in 2006 of CSU campuses was 12.9% (b = -1.91; SE = 0.13, $p < 0.001$), STEM graduation rates improved during the timeframe of the investigation, AY 2006 to AY 2016 (b = 0.07; SE = 0.01, $p < 0.001$). Results indicate average URM STEM graduation rates were increasing 0.8% per year and an overall increase of 11.5% during the course of the 11-year period of the investigation (-1.91 + (0.07*11) = -1.13). In comparison to the overall STEM graduation rates, URM students started the AY 2006 initial status lower than overall STEM population, but URM graduation rates increased at a steeper slope.

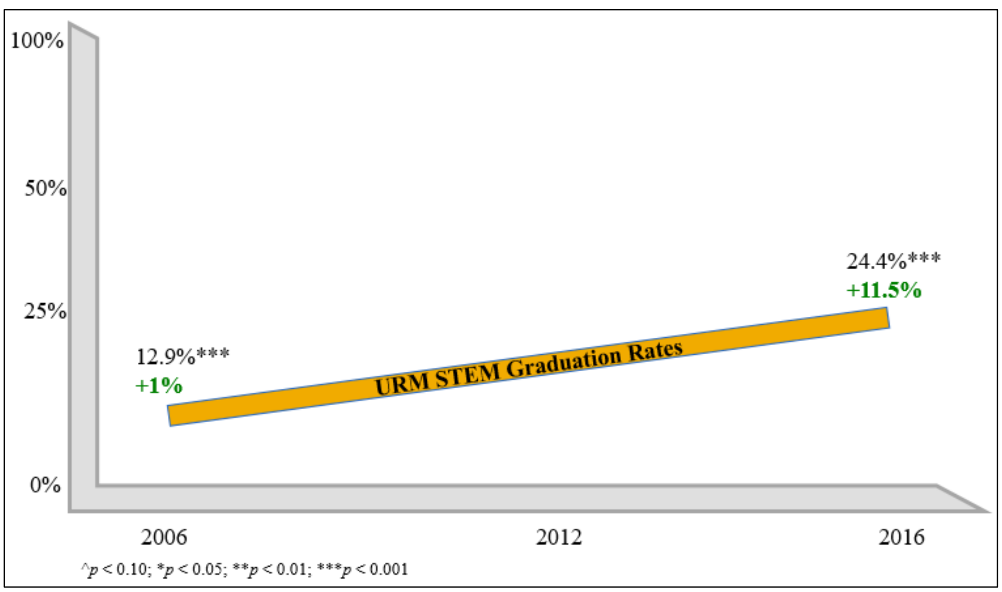

Figure 4.7.

Visual Representation of Model 6 Results

Piecewise model with URM STEM graduation rates. Model 6a uses the framework developed for Model 2d (piecewise growth rates and elevation change) and creates the piecewise model for URM STEM graduation rates. Table 4.12 shows the results for Model 6a that compares against the unconditional growth model (Note: Alternative models were tested and model 6a fit the data model effectively). Included in Table 4.12 are the results from each model estimated with maximum likelihood tests (Raudenbush & Bryk, 2002; Singer & Willett, 2003).

Model 6a incorporated aspects from the previous piecewise models to complete the parsimonious model to examine the impact of the Great Recession on STEM graduation rates ($\chi2 = 34.42$, $p < .01$; AIC = 192.54; BIC = 220.45, Deviance = 176.54). The coefficient estimates for Model 6a included the growth rates pre- and post-Great Recession, with an elevation change in AY 2012. In this model, the elevation change was fixed across CSU campuses, while the growth rates were allowed to vary randomly across CSU institutions (Raudenbush & Bryk, 2002).

Model 6a shows that the initial status of overall STEM graduation rates in AY 2006 for the CSU campuses was 15.1% and remains statistically significant ($b = -1.73$, SE = 0.13, $p < 0.001$). The growth rate from AY 2006 to AY 2011 turned non-significant with the inclusion of the growth rate after the Great Recession ($b = -0.01$, SE = 0.02, $p > 0.05$), with STEM graduation rates decreasing 0.2% per year and 1.9% across the 6-year period. In AY 2012, the overall STEM graduation rates at the onset of the Great Recession showed an average increase at CSU campuses to 17.2%, marking a 2.1% increase from AY 2006 ($b = 0.15$, SE = 0.07, $p < 0.05$). This relationship remained statistically significant, but did not vary across CSU campuses. The difference between the post-Great Recession and pre-Great Recession growth rate also showed a steeper and significant increase in URM STEM graduation rates ($b = 0.13$, SE = 0.03, $p < 0.001$). On average, URM STEM graduation rates at CSU campuses were increasing by 1.8% annually and 8.8% in the five years after the Great Recession (-1.73 + ((0.13 + -0.01*5) = -1.16; -1.16*exponent/1 + (-1.16*exponent) = 0.24; 0.24-0.15=0.09; 0.09/5 = 0.02). Figure 4.8 shows a visual representation of the Model 6a results.

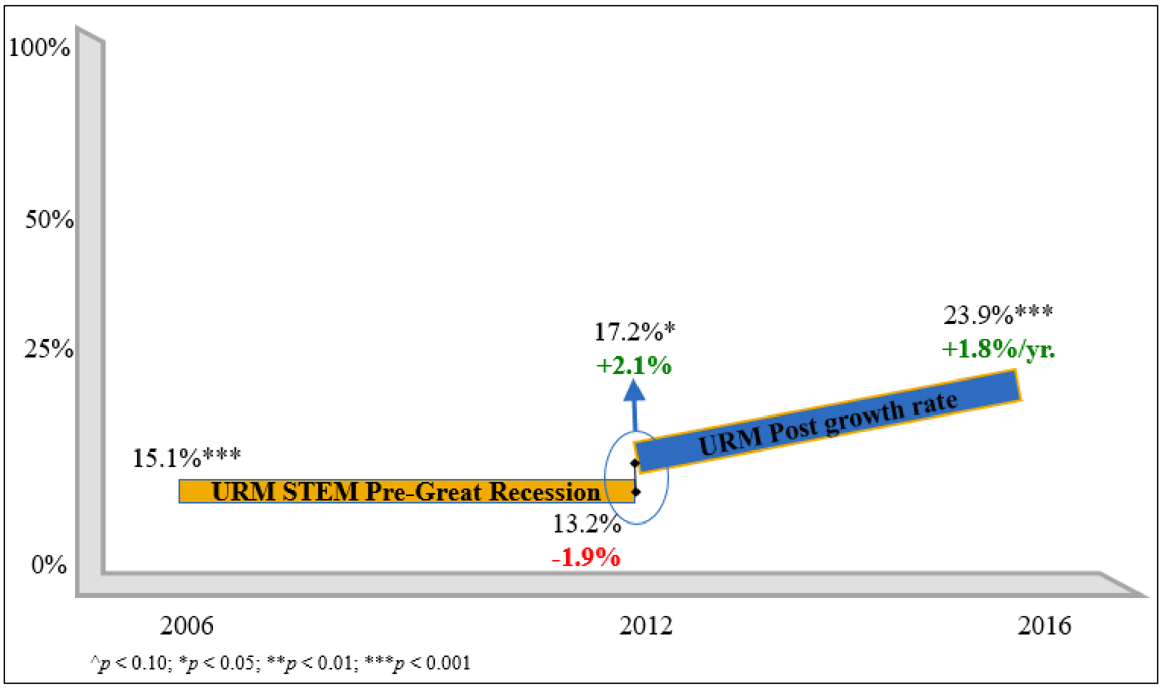

Figure 4.8.

Visual Representation of Model 6a Results

URM GRs Piecewise model with institutional variables. The next models aimed to address the extent to which resource allocations and institutional characteristics were associated with URM STEM graduation rates. The goal of these final two models was to compare Model 4 and 5 to Model 6b and 6c. Model 6b included student services, institutional support, and NIH and NSF training grant funding for each academic year using the same approach as Model 4. Examination of the relationships between URM

STEM performance and resource allocations before and after the Great Recession tied important funding mechanisms that are unique to URM STEM populations at comprehensive institutions. Table 4.13 shows the results from Model 6b and Model 6c.

Table 4.13

Model 6b & 6c – URM STEM GRs, Resource Allocations, Institutional Characteristics, and Great Recession (GtRc) (N = 242)

Effects	Model 6b		Model 6c	
	b	SE	*b*	SE
Initial Status				
Intercept	-1.727*	0.12	-1.727*	0.07
Instructional Support	-2.581	4.68	5.708^	3.24
Student Services Support	7.493^	3.84	2.167	2.72
NIH/NSF Grants	3.453	6.55	-0.410	4.11
Campus Selectivity			0.007***	0.00
STEM Cohort Size			-0.001**	0.00
Time 1: AY 2006-2016				
Growth Rate	-0.014	0.02	-0.014	0.01
Instructional Support	-1.195*	0.58	-0.861^	0.52
Student Services Support	-0.232	0.43	-0.675^	0.37
NIH/NSF Grants	-1.128	0.84	-0.659	0.73
Campus Selectivity			0.000	0.00
STEM Cohort Size			0.000***	0.00
Time 2: Post-GtRc: AY2011-2016				
Intercept	0.153*	0.07	0.153*	0.07
Post-GtRc Growth Rate	0.128***	0.02	0.128***	0.02
Instructional Support	0.827	0.75	-0.025	0.66
Student Services Support	1.092*	0.47	1.389**	0.39
NIH/NSF Grants	1.487	1.18	0.621	1.04
Campus Selectivity			-0.001*	0.00
STEM Cohort Size			-0.000**	0.00
Goodness-of-fit				
AIC	196.88		158.06	
BIC	256.19		238.31	
Deviance	162.88		112.06	

^$p < 0.10$; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Using the piecewise technique developed, the research sub-questions aimed to examine the relationship of resource allocation strategies and institutional characteristics with URM STEM graduation rates, before and after the Great Recession. Results for the model estimates in Table 4.13 report the ML coefficients and standard errors. Model 6b included the resource allocation categories and piecewise term. This model showed significant improvement in model fit compared to the nested model ($\chi2$ = 72.42, $p < .001$; AIC = 196.88; BIC = 256.19, Deviance = 162.88).

Results indicated the average URM STEM graduation rates for AY 2006 was 15.1% for an average CSU campus (b = -1.73, SE = 0.12, $p < 0.001$). These models reveal some new relationships. Student services support showed a positive, significant relationship (b = 7.49, SE = 3.84, $p < 0.10$). Accordingly, a 1% increase in the share of student services-related spending is expected to result in an increase of 0.9% in the average URM STEM graduation rates in AY 2006 when a campus spends average amounts on instructional support and NIH/NSF training grants. Figure 4.9 shows a visual representation of the Model 6b results.

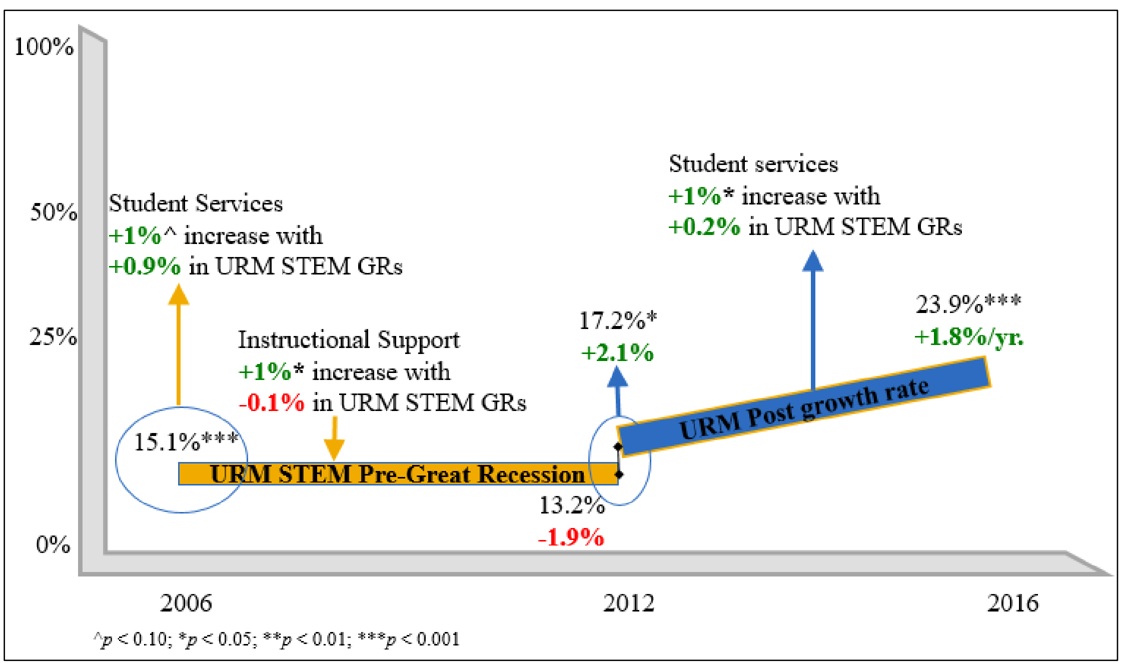

Figure 4.9.

Visual Representation of Model 6b Results

In AY 2012, the URM STEM graduation rates at the onset of the Great Recession showed an average increase at CSU campuses to 17.2%, marking a 2.1% increase from AY 2006 ($b = 0.15$, SE = 0.07, $p < 0.05$). After the Great Recession, the URM STEM performance growth rates displayed a steeper, significant slope ($b = 0.13$, SE = 0.02, $p < 0.001$). On average, URM STEM graduation rates at CSU campuses increased by 1.8% annually and 8.8% in the five years after the Great Recession. Additionally, student services support was positively related to the post-Great Recession growth rates ($b = 1.09$, SE = 0.47, $p < 0.05$). This translates into an increase of 0.2% per year and 0.8% from AY 2012 to 2016 in average URM STEM graduation rates for each 1% increase student services support spending when a campus spends average amounts on instructional support and NIH/NSF training grants. Instructional support showed a significant, negative relationship with the overall growth rate from AY 2006 to 2016 ($b = -1.20$, SE = 0.58, $p < 0.05$). Accordingly, an increase of 1% in instructional support related spending is expected to result in a decrease of 0.1% per year in the URM STEM graduation rate and a total decline of 0.2% from AY 2006 to 2016, when a campus is spending average amounts on student services and training grant allocations.

Model 6c included the resource allocation categories, institutional characteristics, and piecewise term; similar to Model 5. Selectivity measured the same aspect of the institution, but the STEM cohort size changed from all STEM declared major students in the cohort to the number of URM declared STEM major students in the cohort. This model showed significant improvement in model fit compared to the nested model ($\chi2 = 196.24$, $p < .001$; AIC = 158.06; BIC = 238.31, Deviance = 112.06). Results indicated the average URM STEM graduation rate for AY 2006 for an average CSU campus did not change from the previous model and remained 15.1% (b = -1.73, SE = 0.12, $p < 0.001$). Figure 4.10 provides a visual representation of Model 6c that highlights the significant relationships.

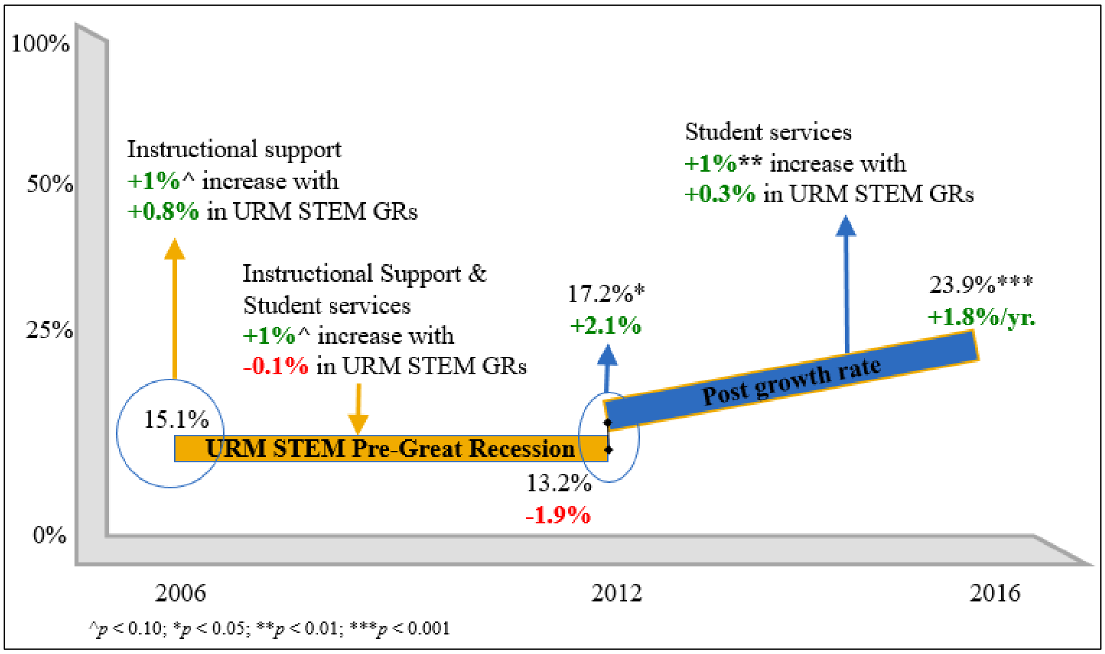

Figure 4.10.

Visual Representation of Model 6c Results

The new relationships in Model 6c revealed instructional support variables and institutional characteristics variables were significantly related to the URM STEM performance in AY 2006. Instructional support showing a positive, significant relationship with URM STEM graduation rates (b = 5.71, SE = 3.24, $p < 0.10$). Accordingly, an increase of 1% spending on instructional spending is expected to result in an increase of 0.8% in the average URM STEM graduation rates in AY 2006 when a campus has average spending and institutional characteristics. Selectivity also showed a positive, significant relationship with URM STEM graduation rates (b = 0.01, SE = 0.00, p < 0.001), where an increase in 10-point selectivity score resulted in a 0.9% increase in the AY 2006 URM STEM graduation rates when a campus has average spending and institutional characteristics. The URM STEM cohort size showed a significant, negative relationship with URM STEM graduation rates. Accordingly, an increase of 10 URM STEM students in AY 2006 would result in less than a 0.1% decline in URM STEM graduation rates.

The URM STEM performance growth rate of no significant growth, with a slightly negative trend. After accounting for selectivity and URM STEM cohort size, instructional support remained negative and showed an increase in 1% spending would result in a 0.1% decline per academic year (b = -0.86, SE = 0.52, p < 0.10), when spending the average amount and displaying average institutional characteristics. Additionally, student services showed a negative relationship (b = -0.68, SE = 0.37, p < 0.10), where an increase of 1% in student services related spending would result in a less than 0.1% decline per academic year. The URM STEM cohort size showed a positive relationship (b = 0.00, SE = 0.00, p < 0.001), where an increase in the cohort of 10 URM STEM students would result in less than a 0.1% increase in URM STEM graduation rates.

In AY 2012, the average URM STEM graduation rate at the onset of the Great Recession showed an increase, on average, at CSU campuses to 17.2%, marking a 2.1% increase from AY 2006 (b = 0.15, SE = 0.07, p < 0.05). After the Great Recession, the URM STEM performance growth rates displayed a steeper, significant slope (b = 0.13, SE = 0.02, $p < 0.001$). On average, URM STEM graduation rates at CSU campuses were increasing overall graduation rates by 1.8% annually and 8.8% in the five years after the Great Recession.

Instructional support was no longer significantly related to URM STEM graduation rates ($b = -0.03$, SE = 0.66, $p < 0.05$) after the Great Recession. However, student services displayed a stronger, positive association after the Great Recession with URM STEM graduation rates ($b = 1.39$, SE = 0.39, $p < 0.01$), where an increase of 1% in student services-related spending is expected to be associated with a 0.3% in URM STEM graduation rates and 0.9% from AY 2012 to 2016. In contrast, the two institutional characteristics showed negative relationships with URM STEM graduation rates after the Great Recession. Campus selectivity was a significantly and negatively related to URM STEM graduation rates ($b = -0.00$, SE = 0.00, $p < 0.05$), although the magnitude of the effect is quite small. Accordingly, an increase of 10 in selectivity score would result in less than a 0.1% decrease in URM STEM graduation rates. STEM cohort size also showed a new significant association, with a negative relationship with URM STEM graduation rates after the Great Recession ($b = -0.00$, SE = 0.00, $p < 0.01$), where an increase in 10 URM STEM students in the cohort would result in a decrease in URM STEM graduation rates by 0.01% and a 0.07%, when a campus with average selectivity spends average amounts.

Chapter 5

Discussion and Conclusion

A healthy STEM pipeline depends on the success of comprehensive institutions producing STEM degrees coupled with underrepresented minority (URM) students graduating in increased numbers (Allen-Ramdial & Campbell, 2014; Carnevale et al., 2011; Schneider & Deane, 2015). Despite the growth of enrollment in STEM disciplines overall, coupled with the influx of URM students enrolling in the STEM pipeline, subsequent increases in STEM degree completion have lagged, thereby causing alarm among economists, educators, and policy analysts (Cannady et al., 2014). There has been a substantial amount of research seeking to uncover barriers to STEM degree production (Baum et al., 2013; Hurtado et al., 2011; Maltese & Tai, 2010; Museus et al., 2011; Xie & Killewald, 2012). However, the focus strays away from comprehensive institutions and trends towards the ends of the higher education spectrum – community colleges and flagship institutions (Henderson, 2009; Ogren, 2005). Additionally, previous research found a significant effect of spending at the institutional level on graduation rates, with respect to institutional characteristics (Webber & Ehrenberg, 2010). Incorporating previous research regarding STEM pipeline success and institutional expenditures, this investigation explored three types of resource allocation strategies to determine which types of resources are related to STEM graduation rates at comprehensive institutions.

This chapter begins with a summary of the key findings from the current investigation organized by topic and research question. This is followed by a discussion of the findings placed within the broader context of prior literature, the STEM pipeline, and higher education. Next, implications of the findings are reviewed, with a particular focus on the policy and equity implications using a Critical Race Praxis for Education (CRP-Ed) and critical quantitative lens in higher education. This chapter finishes with a discussion of the limitations of this investigation and suggested directions for future research with a particular focus on federal STEM training programs.

Summary of Key Findings

This multilayered investigation examined the ramifications of decisions and strategies used by comprehensive campuses to increase and maintain STEM student performance. The behaviors of these institutions have largely been reactionary, as policy changes and budget cuts have forced universities to make decisions about resource allocation. Based on the models developed from the research questions, several findings bring to light alternative perspectives of the STEM pipeline and institutional resources that are related to STEM graduation rates. Findings were organized based on three overall topics: overall STEM graduation rates, URM STEM graduation rates, and relationships between resource allocations and STEM graduation rates.

The two primary research questions which guided this investigation:

1. To what extent did the Great Recession have an impact on STEM graduation rates at comprehensive institutions?
2. To what extent are various forms of resource allocations associated with STEM graduation rates and URM STEM graduation rates at comprehensive institutions?

Therefore, the main goals of this investigation were to: (1) examine the differences in STEM performance between comprehensive institutions with special attention given to the Great Recession; (2) explore the relationship between overall STEM graduation rates and URM STEM graduation rates; (3) and assess the relationships between resource allocation strategies and both overall and URM STEM graduation rates, while accounting for institutional characteristics.

This section provides three tables that summarize the key findings and closes with a discussion of the major findings pertaining to these relationships. The numbers listed in the tables pertain to the sub-questions listed at the beginning of chapter three (see Table 5.1, 5.2, & 5.3). To answer the research questions, it was necessary to explore the different relationships between CSU institutions and the effect of the Great Recession on overall and URM STEM graduation rates, while adding other institutional characteristics, URM STEM graduation rates, and resource allocation strategies in a stepwise fashion. Table 5.1 summarizes the important findings regarding overall STEM graduation rates.

Table 5.1

Summary of Findings for Overall STEM Graduation Rates (GR)

Research Question*	Key Finding(s)
1. Differences in growth rates for six-year STEM GRs at CSU campuses.	- There were significant differences found in STEM GRs between CSU campuses. Although the model did not account for added variability in growth rates, the final model accounted for 0.6% between campus differences in AY 2006 GRs
2. Change in overall STEM GRs before and after the Great Recession.	- At the onset of the Great Recession, the average STEM GRs significantly decreased across campuses (3.3%); the impact was approximately the same across the CSU system. - STEM GRs growth rates showed a significant steeper in slope after the Great Recession.

Note: Full sample of all CSU Campuses were 22, sampled excluded CSU Maritime Academy. Years included academic year (AY) 2006-2016
*Research questions shortened to highlight the topical aim of the question.

Broadly, this investigation found CSU campuses evolved over time, adapting campus culture and climate with organizational behaviors, such as resource allocation strategies. This aids in developing new approaches for spending on STEM pipeline issues by providing insight into the unique relationships within comprehensive institutions that propels STEM and URM STEM populations to graduate. The Great Recession pushed CSU campuses in different directions, as evinced in the varying performance and spending decisions between campuses.

Assessing URM STEM graduation rates was another important aim of this investigation. Three URM populations were included as independent variables in the analysis: (1) Black, (2) Latinx, and (3) Southeast Asian. Each were included as independent variables to assess connections between each population and overall STEM graduation rates. Table 5.2 summarizes the findings regarding URM STEM graduation rates and their relationships to overall STEM graduation rates.

This investigation substantiates previous STEM pipeline research on URM students regarding black, Latinx, and Southeast Asian STEM populations being marginalized during times of financial pressures (Chen & Soldner, 2013; Crisp et al., 2009; Williams, 2014). Both black and Latinx students were found to have significant negative relationships to the overall STEM performance growth rates; black students were negatively associated with the growth rate from AY 2006 to 2016 and Latinx students were negatively associated with the growth after the Great Recession. Although the graduation rates of Southeast Asian students were positively related to the overall STEM performance in AY 2006, there was no significant relationship between either of the growth rates of STEM graduation rates with Southeast Asian students. Adding the URM populations to the model accounted for the greatest amount of variability in overall STEM graduation rates, the negative relationships with black and Latinx students highlights the need to more fully explore URM populations at comprehensive institutions.

Table 5.2

Summary of Findings for Ethnic Graduation Rates (GRs) as Independent Variables

Research Question*	Key Finding(s)
3. Relationships between black, Latinx, and Southeast Asian STEM GRs and overall STEM GRs	- Black students showed a negative relationship to overall STEM performance growth rates from AY 2006-2016 - SEA students show no significant relationships to either growth.
3. Black, Latinx, and Southeast Asian STEM GRs and overall STEM GRs <u>after the Great Recession</u>	- Latinx populations showed a significant negative relationship to overall STEM graduation rates after the Great Recession. - URM STEM GRs accounted for 40% of variability in STEM growth rates after the Great Recession.

Note: Full sample of all CSU Campuses were 22, sampled excluded CSU Maritime Academy. Years included academic year (AY) 2006-2016
*Research questions shortened to highlight the topical aim of the question.

The next set of findings converged resource allocation categories together with URM STEM graduation rates and added institutional characteristics. The relationships between three types of resource allocation categories and overall STEM graduation rates were examined: (1) instructional support; (2) student services; and (3) NIH and NSF federal training grant funding. Each was entered into the model separately to understand the unique relationships different resource allocation categories may have with overall STEM graduation rates.

Table 5.3 provides a summary of the findings regarding resource allocations and institutional characteristics. CSU campuses utilized different resource allocation strategies before and after the Great Recession, however only instructional support resulted a negative relationship for AY 2006. None of the other resource allocations showed significant relationships with overall STEM graduation rates at CSU campuses. This contrasted with previous research on student services, instructional support, and STEM success (Gansemer-Topf & Schuh, 2003; Webber, 2012; Zhang, 2008), thus warranting further research into the nature of this relationship with URM STEM graduation rates.

Table 5.3

Summary of Findings for Resource Allocations

Research Question*	Key Finding(s)
4. Relationships between STEM GRs and resource allocations, accounting for the Great Recession	- In AY 2006, CSU campuses started with lower STEM GRs with higher levels of instructional support. - Student services and NIH/NSF training grants did not show a significant relationship with STEM GRs in AY 2006 or growth rates. - After the Great Recession, CSU campuses spent more overall and proportionally on student services than instructional support and NIH/NSF training grants.
5. Relationships between STEM GRs and resource allocations, controlling for institutional characteristics	- Selectivity showed a positive significant relationship with STEM GRs in AY 2006, however a negative relationship after the Great Recession. - STEM cohort size did not show any relationship to STEM graduation rates.

The final set of findings aimed to test the previously built models with the URM STEM graduation rates as a collapsed dependent variable. Specifically, black, Latinx, and Southeast Asian students were combined into a URM STEM graduation rate variable to examine resource allocation strategies before and after the Great Recession. Despite starting with a lower STEM graduation rate in AY 2006 and showing a non-significant negative trend, the URM populations showed steeper and more consistent upward trajectory. Table 5.4 provides a summary of the findings regarding the modeling building and the important resource allocation findings.

Table 5.4

Summary of Findings for Resource Allocations

Research Question*	Key Finding(s)
6. URM STEM GRs before and after the Great Recession	- URM STEM GRs started with lower performance in AY 2006 than overall STEM GRs. - URM STEM GRs did not have a significant growth rate overall (AY 2006-2016). - However showed a steeper growth rate after the Great Recession. - At the onset of the Great Recession, URM STEM GRs significantly increased, as opposed to declining (in the case for overall STEM GRs).
6. URM STEM GRs relationships between resource allocations, controlling for institutional characteristics	- Selectivity showed a positive significant relationship with URM STEM GRs in AY 2006, however a negative relationship after the Great Recession. - URM STEM cohort size showed a negative relationship to URM STEM graduation rates in AY 2006 and after the Great Recession, however a positive relationship to the URM STEM performance growth rate from AY 2006-2016.

Discussion and Findings in Context

Overall STEM graduation rates. Since this research was focused specifically on the CSU system, a subset of comprehensive institutions, it was important to examine the extent to which the Great Recession had an impact on overall STEM graduation rates. Consequently, separate research questions were examined to ascertain whether there were differences between CSU campus' STEM graduation growth rates before and after the Great Recession, with regard to other institutional characteristics and various URM

STEM graduation rates at CSU campuses. These initial research questions served to provide basic analysis of STEM performance across the CSU system included in the sample. Three findings regarding overall STEM six-year graduation rates emerge as important aspects of institutional learning and adaption to environmental factors.

First, the differences found between CSU campuses in STEM six-year graduation rate performance further confirms the diversity and variation among comprehensive institutions, where often they are ill-defined and/or grouped together negating comparisons within this categorical group of institutions. Previous organizational studies examining the boundaries that divide or categorize comprehensive institutions do not account for the unique characteristics within the larger group. By grouping comprehensive institutions together, research has missed important institutional distinctions in terms of services that comprehensive campuses provide to students, specifically those available to URM students (Fryar, 2015; Hurtado et al., 2011). Additionally, the general grouping of comprehensive institutions together without consideration of different aspects of the campus climate, culture, and practices penalizes institutions when using measurements that benefit research-intensive institutions.

For example, results from basic descriptive statistics (see Table 4.1d) showed evidence of the breadth of the CSU system reached selectivity scores of research-intensive institutions, while also showing selectivity ratings of community colleges, with other campuses in between this range. Additionally, the pairwise correlations (see Table 4.2) of selectivity showed relationships between STEM performance and overall graduation rates and in URM populations. A positive selectivity relationship would have been expected based on previous organizational research and theory. Thus, it would also be expected to absorb the majority of variability in student success (Oseguera, 2005; Titus, 2004). However, selectivity was not a positive relationship with growth rates after the Great Recession suggesting that this institutional selectivity does not account for all of the between-institution variation of CSU campuses, in particular for URM STEM graduation rates.

This finding expanded on previous research focusing on general institutional student success. Yin (2015) analyzed the expected performance of comprehensive campuses against their own observed performance across number of student success markers. Some campuses performed higher or lower than expected in graduation rates, retention rates, and financial aid expenditures based on the composition of the incoming student cohort. This investigation is a direct extension of Yin's (2015) research by focusing on STEM pipeline success and important institutional relationships with resource allocation categories. While previous studies that used an organizational theory lens have aimed at understanding components of institutional effectiveness (Ryan, 2004; Tinto, 2012), this investigation narrowed previous findings and provided a more nuanced perspective of success in the STEM pipeline and the relationships at work within a smaller sub-sample context within comprehensive institutions.

The importance of the context for student success highlights the need to continue to investigate comprehensive institutions (Henderson, 2009; Horn, Weise, & Armstrong, 2015). For example, the campus selectivity was found to have a negative relationship after the Great Recession. This substantiates findings from Chingos (2012) that tied together selectivity and students attending a campus with lower selectivity than they were qualified for (see: undermatching theory for a detailed description) with simulations that reassigned students into more selective institutions. If the student was eligible for a more selective campus, the student was replaced to a more competitive campus. Although graduation rates were found to be higher among the most selective campuses, increased selectivity did not effectively raise institutional success across institutions nor did it close the achievement gap between socioeconomic and ethnic groups. In essence, reshuffling students across different campuses would not have a wide enough impact to increase overall graduation rates. Despite the perception of selectivity as an avenue to raise STEM graduation rates across institutions, state comprehensive institutions are a large hole in the STEM pipeline, and if patched effectively, will lead to overall greater success across the STEM pipeline, as well as creating more multidimensional metrics for institutional success and broadening the characteristics of *quality* education at college campuses.

Extending the concept of quality higher education, this finding furthers the discussion surrounding selectivity and the possible impact it has on URM students in the STEM pipeline. Many STEM faculty members believe that increasing selectivity at comprehensive institutions would aid in reaching national STEM degree goals. However, there is a plateau where the return begins to flatten out as selectivity increases when considering institutional context (Bowen & Bok, 1998). At the same time, it is found that URM students enroll with higher levels of interest in STEM, yet many leave STEM or drop out of college by the end of their second year of full-time enrollment (Herrera &

Hurtado, 2011; Strayhorn, 2013a). Campuses electing to raise selectivity as a means to increase STEM graduation rates could potentially mask the diversion of URM students away from STEM disciplines, while also creating negative campus climates that alienate URM students (Fryar, 2015; Rankin & Reason, 2005; Strayhorn, 2013b).

Second, the Great Recession negatively influenced overall STEM graduation rates at CSU campuses. Specifically, the onset of the Great Recession on the AY 2011-2012 budgets at CSU campuses caused a significant drop in overall STEM graduation rates. Economists and policymakers have documented how the Great Recession caused erosion in public funding toward higher education and helped accelerate the expansion of private for-profit higher education institutions (Zumeta, 2010). In turn, many campuses were expected to cut curriculum, programing, and support services in order to meet budget standards (Brown & Hoxby, 2014). Consequently, campuses were expected to lose many students, in particular URM students, during the transition process with students opting to leave a STEM degree program for another discipline or stop attending higher education altogether. This situation was expected to cause institutional STEM graduation rate to fall dramatically in the years following the Great Recession.

This investigation confirms that the Great Recession impacting CSU campuses negatively directly after the onset. However, the growth rate after the Great Recession was not the expected outcome - CSU campuses performed *better* after the Great Recession occurred. There are a few possible explanations for this occurrence from the literature, with evidence from this investigation adding additional perspectives to the understanding of the response to the Great Recession.

While many states continue to fund higher education below pre-recession levels (Mitchell, Palacios, & Leachman, 2014), previous research found enrollments increased in the years leading up to the Great Recession pushing many students into less selective institutions and towards comprehensive institutions (Barr & Turner, 2013; Fryar, 2015). Based on the evidence from this investigation (see Table E.1.4), most CSU campuses increased their STEM enrollment after the Great Recession, while also maintaining, or in some cases increasing, an upward trajectory of STEM graduation rates. Coupled with the increases in student services support by CSU campuses, the evidence suggests institutions have prioritized student-centered climates, which has led to some innovative practices and policies to aid students in attaining STEM degrees (Hurtado et al., 2011).

The post-Great Recession growth rates of CSU campuses provided evidence that goes beyond the traditional metrics of institutional analysis. The findings indicated the success of comprehensive institutions after the Great Recession benefitted from increased enrollments, coupled with the change in institutional behavior to spend more on student services support. Previous research showed funding toward student services after the Great Recession generally prioritized programing for academic advising, orientation, and cross-departmental, campus-wide policies aimed at student success (Desrochers & Hurlburt, 2016). Moreover, the reinvestment toward student services often created diversity training series for faculty and administrators allowing open discussions around race and student success in higher education, specifically for STEM disciplines, often exposing STEM faculty to unique barriers underrepresented minority students face in their STEM experiences (Allen-Ramdial & Campbell, 2014; Schultz et al., 2011).

Although student services resources were not found to be significantly related to overall STEM graduation rates, the change in organizational behavior to allocation more proportional spending towards students shows an important correlation that is worth investigation further. This counter-narrative at the institutional level highlights a possible building of strength-based characteristics for comprehensive institutions, in contrast to aggregated student characteristics and outcomes. While student-level research has built strength-based approaches to counter deficit frameworks (Metcalf, 2010; Rios-Agular, 2014), similar frameworks apply for comprehensive institutions that tend to serve larger populations of URM and low-income students (Fryar, 2015; Museus & Liverman, 2010). For example, the creation of a scorecard metric counting programs that include faculty involvement with early STEM students or, at the institutional level, giving additional incentives and awards to URM faculty who achieve tenure in STEM at comprehensive institutions. This investigation offers possible alternative institutional behaviors and characteristics for comprehensive institutions that highlight innovative practices encouraging STEM students through the pipeline (Hubbard & Stage, 2010).

Third, including the URM STEM populations in the model to examine their relationship to overall STEM graduation rates (Model 3) accounted for more variability prior to the Great Recession (31.9%) than after the Great Recession (9.5%). Recall that the aim of this model was to examine the attainment gaps before and after the Great Recession that existed when URM STEM performance was included in the model. This finding reveals that prior to the Great Recession, URM populations accounted for almost a third of the variability in STEM graduation rates. However, the significant decline in the amount of explained variability shows that the attainment gaps between URM populations and the overall population grew after the Great Recession. Therefore, despite a higher STEM performance growth rate after the Great Recession, this finding suggests that some of the practices and policies prior to the Great Recession were successful. The natures of such changes in policies, practices, and funding strategies should be more fully explored.

Moreover, the overall STEM performance growth rates showed different relationships with black and Latinx populations prior to and after the Great Recession. Specifically, results showed black student populations displayed a significant, negative relationship, whereas after the Great Recession, it became non-significant. Latinx students displayed a significant, negative relationship with overall STEM performance after the Great Recession. This is another aspect of this finding that supports previous literature that finds increasing URM STEM numbers is only part of what needs to happen for transformative change in the STEM pipeline (Chang et al., 2014). The results from the pair-wise correlations also support this aspect, where student services was strongly related to black and Latinx,, which also support previous literature around creating positive campus climates and welcome STEM atmospheres (Hurtado et al., 2010; Kezar & Gehrke, 2009; Kuh, 2009; Manning et al., 2013; Strayhorn, 2013b).

URM STEM graduation rates. Traditional organizational theories emphasize objective, unbiased measurements of institutions (Manning, 2012). This investigation sought to expand organizational theory to understudied comprehensive institutions and their URM groups in the STEM pipeline. To do so, the theoretical lens adopted in this study also incorporated CRP-Ed and critical quantitative theory (Berger & Milem, 2000; Bess & Dee, 2008; Clark, 1986). It would be expected that as all three URM populations increased, the overall STEM graduation rates would follow this trend. However, the findings highlight the necessity to explore URM students in further detail within the comprehensive institutional context since there was no clear pattern to the growth rates in STEM disciplines across the three ethnic groups.

Critical quantitative theory emphasizes exploring quantitative and theoretical models separately for URM groups. Separating URM populations versus including the "underrepresented minority" categorically as a comparison against White and Asian students allows the process to vary by racial group and highlights the differences between each URM group. Teranishi (2007) recognizes that approaches that simply compare race as a categorical variable often view URM students as underachievers, particularly in the STEM pipeline. Although this method did include race as an independent variable for each URM group, it examines URM populations (not individual students) in isolation of their STEM success and in relationship to the overall STEM population, acknowledging the possibility of diverse experiences and outcomes. Moreover, another CRP-Ed and critical quantitative aspect of this investigation created the counter-narrative model that examined the association between URM STEM graduation rates and resource allocation strategies, separately from the overall STEM population.

Four findings are notable that address racial disparities in STEM six-year graduation rates and the STEM pipeline at comprehensive institutions that have implications for the STEM workforce. First, the relationships between URM STEM graduation rates and overall STEM graduation rates suggests that the overall STEM performance may not fully depend on the success of URM students. Despite URM populations comprising almost half of the STEM enrollment at CSU campuses, the graduation rates of both the black and Latinx populations were negatively related to the STEM growth rates overall and after the Great Recession, respectively. This finding calls into question the effectiveness of institutional STEM interventions for URM populations and highlights that despite such efforts, URM populations continue to be marginalized in the STEM pipeline. Based on the STEM pipeline literature, this finding confirms that comprehensive institutions need to continue to develop new innovative approaches to training URM STEM students (Carnevale et al., 2011; Rankin & Reason, 2005; Schneider & Deane, 2015; Strayhorn, 2013b).

Second, although arguments between economists and policymakers continue regarding the depth and breadth of the "STEM Crisis," advocates agree that the STEM workforce will continue to follow the success trajectory of URM populations (Carnevale et al., 2011; Chen & Solder, 2013; Xue & Larson, 2015, pg. 9). Findings from this investigation imply that a more nuanced approach to understanding relationships between URM populations and STEM graduation rates. Rios-Aguilar (2014) explained that significance and non-significance does not equal "educational significance" in higher education (p. 99). As the STEM pipeline becomes more dependent on the success of URM populations, the STEM workforce will also need to begin to reflect the growing population, specifically more Latinx, Black, and Southeast Asian STEM workers will be needed (Museus et al., 2011). By extension, practices and policies will also need to become more pliable to the varying needs of URM populations (Hurtado et al., 2011). The findings from this investigation showed an absences of significant relationship between the overall STEM growth rates and URM populations in some cases. Although part of this is due to low enrollment, this relationship does warrant further exploration through a CRP-Ed lens. More importantly, this suggests that there are alternative explanations for the reasoning behind URM students leaving STEM despite low enrollment numbers. Previous research showed the culture within STEM disciplines and STEM undergraduate degree programs often isolate and alienate URM students (Allen-Ramdial et al., 2014; Etzkowitz et al., 1994; Hurtado et al., 2011).

Meaningful faculty interactions within the first two-year of STEM degree programs show higher levels of retention in STEM majors (Chang et al., 2008); it would be expected at comprehensive institutions that early interactions with faculty would be prominent with a high commitment to teaching and learning (Henderson, 2009; Ogren, 2005). However, the culture of STEM disciplines are deeply focused on publication and grant awards, often removing faculty from frequent interactions with undergraduate students (Allen-Ramdail & Cambell, 2014). Additionally, the subculture of STEM within comprehensive institutions could dominate over positive campus climates build around the STEM subunit causing URM students to feel chilly climates in their interactions with faculty, graduate students, and peers (Cole & Espinosa, 2008). This finding highlights the lingering STEM culture could still be pushing out URM students from the STEM pipeline even within comprehensive institutions where the mission is supposed to be focused more on teaching, than research and grants.

Moreover, this finding highlights a possible clash of cultures within a drifting mission. Findings from HBCU campuses show development of a strong sense of belonging and academic grit within URM STEM majors (Schultz et al., 2011; Strayhorn, 2013b). This often leads to higher rates of STEM degree attainment and institutional outcomes (Allen, 1992; Hurtado, 2010; Simon et al., 2015). Many comprehensive institutions have adopted similar practices to increase their STEM performance and URM student success (Horn et al., 2015). However, comprehensive institutions are not immune to creating cultures that mimic traditionally white-institutional climates to strive and achieve higher prestige (Schneider & Deane, 2015; Titus et al., 2017). In particular, within the small-unit departments where STEM cultures and climates control their own environments, STEM faculty can instill behaviors that focus on their own traditions over the broader scope of the institution, often times marginalizing URM students in the process (Chang et al., 2008; Hurtado et al., 2011).

Approaching the analysis using the CRP-Ed and critical quantitative lens highlights the limited institutional variables that address the increased success after the Great Recession. There is a large body of work devoted to URM success in STEM that is not currently measured at the institutional level. Higher ratios of faculty of color has shown extensive positive relationships and prediction for a number of cognitive and non-cognitive factors in STEM development (Hubbard & Stage; 2010; Schwartz, 2012; Strayhorn, 2013b; Tsui, 2007; Webber, Laird, BrckaLorenz 2013). However, the CSU system and many other comprehensive institutions do not publicly provide the ratios of faculty of color in STEM nor do departments provide this information when disaggregating STEM into separate disciplines. Despite the continuous support for use of these metrics, STEM administrators are hesitant to provide information about the access and retention of faculty of color in STEM. Not providing this information restricts research from understanding important relationships at work within this context.

Third, this finding focuses on the URM population success separately from the overall STEM population. Although the URM STEM graduation rates started lower than the overall population, the URM populations showed a steeper trajectory overall and after the Great Recession. The changing priority of institutional behaviors towards more student-focused funding confirms literature that identifies student services support as a mechanism to reach and support URM populations in STEM (Harper & Hurtado, 2007; Strayhorn, 2013b). Specifically, student-focused funding aids institutions to transform their climate into a supportive environment that develops opportunities for URM students to develop their scientific identity and connect with other URM individuals in the STEM workforce (Hurtado et al., 2010; Rine, 2014).

Terinishi (2007) examined the diverse populations within the "Asian" category, highlighting unique barriers that Southeast Asian students faced during their academic experience. In this investigation, the Southeast Asian population showed the only positive relationship to overall STEM graduation rates in AY 2006, however no relationships to either growth rate. This relationship could be examined further to understand the types of support mechanisms and student services support that aided this population through the STEM pipeline and could be culturally adapted for black and Latinx students at comprehensive institutions.

Fourth, there was a significant increase at the onset of the Great Recession for URM STEM graduation rates. This increase also was significant across CSU campuses, making it notable that CSU campuses improved the success of URM STEM populations, on average, at the onset of the Great Recession. This runs counter to previous literature (Abington, 2014; Chen & Soldner, 2013; Titus, 2006), however, the policy developments highlights the potential interest convergence between policy and accountability, using a CRP-Ed lens to highlight consequences of colorblind and objective policies (Jayakumar & Adamian, 2015). Specifically, one example of a policy development was creating a set of requirements for students who have completed more than 120 units seems to be effective in increasing URM STEM graduation rates at CSU campuses. This policy was created in light of the increasing demands from the U.S. Department of Education removing financial aid to students who completed more than 150 units and the pressure from NSF and NIH for increased success metrics of STEM and URM STEM students in order to obtain federal training grants.

With the pressing accountability metrics, the implementation of this policy required a shift in the approach to services for STEM students. Further, it pushed institutional administrators and faculty to reflect on practices in STEM programs and curriculum. Many found the research and best practices on student services to be the cheapest and most effective strategy for changing the climate of STEM on CSU campuses. Targeted practices toward URM STEM students to develop educational plans, assist with graduation requirements, and establishing career aspirations were included among many CSU polices. Additionally, involving institutional research practitioners allowed campuses to uncover patterns of racial attainment gaps at their campuses that were unknown or ignored prior to the Great Recession. For example, half of the CSU campuses reported over 50% of their undeclared students identified as URM students and a significant proportion were considering a STEM major (CSU, 2016; NSF, 2015). Active advising, as well as financial incentives, faculty engagement, and supportive learning communities, created avenues for STEM and URM STEM students to be successful. This incorporation of previous literature into the CSU campus culture was new and, according to the findings of this investigation, brought a positive result for the STEM success of URM populations.

However, many of these policies remained race-neutral in form. From a CRP-Ed perspective, these policies were constricted by the colorblind narratives of the policy realm and fall short of disrupting systemic problems of race and racism at CSU campuses (Jayakumar & Adamian, 2015). Additionally, as the interest convergence window closes on the Great Recession impact, the focus for CSU institutions could turn away from supporting STEM students towards other more institutional prestige gaining elements and practices (Bastedo, 2012; O.Meara, 2007; Perna & Finney, 2014). The focus on policy outcomes at the student level continues to focus on the lack of preparation or motivation of students. This is often referred to as deficit perspective of students and relieves faculty, staff, and administrators of critical reflecting on the delivery of practices and process on campus (Bensimon, 2007). Without challenging previously held understandings and acknowledging subtle racist practices, policies fail to transform the institution and the underlying culture (Bensimon, 2005). Institutional leaders need to understand their active role in shaping outcomes by questioning their practices (Kuh, 2009). This is the next step in transforming institutional outcomes and creating long-lasting change in STEM higher education.

Resource allocation strategies. Drawing upon Berger and Milem's (2000) organizational impact model, this investigation examined the influence of institutional structural demographics (selectivity and STEM cohort size) and organizational behaviors (institutional resource allocation strategies) on STEM graduation rates. Research on resource allocation strategies have focused on overall graduation rates, individual student success, and other institutional priorities (Abington, 2014; Gansemer-Topf & Schuh, 2003; Hamrick et al, 2004; Ryan, 2004; Webber, 2012; Webber & Ehrenberg, 2010;). This investigation expands this research to focus on the STEM pipeline and comprehensive institutions, while examining the impact of the Great Recession.

The organizational lens contextualizes colleges and universities as a conglomeration of individuals that creates priorities and cultures through structure and behaviors (Bess & Dee, 2008; Titus, 2006). The focus on resource allocation strategies provides an unfiltered view of institutional values and provides a way in which to quantify institutional behavior. The impact of the Great Recession suggests a stark institutional shift in behavior at CSU campuses. Prior to the Great Recession the overall spending on instructional support well surpassed that spent on student services. However, student services received a greater proportion of instructional support spending when analyzing the percent dedicated to student services of educationally related expenditures. After the financial crash, campuses changed behavior and began funneling more overall spending and proportional spending towards student services. This assessment and realignment of resource allocations shows a trend of increases in graduation rates post-Great Recession. Although this general finding is descriptive in nature, it provides a foundation for the important findings regarding the resource allocation strategies at CSU campuses. Similar to the previous sections, two significant findings contribute to the body of literature, along with one non-significant finding. Additionally, the CRP-Ed and critical quantitative lens allows the investigation to analyze "*why*" and "*who*" these resource allocations will benefit most (Carter & Hurtado, 2007; Williams, 2014).

First, the results show a positive relationship between student services support and URM STEM graduation rates. Additionally, after accounting for selectivity and URM STEM cohort size, student services allocations increased the magnitude and strength of the student services relationship after the Great Recession. Findings broaden current limited research supporting the argument that specifically STEM students benefit from supportive interactions with non-faculty staff and advisors who provide a warm, welcoming atmosphere (Espinosa, 2011; Harper, 2010;). These staff members aid in developing a sense of belonging on campus through social and academic networking, while negating the feeling the alienation common in STEM disciplines (Brown et al., 2013; Hurtado et al., 2011; Trujillo & Tanner, 2014).

Specifically, the five highest spending campuses for student services in 2006 would typically spend $367/FTE and rose to $567/FTE in 2016 (see Appendix E, Table E.1.5). The lowest spending campuses for student services showed dramatically different circumstances with average spending in 2006 at $218/FTE and rising to $469/FTE in 2016. These also showed differences in STEM graduation rates when averaged across the five campuses, with the top five campuses trending higher at each observation point.

Students entering college could develop STEM aspirations despite not initially showing interest in STEM through early academic and social integration on campus (Wolniak, 2016). When institutions employ student services professionals, an avenue to broaden the STEM pipeline is created through early interactions between staff and current STEM students that fostering academic grit and perseverance within students (Strayhorn, 2013b). Many of these practices and interventions to encourage students into the STEM pipeline occur through student services professionals. Although employing such personnel requires funding, it brings returns in the form of STEM student population growth and also sends an institutional message about the elevated value of student success embedded in the campus climate (Kuh, 2009; Pike et al., 2011).

This finding suggests institutions should build strong student services support networks on campus in order to help students maintain academic success (Hurtado et al., 2011; Schultz et al., 2011; Strayhorn, 2013b). The development of cognitive and non-cognitive factors in STEM is facilitated through interaction with student services professionals outside of the classroom (Manning, Kinzie, & Schuh, 2013), and this is especially the case for URM students (Hurtado et al., 2011; Strayhorn, 2013b). Prior research indeed highlights important aspects that exist outside the classroom that are necessary to support STEM and URM STEM students at comprehensive institutions (Allen-Ramdial & Campbell, 2014; Harper, 2010; Seymour et al., 2004). Moreover, student affairs professionals often are more equipped to recognize and disrupt systemic barriers impeding URM STEM students than are STEM faculty (Schultz et al., 2011). Providing more individuals to reach and support URM STEM students will enable the institution to change the culture of STEM to be a more inclusive structure and environment (Museus & Liverman, 2010).

Second, the results from this investigation found instructional support showed a negative relationship with overall STEM performance in AY 2006 and URM STEM performance growth rates. However, the relationship between instructional support and both STEM graduation rates was positive in other cases (e.g. URM STEM performance in AY 2006). The CRP-Ed and critical quantitative lens provides support for validating this finding that there exists discrepancies between theory and fact (Stage, 2007; Williams, 2014).

Although training for teaching and learning methods update archaic instructional methods, it does not account for culturally bias and insensitive discourse within the classroom. Many STEM faculty posit that STEM majors are wholly objective and struggling students do not have the "necessary requisite skills" to be in science (Brown, et al., 2013). Yet, the literature about URM students in science show success at HBCU institutions, as well as at traditionally-white institutions when provided opportunity and support by faculty, staff, and peers (Hurtado et al., 2011; Gasman & Nguyen, 2014; Myers & Pavel, 2011; Strayhorn, 2013b)

Additionally, STEM faculty often advocate for students to leave their family and friends to invest time to become a "real scientist" in the workforce (Hurtado et al., 2011;

Maltese, & Tai, 2011; Schultz et al., 2011). However, the findings of this study are consistent with the extant literature, which suggests that how students are supported through the process in STEM majors does matter to their long-term success and entry into STEM careers (Allen-Ramdial & Campbell, 2014; Carpi et al., 2011; Cole & Espinoza, 2008; Schultz et al., 2011). It appears that investment in instructional support is not permeating through to the STEM culture to disrupt long held views of STEM performance and a hole in the STEM pipeline remains. Although the new technology and updated teaching methods may have improved STEM student outcomes (Webber, 2012), the evidence provided by this study points to the need to broaden institutional measurements of faculty interaction, engagement, and diversity on campus in STEM departments (Chang et al., 2014; Griffin et al., 2010; Museus et al., 2011).

Furthermore, because the CSU system reflects many characteristics of other comprehensive institutions, the demographics of CSU STEM faculty provide insight into potential reasons for the negative relationship between instructional support and STEM graduation rates (both overall and specifically among URM students). Official reports on faculty in the CSU system do not include ethnicities and demographic data for faculty percentages in STEM (CSU, 2016). Through NSF and NIH, the data (unofficially) notes that the CSU STEM departments lack diversity (in ethnicity and gender) in faculty and administrative positions across the system (NSF, 2015). Although the CSU system has publically attempted to hire and retain STEM faculty of color, the percentages of URM STEM faculty that remain in the system are low (NSF, 2017).

This indirectly connects to previous studies that found the ratio of minority faculty and college sponsored student interactions with faculty of color were characteristics of successful institutions in STEM. These activities often led to higher degree completions and doctoral enrollment of URM STEM students (Hubbard & Stage, 2010; Hutchinson et al., 2006; Kezar & Gehrke, 2009; Schultz et al., 2011). With the majority of faculty as white males, the evidence points to a disconnect between the cultural and ethnic backgrounds of faculty that do not match with the majority of the student population enrolled at the CSU system. Instructional support funding often goes towards in classroom support, however this reflects a cultural problem that is highlighted by the negative relationship between instructional support and STEM student performance.

However, the lack of consistent findings regarding the nature of the relationship between instructional support and STEM graduation rates from this investigation requires further investigation. For example, it is possible that resources dedicated to instructional support could require a longer timeframe to benefit the institution. As mentioned previously, instructional support provides resources for faculty salaries, technology, and pedagogical development most often for high-impact, gateway courses, as well as some related research expenses (Barr et al., 2008; Eagan et al., 2010; Marsh, 2014). While the current student found instructional support was negatively related to STEM graduation rates, previous studies that utilized longer periods of data found a positive relationship. Such extant research found increased levels of instructional support predict first-year retention rates (Gansmer-Topf & Schuh, 2004; Griffith & Rask, 2016; Webber &

Ehrenberg, 2010), degree completion (Ryan, 2004), and STEM degree completion (Webber, 2012). The conflicting results between the current study and prior research suggest the impact of instructional support on STEM performance should be further examined over a longer period of time.

Economic theory on college student outcomes posits the investment in instructional support provides resources to faculty to reach a broad range of students. Theoretically, instructional support investments cost the institution less, while reaching a large population. Therefore, equipping faculty and instructors with advanced training in teaching and learning methods for college courses is seen as an economically sound investment, though it takes additional time to embed these new practices into the campus culture and climate (Bess & Dee, 2008; Manning, 2012).

An interesting finding is that NSF and NIH federal training grant money was not significantly related to STEM graduation rates any of the models, even though one of the main aims of these programs is to broaden participation in STEM disciplines (NSF, 2017). Despite the limited number of resource allocation categories included, no model shows any significant relationship between NSF and NIH federal training grant and STEM graduation rates. In the wake of the Silicon Valley expansion and other national economic developments, there was a significant amount of funding dedicated to public universities to increase URM student STEM engagement and, after the Great Recession, federal training programs were expanded to include more inclusive policies for student participation (NIH, 2015; NSF 2015). Yet, these findings highlight the possibility that these programs, despite helping those participating students, are not yet impacting the broader parts of the pipeline as effectively as predicted.

Literature often cites the importance of federal training programs for individual students to be successful along the STEM pipeline (Hathaway et al., 2002; Hunter et al., 2007; Hurtado et al., 2011; Jones et al., 2010; Strayhorn, 2010b), pointing to their contributions to a well-developed sense of belonging in STEM, a refined since of scientific identity, and higher inward self-efficacy (Hutchinson-Green, et al., 2006; Schultz et al., 2011; Trujillo & Tanner, 2014; Williams, 2014). However, findings from this investigation cloud the outcomes of previous studies when considering that these benefits are limited to a small fraction of the URM STEM population. Many of the federal training programs target students enrolled in upper division coursework and advanced STEM experiences (NIH, 2015). Because federal policy requirements are stringent and inflexible, program administrators consider students who already have a 3.00 GPA or higher prior to participation, which limits the pool of participants. Research on early experiences in STEM suggest URM students are discouraged and advised away from STEM prior to reaching the upper division coursework necessary for post-baccalaureate programs (Barr et al., 2008; Blickenstaff, 2005; Stolk & Herter, 2009). Therefore, many of the potential funding and training benefits for URM students end up missing the broader population.

Additionally, multiple programs at the same campus often instigate internal competition or conduct overlapping functions for the same students due to the limited population to choose from on campus (Schultz et al., 2011). Through an organizational theory lens, each unit is *suboptimizing*. Suboptimization in higher education means that units of an organization work only toward the goals of their particular unit, failing to cross-coordinate duplicate responsibilities and lose sight of the larger purpose and mission of the university or college. In this case, suboptimization implies a failure to broaden participation in STEM among URM student populations (Bess & Dee, 2008). The findings from this investigation provide evidence the CSU system may be suboptimizing their training grants, serving a limit population of URM STEM students enrolled at their campuses.

Moreover, policy and program requirements often misalign with the contextual factors at comprehensive institutions. As a result, that further penalize these institutions and cause institutional behavior that reflects flagship-research institutions (Fryar, 2015; Henderson, 2009). For example, personnel budgets (faculty and staff salaries/benefits) for NIH/NSF training grants are limited to 20% of the annual budget. This severely limits interactions of the grant staff and faculty with the broader STEM pipeline and may restrict the future impact for STEM students. The inflexibility of policies and the sub-optimizing of campus programs provide a reason the non-significance of federal training grant funding to overall STEM graduation rates in this investigation.

Lastly, this investigation expands on variables outside of the commonly used metrics and calls for more measurements of intermediate actions of institutions. For example, the institutionalization of undergraduate research programs is, at its core, organizational learning from organizational behavior (Bensimon, 2005; Boyce, 2003; Kezar, 2005; Levitt & March, 1998). Previous research has shown development of the scientific identify in URM STEM students and a sense of belonging as a scientist is facilitated more effectively by participating in undergraduate research experiences (Hathaway et al., 2002; Hunter et al., 2007; Jones et al., 2010; Schultz et al., 2012; Schwartz, 2012). Other studies that utilized aggregate data have shown similar outcomes across demographic groups in STEM when incorporating undergraduate research experiences into curriculum for first and second year STEM students (Brownell et al., 2015; Kerr & Yan, 2016). Allocating resources through funding, faculty participation, administrative support, and curriculum development, the institution changes a temporary service to URM populations to an intentional action. Thereby changing the underlying value system at the institution that undergirds the culture of STEM (Bensimon, 2005).

Limitations of the findings. Some important limitations of the findings of this investigation should be recognized. Multilevel growth modeling was used to target relationships between STEM graduation rates and important institutional behaviors and characteristics. The goal was to uncover relationships between the outcome variables and these institutional aspects using a parsimonious model that accounted for literature-supported characteristics and behaviors. However, it is difficult to determine if all applicable confounding variables were accounted for in the models. As such, omitted variable bias may be present throughout the modeling process, specifically regarding additionally institutional characteristics. Additionally, this investigation did not strive to predict STEM graduation rates, but instead focused on the relationships among a limited number of variables of interest based on previous literature. Although this investigation minimized omitted variable bias to the greatest extent possible, the findings are not necessarily generalizable to all comprehensive institutions or public universities in the STEM pipeline, as the findings reflect relationships based only on the participants at this regional set of institutions.

With the sample of institutions delimited to the CSU system, this investigation includes characteristics that are unique to the CSU system. Along the higher education spectrum, the CSU system falls between community colleges and a research-intensive systems. CSUs have developed many measurements other universities have not yet created. Yet, measurements of institutional characteristics raise certain data concerns. First, for some CSU campuses, the participation of black and Latinx students were minimal (none in some cases), suggesting that the distribution of STEM graduation rates of URM populations had some limitations. Second, although the Asian American population is disaggregated into two subgroups (Asian and Southeast Asian), these two groups oversimplify the diversity of Asian American students and may overlook key differences that exist between various Asian American populations (Terinishi, 2007). For example, Fresno State University has a high population of Hmong population but a non-representative Cambodian population; the reverse is evident for Long Beach State University (high Cambodian population and low Hmong population). The needs of each and the context where each exist could show differences by groups even within the Southeast Asian communities enrolled in STEM disciplines.

Although these findings provide some evidence of the URM populations being strongly related (both negative and positive) to overall STEM graduation rates, in particular the Latinx and black populations, there are some cautions with this model.

Both the black and Southeast Asian population comprise only a small portion of the STEM enrollment and there is a small likelihood of finding a significant result among these populations with a lack of representation in STEM disciplines. Additionally, STEM graduation rates and overall graduation rates change minimally from year-to-year, which is another potential limitation. The significant levels point to limited variability in both the outcome and the URM graduation rate variables. Therefore, the generalizability of these findings are further limited.

Another limitation of this investigation rests within the cohorts of entering students. This is a problem with many repeated, cross-sectional public data aimed at tracking outcomes for institutions, states, and regions (See Appendix E.1 in Appendix E for a further definition of these data). Other statistical techniques often utilized in social change models, disease prevalence, and population dynamics tease apart cohort effects. The cohort that an individual is associated with and creates their formative context can be compared to successive groups of different years with similar contexts (Yang & Land, 2016). The publically available data on STEM graduation rates is limited and does not allow for exploration of cohort effects at this time. Although the approach of this investigation provides useful information for comprehensive institutions in California who are serving URM STEM students, it does limit the generalizability of the study.

The counter-narrative model used a dependent variable that collapsed the success rates of all URM STEM populations together. This was done as a way to increase statistical power, however there is an acknowledgment towards the variation among URM populations (black, Latinx, and Southeast Asian) and the unique experiences each population faces in higher education. This is a limitation that treats the URM populations as one, however despite this limitation, this was an attempted step to disentangle the nuanced relationships between overall STEM graduation rates and URM STEM graduation rates. Further research and more data availability to examine the URM populations independent of one another is necessary to fully conceptualize and identify mechanisms in the STEM pipeline.

Lastly, the cohort measurements that created the STEM six-year graduation rates examined in this investigation were drawn from limited aggregated data of students who were first-time enrolled in college and full-time enrolled throughout their course of study. Although this is a standard measure within the higher education community, it does not capture the full breadth of students at comprehensive institutions and neglects detailed analyses at the student level. In particular, reliance on aggregate data may lead analyses to overlook important nuances of the experiences of URM STEM students at comprehensive institutions. Many students at CSU institutions and other comprehensive institutions begin as part-time students engaging in general education courses while working a full-time job to support their education, families, and/or extended families (Chen, 2013; Crisp et al., 2009; Nora, 2003). However, this analysis cannot account for this population of student since their pathway started as a part-time student. Without capturing the individual experiences as well as leaving out part-time/non-traditional students further limits the findings of the investigation to the subpopulation included in the sample.

Implications for Theory

This investigation drew from relevant aspects of two theoretical bodies, Berger and Milem's (2000) organizational impact model and critical theories (CRP-Ed & critical quantitative) to inform the conceptual model guiding a multilevel examination of STEM six-year graduation rates. The investigation utilized the lens that Jayakumar and Adamian (2015) advocated for in higher education literature, which explored approaches to push against policy and redefine dominant narratives. Seeking to operationalize the constructs of the Berger and Milem model, this investigation modeled previous scholarship (Ryan, 2004; Titus, 2006; Webber & Ehrenberg, 2010) to employ the dimensions of structural-demographic and organizational behavior characteristics within the analyses. A concerted effort was made to merge these two theoretical and conceptual lenses into a cohesive multilevel model, yet there is more organizational frameworks can learn from CRP-Ed.

The findings from this investigation have implications for organizational theory in higher education. Viewing colleges and universities as an organization that can change and adapt through resource allocation behaviors, organizational theory provides an unobstructed perspective of institutional values (Berger & Milem, 2000). The results of this investigation support organizational behaviors and institutional priorities shifted based on the pressure of accountability in STEM as well as the drifting mission on comprehensive institutions. However, through a CRP-Ed lens, organizational theory is pushed to understand organizational behavior through the context of who benefits from changing priorities (Jayakumar & Adamian, 2015).

Highlighting this need are the findings that the performance of different racial/ethnic groups had different relationships with overall STEM graduation rates based on the budgeting priorities of the institution. The demographic and cultural composition of college students is constantly changing. Students are older and are more likely to be minority, first-generation students, and work full or part-time. California is an example of this trend and, in fact, Southeast Asian students are a growing population outpacing growth among other ethnic groups in certain areas (López, Ruiz, & Patten, 2017). Institutional behavior theories should account for these differences at a theoretical level in order to build more effective conceptual frameworks to measure and compare institutional performance at comprehensive institutions and among URM populations.

Given the need for multilevel analysis on institutions, the growth model sought to inform within and between institutional differences. These findings indicate areas of need for this type of expanded conceptual work. The conceptual work in resource allocation behaviors should be built upon to advance a framework that is more reflective of comprehensive institutions as their own group. Although institutional behavior models serve as a basis to begin examining comprehensive institutions, the applicability to comprehensives do not capture the full scope of characteristics and performance within these campuses (Henderson, 2009; Schneider & Deane, 2015). The unique nature of comprehensive institutions must be considered when developing institutional behavior models and requires a shift in thinking that encompasses various forms of institutional success, instead of homogenized expectations that constrain institutional behavior toward singular forms of success.

Another implication for organizational theory confirmed the complexity of comprehensive institutions. Organizational theory posits higher education institutions mean multiple things to multiple people (Masland, 1985; Tierney, 1988). Therefore, the organizational behaviors examined in this investigation showed these institutions blend together different aspects of organizational theory, specifically organizational culture and bureaucracy (Manning, 2012). In this case, the actions and decisions made by individuals at the top of the decision making bureaucracy set the tone for the development of campus climate and culture through traditions and programs (Clark, 1987; Kezar, 2010). The findings from this investigation confirm the tenets of organizational behavior representing a broader meaning within the institution for organizational theory in higher education.

Together, theories of organizational behavior and critical quantitative broaden previous tenets of organizational culture. This investigation suggests realignment of current resource allocations could potentially result in increases in STEM graduation rates. Yet, institutional analysis often contextualizes institutional behavior based on prestige gaining practices (Bastedo & Bowman, 2011; O'Meara, 2007). Previous research on organizational behavior aimed for generalizable results across categorical and/or functional groups (Dee & Leisyte, 2016). The push for efficient and cost-effective practices (e.g. analysis of financial aid practices and entrepreneurial strategies) benefits elite institutions with the clout and resources to adopt characteristics that align with flagship research-intensive strategies.

Implications for Policy and Practice for Increasing STEM Graduation Rates

The results of this investigation offer insight to campus administrators and policymakers on methods for increasing STEM graduation rates. One of the key findings from this investigation is that student services spending is associated with URM STEM performance growth rates after the Great Recession at comprehensive institutions. This allocation strategy includes the staffing of academic advisors, creating workshops geared towards study skills and learning communities, meeting with diverse students in STEM contexts, and participating in study groups (Abington, 2014). Knowing the types of activities that foster the success of STEM students, STEM administrators and faculty at comprehensive institutions can direct resources toward those that directly reach students in STEM majors more effectively.

The current policy climate has shifted towards more objective and measurable outcomes at the student level, while demanding institutions spend resources towards efficient and cost-effective mechanisms for institutional-level success (Alexander, 2000; Titus, 2006). Allowing institutions to allocate funds for student services shifts existing thinking about performance funding policies. Prior policies directly tie funding to objective student achievement benchmarks and sanctions for poor student outcomes, but the findings of this study suggest funding policies should focus on more intermediate institutional outcomes (Conner & Rabovsky, 2011; Li, 2014). Policies that are created to target institutional behavior will directly influence students' day-to-day interactions and achievement on campus, while focusing on the departmental units where the necessary change occurs (Volk et al., 2001). Further, this allows campuses to be rewarded for curriculum changes, assessment improvements, and evaluations of student service programs. The benefit of policies focused on intermediate impact allows campuses to determine the necessary improvements and organizational changes based on institutional context and culture (Bess & Dee, 2008; Manning, 2012).

This finding regarding the importance of well-funded student services for STEM students has implications for equity policy in higher education as well. Student service practitioners often provide a welcoming environment and positive campus climate for STEM students (Crisp et al., 2009; Hurtado et al., 2010). Many STEM students have found their advisors and mentors become a pseudo-family on campus where students are given a space to explore and be vulnerable with their college experiences (Strayhorn, 2013b). This connects to findings about the consequences of negative campus climates for URM students, specifically that URM students react more adversely to negative campus climates (Hurtado et al., 1998; Rankin & Reason, 2005; Strayhorn, 2013a; Wells & Horn, 2015). However, STEM disciplines have been found to create negative climates for URM students (Espinosa, 2011; Hurtado et al., 2011; Kanny & Sax, 2014). Thus, the findings of this investigation suggest that employing student services personnel and staff is one strategy that institutions and campus administrators can adopt to try to directly impact STEM graduation rates. The purpose of such an initiative is to create a more welcoming culture and climate for STEM students by investing more of the educational expenditure dollars in student services and student resources.

Another key finding with crucial policy implications is the negative relationship between instructional support and STEM graduation rates. Many STEM faculty believe students should be objectively measured for knowledge and skills, yet the undertone and attitude set by STEM faculty often ignore and/or diminish STEM students' sense of belonging and self-efficacy (Hurtado et al., 2011; Schultz et al., 2011; Trujillo & Tanner, 2014). Although student services professionals can mitigate some of these issues (Strahorn, 2013b), student-faculty interactions in STEM are critical to the longevity of STEM students, in particular URM students in the STEM pipeline (Cannady et al., 2014; Hubbard & Stage, 2010; Riegle-Crumb & King, 2010; Rine, 2014; Tsui, 2007). STEM faculty members often treat the concept of diversity in STEM as "rhetorical commodity" that fails to address systemic inequalities in STEM fields (Baber, 2015). Therefore, the context of STEM perpetuates systems that benefit only a small portion of URM students that were already successful (Kezar, 2010).

Through a CRP-Ed lens, there are several policies already pursued and developed in the STEM pipeline at some institutions that can be leveraged to disrupt parts of the systemic problems pushing against URM STEM students. The NIH and NSF policies currently wield power over the definition of success against which programs are judged. This monolithic understanding of success within the STEM pipeline does not allow institutions to serve the needs of their diverse population. For example, one success marker restricts programs to select students who plan to enter into STEM doctoral programs after participation. This restriction reduces an already limited pool of URM STEM students due to future interests needed to meet programmatic goals. Acceptance of more flexible outcomes, allowing institutions to rigorously define goals and evaluate program success based on their own institutional context would provide more opportunities for comprehensive campuses to be inclusive of a larger proportion of their students. For example, a high performing institution could set a goal for students to enroll in Ph.D. programs, yet a campuses with higher numbers of students requiring developmental math during their first year in college could aim to connect their programing with K-12 high schools to aid in increasing student preparation entering college.

Expanding on the need for more flexible policies, federal training programs could also become more malleable with student participation requirements. Currently, the NIH and NSF restrict student participation to stringent six-, 12-, or 24-month intervals as it is assumed this best fits STEM training for URM students. Thus, program staff and administrators need to target small windows for student participation. This is often particularly difficult for comprehensive institutions where part-time and non-traditional students are a significant proportion of the student population. This penalizes comprehensive institutions for primarily enrolling students that NIH and NSF targets for participation and thus, seems to misalign with one of the primary goals of broadening participation in the STEM pipeline. Allowing students to define the timeframe and the type of support needed for individual students would allow the training grants to open doors to new populations that are currently being missed by the policy structure.

There is a concern among federal training grant administrators that students may participate in more than one grant programs simultaneously (a student enrolls in an NSF and another NIH program). However, this could be avoided with more stepwise training grants that allow for these programs from different bodies to create partnerships and share resources. In some case studies, "micro research centers" were created between NSF and NIH funding, where students throughout the education spectrum could participate in a federally sponsored program/training (Schultz et al., 2011). Considering the current fiscal climate of higher education and the unlikelihood of obtaining new state-level funding, a more flexible overarching policy would call for federal training grant oversight to allow resource sharing through justified practices that match student needs. Further, the implications of more flexible policies for federal training grants at comprehensive institutions gives comprehensive institutions the ability to expand hiring practices and target more faculty of color to develop URM STEM students as well as provide more role models for URM STEM students to engage with during their STEM careers.

The flexibility of federal funding policies has implications for the STEM workforce as well when considering the different aspects mission of comprehensive institutions. One important aspect of comprehensive institutions' mission is dedicated to serve and support the local community (Henderson, 2009; Ogren, 2005). Allowing STEM training grants to be connected with local industry as an evaluative STEM outcomes supported by the grant, the STEM curriculum at the institution can provide skill development that is feeding the local STEM workforce and STEM careers as well as providing stability for long term success for individuals, in particular URM populations. This also encourages the STEM workforce to be actively engaged with higher education (Schneider & Deane, 2015), which often leads to better economic outcomes for the local community (Cannady et al., 2014).

Flexible federal policies for comprehensive institutions have policy implications for career readiness as well. Providing undergraduate research experiences is another approach to preparing students for future careers. This includes policies that develop internships and related work experiences, as well as provide local STEM agencies/companies to engage with undergraduate students and the local comprehensive institution (Hunter et al., 2007; Jones, et al., 2010). The types of skills developed during these experiences and while earning a STEM degree is related to greater STEM career readiness, STEM workforce entry, and STEM competencies that require less on-the-job training by the STEM employer (Hathaway et al., 2002; Kerr & Yan, 2016; NSF, 2015). Although the connections between STEM career readiness and STEM workforce longevity is limited, the gains provided by undergraduate research experiences has shown potential for STEM career readiness and needs to be explored further for the impact is has on STEM workforce longevity (Hurtado et al., 2010).

Additionally, there are important long-term benefits and implications URM students entering into the STEM workforce. As mentioned above, STEM degrees often provide the skills necessary to maintain long term security in STEM careers as well as transferrable skills, including critical thinking, laboratory procedures, and research experiences (Cannady et al., 2014; Hurtado et al., 2010; Xie & Killewald, 2012). Moreover, literature has found STEM degrees and skills to lead to higher paying jobs for URM populations with less percentages of unemployment among URM STEM individuals, when compared to non-STEM individuals (Carnevale et al., 2011; Chen & Soldner, 2013).

In higher education, findings show URM students experience hostile feelings in STEM majors and departments (Cole & Espinoza, 2008). The STEM workforce also corroborates this finding (DOL, 2007). Yet, as more URM individuals are entering the STEM workforce and more communities are setup as support systems, the proportion of URM STEM workforce participants continues to increase and role models in the STEM workforce for URM student identify helps to negate some of these hostile climates within the STEM workforce (Cannady et al., 2014; Schultz et al., 2011). Moreover, as more STEM individuals of color enter the STEM workforce, they provide insights and solutions that serve their community more readily and effectively (Crenshaw, 2011; Solorzano & Villalpando, 1998). These federal and state policy implications shift the responsibility toward on higher education administrators to be disruptive and innovative to connect with local STEM workforce entities.

Recommendations for Future Research

Future research should continue to engage in organizational concepts and the exploration of more intricate organizational STEM pipeline issues through a critical perspective. Such an approach can challenge and illuminate conflict while developing critiques through quantitative methods (Stage 2007; Wells & Stage, 2015). Extending the findings of this investigation, future research should fully explore the effect of STEM faculty ethnic composition on STEM students at comprehensive institutions, assessing interactions with gender and STEM discipline. Although previous research has explored some aspects of minority faculty ratios and STEM outcomes, the majority focuses on general individual student success and overall faculty ratios across the entire campus, not specific to STEM disciplines. Additionally, future research should assess the effect of graduate student composition at an institution on undergraduate STEM graduation rates and STEM outcomes, where little research has been done. Currently, data within the STEM pipeline lacks the depth for institutional constructs of faculty and graduate student populations. These data could provide additional perspectives on institutional climates and behaviors.

One approach suggested by Carter and Hurtado (2007) recommended utilizing comparative quantitative methods to tease apart specific group characteristics. Through analysis of the general population and the specific group of interest, future studies may expose hidden relationships and alternative models that can further explain broad differences among institutions as well as distinctions within comprehensive institutions. This approach addresses the need to have context-specific information about the institution and include deeper investigations of subpopulations of the larger groups of interest. For example, the broad category of the Asian ethnic group has shown to be inaccurate when computing the heterogeneity within the overarching ethnic group. Unpacking potential nuances between Asian American, Southeast Asian, and/or Pacific Islanders, future research using a comparative quantitative method could uncover important social and contextual differences between these populations at comprehensive institutions that account for varying experiences in STEM undergraduate research.

As more contextual variables are found, separate analysis for each disaggregated Asian population could build new models that glean information unique to each group.

Another approach to gain insight into institutional climates and behaviors at comprehensive institutions is to utilize mixed methodologies that support a critical perspective. Qualitative examinations of processes and routines in the context within which resource allocation decisions are made could illuminate conflict within decision-making processes and highlight strategic, political, or environmental motivations for resource disbursement. Through qualitative analysis, new frameworks for describing comprehensive institutions could develop while quantitative analysis could uncover specialized models for in-depth research on comprehensive institutions and the climates that are built through resource allocation strategies. By creating models to test unique relationships within comprehensive institutions, the definition of institutional success can be redefined to match the needs and qualities of the students and campuses at comprehensive institutions.

Lastly, an alternative set of statistical methods described by Malcom-Piqueux (2015) highlights person-centered approaches through critical quantitative analysis. Through cluster analysis, latent class analysis, and latent class growth analysis, these approaches run counter to traditional variable-centered statistical techniques. Variable-centered approaches assess the impact of specific variables on the outcome of interest, whereas person-centered approaches identify groups through underlying and/or unobserved characteristic and behaviors. Person-centered approaches could provide future research with more accurate comparison groups between and within institutions, using resource allocation behaviors coupled with survey responses from academic administrators in STEM departments describing their motivations for the decisions made in their department. Performance comparisons could include more campus climate issues that would allow for meaningful contrasts between STEM departments.

Conclusion

The results from this investigation illuminate crucial resource allocation strategies. Specifically, there are four key findings with implications for STEM programs at comprehensive institutions: (a) student services resources were positively associated with average STEM graduation rates and STEM graduation rates growth rates; (b) instructional support was negatively associated with STEM graduation rates, but was positively related to growth rates; (c) federal training grants are not broadening participation in STEM; and (d) STEM graduation rates growth trajectories were steeper after the Great Recession. Perhaps the most informative results come from the finding that differences between comprehensive campuses are large. This suggests that institutional behavior does influence STEM graduation rates. Furthermore, results from the current study suggest that the Great Recession did impact STEM graduation rates, but in a positive way that allowed comprehensive campuses to adjust and adapt to the environment to be more effective for their STEM students.

To ensure the success of URM STEM students, comprehensive institutions must continue to command a large role in the productivity of STEM degrees. Through a multilevel growth model, the strength of this investigation pushed forward a number of resource allocation strategies and institutional characteristics findings, while expanding the research on comprehensive institutions. These findings highlighted the need to advance intentional institutional behaviors, through research allocation strategies, in the

STEM pipeline through a critical lens. Situating these findings and implications within the current context of higher education, future policymakers and administrators can understand the impact that resources have on post-secondary outcomes as the funding streams leading into colleges and universities swing toward full recovery. As URM student enrollment continues to grow with diverse interests and experiences, the expanded knowledge of institutional behaviors in the STEM pipeline will prove vital to the success comprehensive institutions and allow this group of campuses a voice in the discussion.

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APPENDIX A

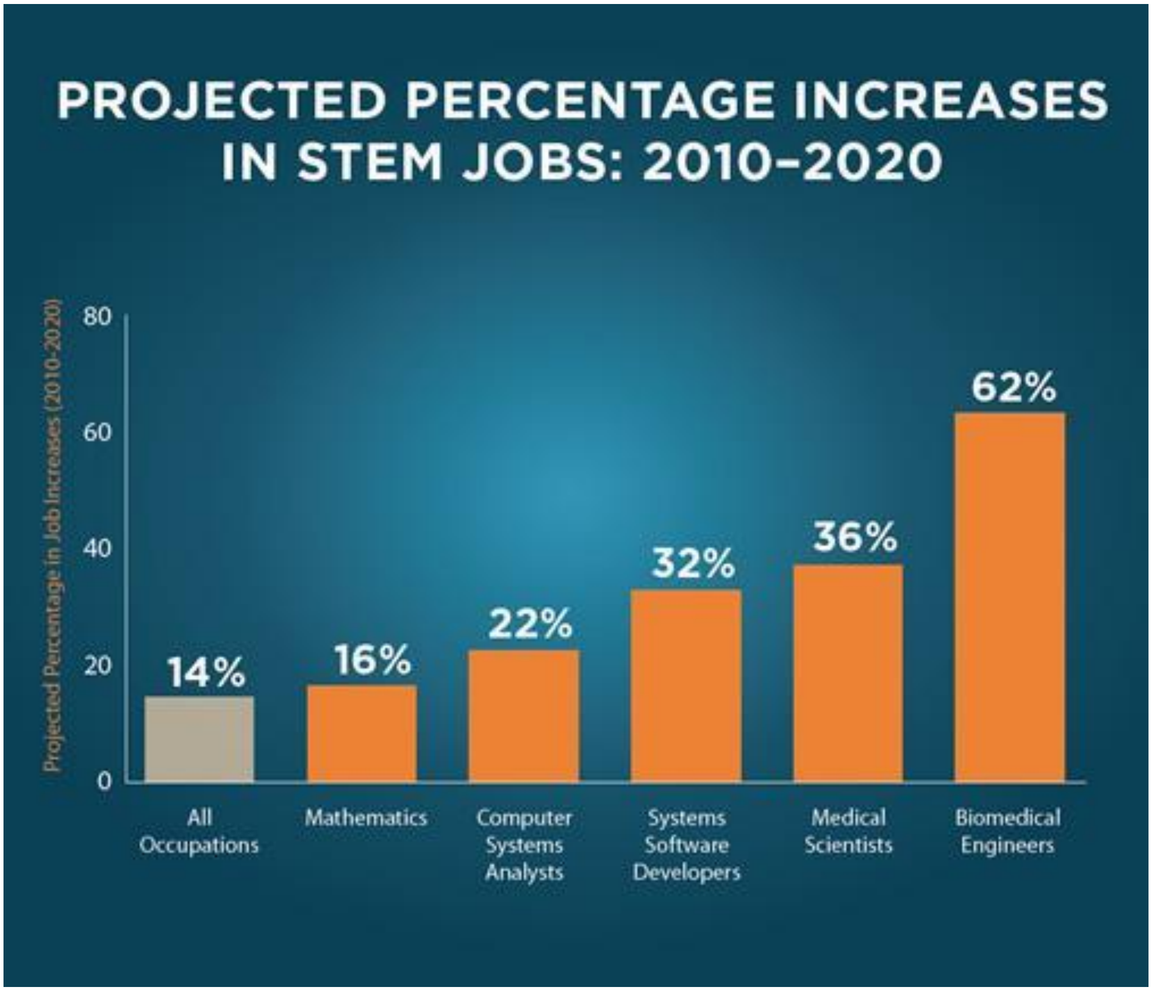

Figure A.1.

Projected percentage increases in STEM jobs: 2010-2020. Reprinted from "Science, Technology, Engineering and Math: Education for Global Leadership", by U.S. Department of Education. Retrieved from https://jcmf.cz/sitres/default/files/Z-9_STEM.pdf

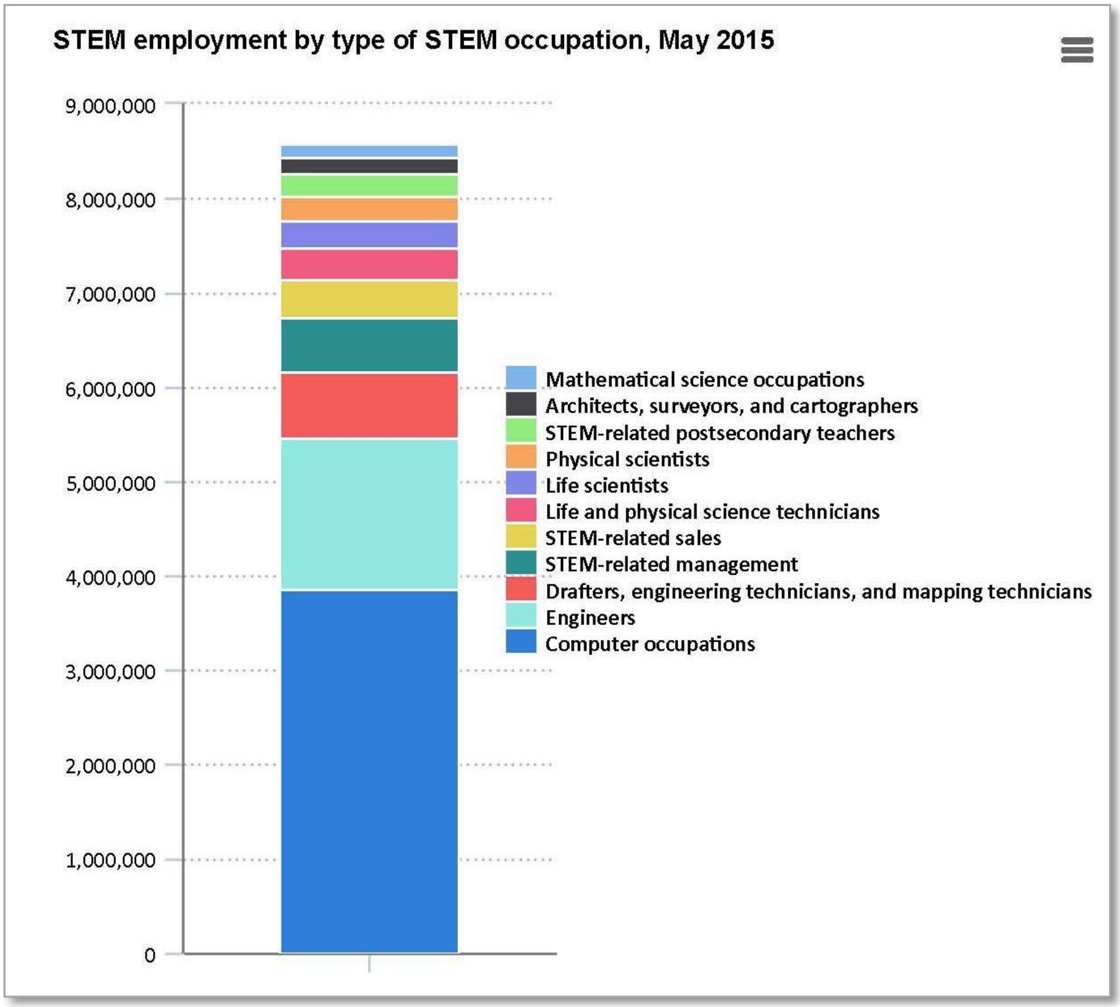

Figure A.2.

STEM Employment by type of STEM Occupation, May 2015. Reprinted from "STEM Occupations: Past, Present, And Future" by U.S. Department of Labor and Statistics.

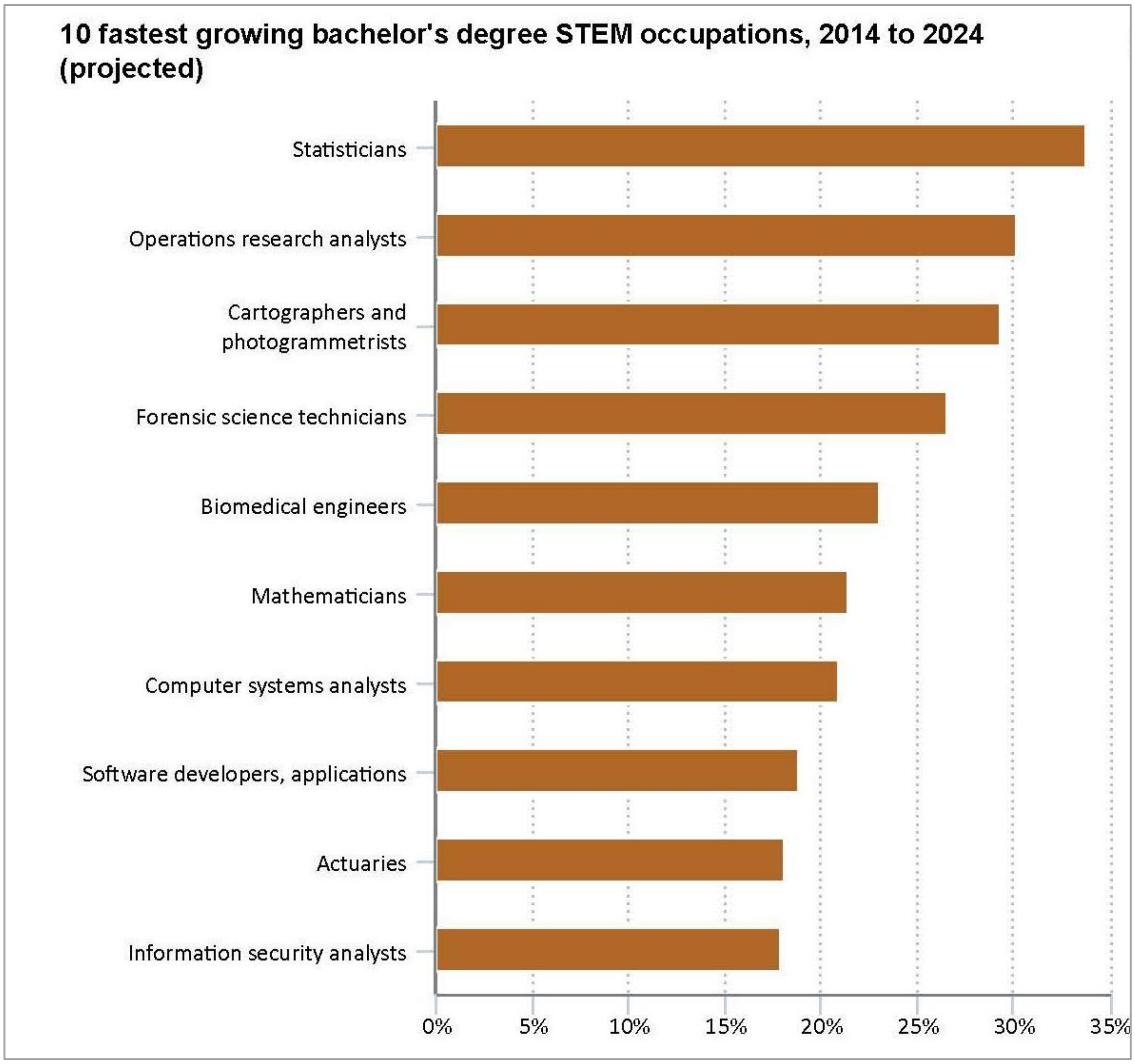

Figure A.3.

STEM Employment by type of STEM Occupation, May 2015. Reprinted from “STEM Occupations: Past, Present, And Future” by U.S. Department of Labor and Statistics.

APPENDIX B

Table B.1

List of STEM Disciplines and Degree Programs

BIOLOGICAL SCIENCES
Biology (general)
Biochemistry/Biophysics
Botany
Marine (Life) Science
Microbiology/Bacteriology
Zoology
Other Biological Science

COMPUTER SCIENCE/TECHNOLOGY
Computer Science
Health Technology (medical, dental, laboratory)

ENGINEERING
Aeronautical/Astronautical Engineering
Civil Engineering
Chemical Engineering
Computer Engineering
Electrical or Electric Engineering
Industrial Engineering
Mechanical Engineering
Other Engineering

ENVIRONMENTAL SCIENCES
Environmental Science
Atmospheric Science (incl. Meteorology)
Earth Science
Marine Science (incl. Oceanography)

HEALTH PROFESSION SCIENCES
Medicine/Dentistry/Veterinary Medicine
Nursing
Pharmacy

MATHEMATICS/STATISTICS
Mathematics
Statistics

PHYSICAL SCIENCES
Astronomy
Chemistry
Physics
Other Physical Science

Source: National Science Foundation, 2017

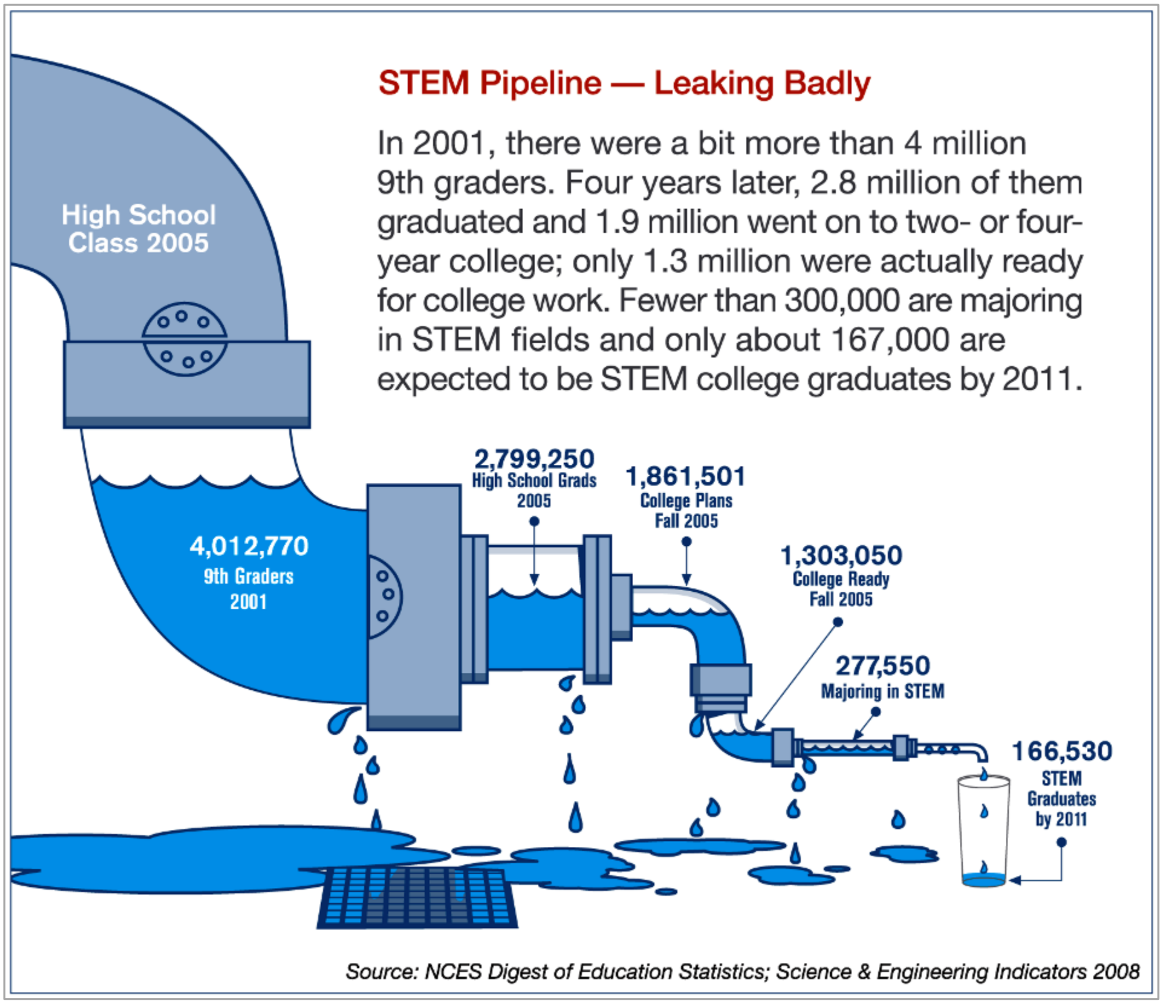

Figure B.1

Alternative Visualization of STEM Pipeline

Source: NCES; Science and Engineering Indicators 2008

APPENDIX C

Table C.1

Descriptive Statistics of CSU Campuses (N=22 campuses)

Campus	STEM 6-year Grad Rate			Cohort Size			Campus Selectivity		
	Ave 10	Hi	Lo	Ave 10	Hi	Lo	Ave 10	Hi	Lo
Bakersfield	18.29%	26.40%	12.60%	119.18	197	72	969.82	1030	916
Channel Islands	38.21%	48.10%	31.30%	70.73	94	52	1042.64	1063	1008
Chico	33.41%	43.80%	21.30%	443.64	608	343	1055.55	1074	1039
Dominguez Hills	8.46%	14.60%	3.10%	85.36	131	54	863.64	888	825
East Bay	20.20%	32.10%	15.20%	150.82	222	100	953.55	971	918
Fresno	23.74%	32.70%	19.10%	497.27	696	363	987.64	1003	971
Fullerton	20.20%	29.40%	15.90%	557.27	745	385	999.55	1027	984
Humboldt	26.90%	35.70%	22.50%	328.27	504	234	1069.18	1081	1046
Long Beach	26.35%	38.60%	14.30%	713.00	1024	475	1035.82	1057	1002
Los Angeles	19.00%	35.40%	11.90%	251.18	407	160	918.45	964	894
Monterey Bay	24.83%	40.10%	15.80%	130.18	220	78	1010.18	1029	980
Northridge	21.19%	25.20%	16.20%	556.73	921	409	972.82	986	960
Pomona	34.99%	51.70%	27.30%	1189.64	1449	917	1067.55	1126	1046
Sacramento	16.57%	21.80%	12.80%	475.27	665	398	996.27	1010	984
San Bernardino	18.62%	29.30%	11.10%	254.18	388	132	932.73	957	908
San Diego	33.25%	46.50%	23.40%	643.82	808	461	1096.27	1122	1061
San Francisco	19.56%	30.10%	10.70%	411.27	627	261	995.73	1014	969
San Jose	22.74%	33.10%	15.70%	727.36	916	537	1035.55	1089	1012
San Luis Obispo	56.15%	65.80%	47.30%	1796.27	2583	1366	1215.55	1242	1181
San Marcos	10.53%	19.20%	4.10%	112.73	176	55	1021.00	1050	984
Sonoma	27.68%	36.70%	17.60%	150.64	247	97	1067.27	1090	1037
Stanislaus	25.75%	32.10%	19.80%	112.45	207	56	993.09	1036	942
System	31.17%	38.90%	25.00%	9813.82	11857	7940	1060.45	1073	1049

Table C.2

Average Proportion and Headcounts of URM STEM groups at CSU Campuses

	Ave over 10	Black HC	LAX HC	SEA HC	AA Pro	LAX Pro	SEA Pro	URM Pro
Bakersfield	119.1818	8	51.45455	54.54182	0.067124	0.431732	0.457635	0.956491
Channel Islands	70.72727	2.090909	15.72727	16.98545	0.029563	0.222365	0.240154	0.492082
Chico	443.6364	10.54545	65.81818	68.45091	0.02377	0.148361	0.154295	0.326426
Dominguez Hills	85.36364	28.27273	38.09091	40.37636	0.331203	0.446219	0.472993	1.250415
East Bay	150.8182	21.63636	27.90909	30.14182	0.14346	0.185051	0.199855	0.528366
Fresno	497.2727	27.09091	148.4545	154.3927	0.054479	0.298537	0.310479	0.663495
Fullerton	557.2727	27.27273	179.4545	190.2218	0.04894	0.322023	0.341344	0.712307
Humboldt	328.2727	12	50.18182	54.19636	0.036555	0.152866	0.165096	0.354517
Long Beach	713	44.36364	209.5455	217.9273	0.062221	0.293893	0.305648	0.661762
Los Angeles	251.1818	18.27273	142	150.52	0.072747	0.565328	0.599247	1.237322
Monterey Bay	130.1818	5.272727	36.90909	39.86182	0.040503	0.28352	0.306201	0.630223
Northridge	556.7273	54.18182	199.7273	207.7164	0.097322	0.358752	0.373103	0.829177
Pomona	1189.636	41.63636	343.0909	363.6764	0.034999	0.2884	0.305704	0.629103
Sacramento	475.2727	38.90909	88.81818	95.92364	0.081867	0.186878	0.201829	0.470574
San Bernardino	254.1818	29.09091	111.4545	115.9127	0.114449	0.438484	0.456023	1.008956
San Diego	643.8182	27.81818	134.9091	143.0036	0.043208	0.209545	0.222118	0.474872
San Francisco	411.2727	26.72727	74.81818	80.80364	0.064987	0.181919	0.196472	0.443378
San Jose	727.3636	34.63636	115.2727	119.8836	0.047619	0.15848	0.164819	0.370919
San Luis Obispo	1796.273	16.27273	190.8182	202.2673	0.009059	0.10623	0.112604	0.227893
San Marcos	112.7273	4.727273	27.09091	29.25818	0.041935	0.240323	0.259548	0.541806
Sonoma	150.6364	4.636364	21.72727	22.59636	0.030779	0.144237	0.150006	0.325021
Stanislaus	112.4545	3.363636	34.54545	36.61818	0.029911	0.307195	0.325627	0.662732
System	9813.818	488	2314.273	2499.415	0.049726	0.235818	0.254683	0.540227

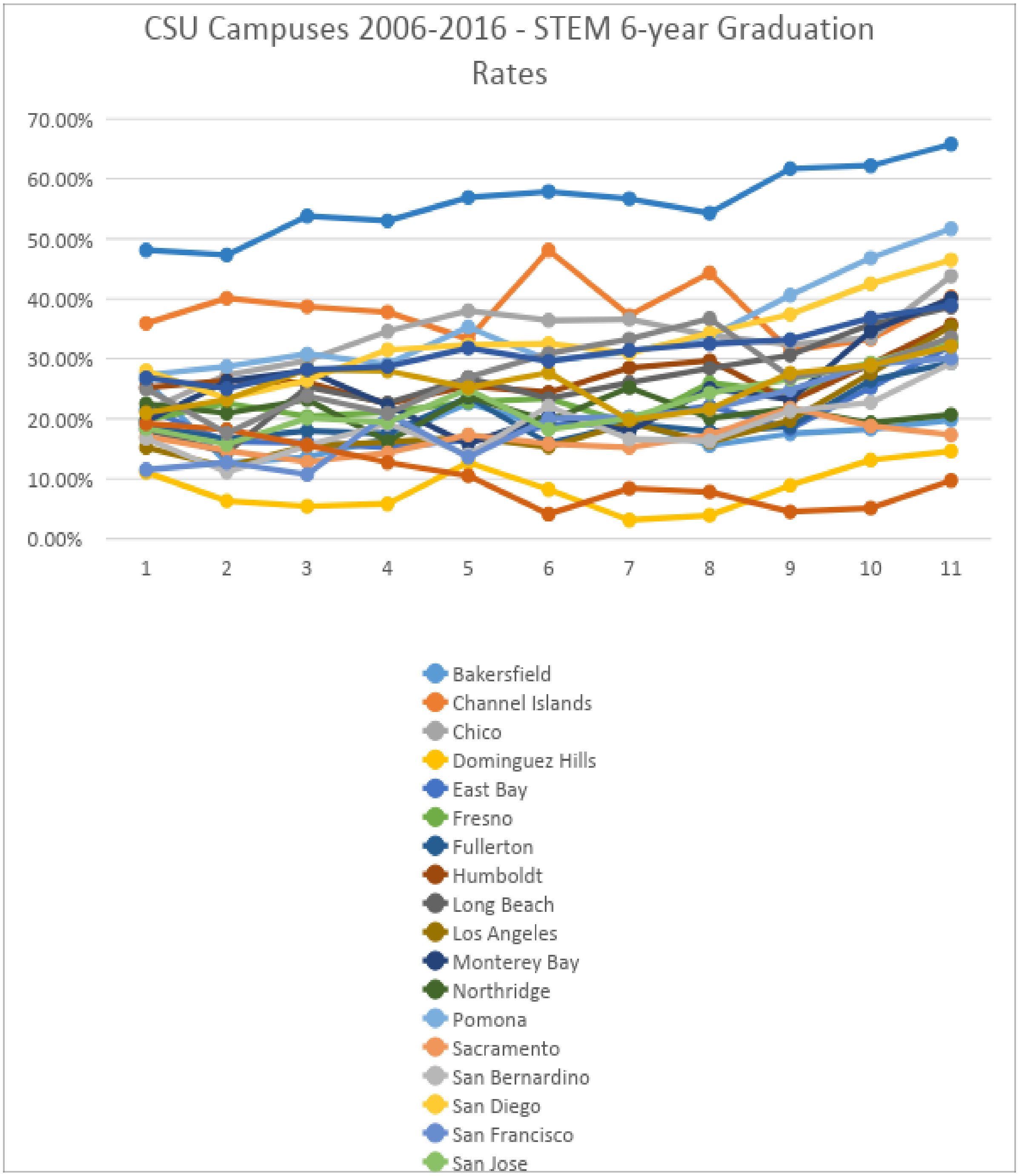

Figure C.3

Descriptive Statistics of CSU Campuses

APPENDIX D

Table D.1

Coding for Time: Incremental Change Model (Raudenbush & Bryk, 2002, pp. 179)

	Years										
	Phase 1					Phase 2					
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
a_{1t}	0	1	2	3	4	5	6	7	8	9	10
a_{2t}	0	0	0	0	0	1	2	3	4	5	6

	Years										
	Phase 1				Phase 2			Phase 3			
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
a_{1t}	0	1	2	3	4	5	6	7	8	9	10
a_{2t}	0	0	0	0	1	2	3	4	5	6	7
a_{3t}	0	0	0	0	0	0	0	1	2	3	4

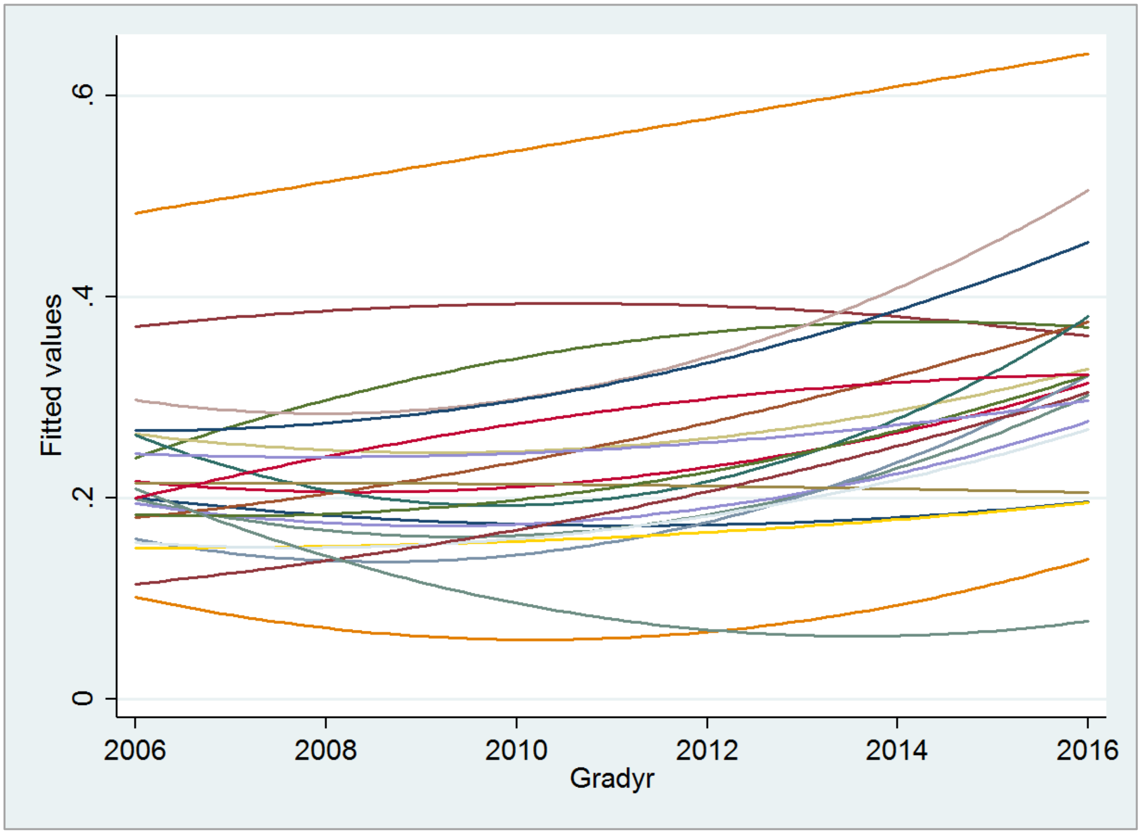

Figure D.2

Descriptive Statistics of CSU Campuses

Appendix E

Table E.1.1

Growth Modeling – Institutional Resource Allocations & Characteristics

Effects	Model 1	Model 5	Model 6	Model 7	Model 7a
Fixed Effects					
Initial Status					
Intercept	-1.438*** (0.11)	-1.053* (0.512)	-0.823* (0.489)	-0.936 (0.436)	-0.906* (0.438)
Intercept Post-GtRc				-0.079 (0.057)	-0.081 (0.058)
Instructional Support		-7.704* (0.708)	-2.19*** (0.672)	-1.653** (0.61)	-1.766** (0.634)
Student Services Support		0.854* (0.423)	0.88* (0.401)	0.705* (0.366)	0.721* (0.366)
NIH/NSF Grants		-0.874 (1.63)	-0.863 (1.54)	-0.364 (1.42)	-0.511 (1.43)
Post-GtRc*NIH/NSF Grants		-0.874 (1.63)	-0.863 (1.54)	-0.364 (1.42)	0.128 (0.244)
Rate of Change					
Overall Linear Growth	0.047***	0.066***	0.064***	0.035	0.035
Post-GtRc Linear Growth				0.078*	0.014
Random Effects					
Variance Components					
Within	0.059***	0.057***	0.053	0.042	0.042
In Initial Status	0.260***	0.254**	0.266	0.193	0.193
In rate of change	0.002**	0.002**	0.001	0.004	0.004
In Initial Status Post-GtRc					
In rate of change Post-GtRc				0.006	0.007
Goodness-of-fit					
AIC	136.33	132.47	111.75	82.32	84.07
BIC	153.78	163.87	150.12	138.14	143.38
Deviance	126.33	114.47	89.75	50.32	50.07

AIC = Akaike information criterion; BIC = Bayesian information criterion; ICC = Intraclass Correction. Full sample of all CSU Campuses, excluding CSU Maritime Academy. Likelihood ratio test (with scaling correction) based on comparison with previous model. Standard Errors (SE). Deviance tests an alternative model fit measurement. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table E.1.2.

Growth Modeling – Institutional Resource Allocations & Great Recession

Effects	Model 1	Model 5	Model 6	Model 7	Model 8	Model 9
Fixed Effects						
Intercept	-1.438*** (0.11)	-1.09* (0.519)	-0.833 (0.499)	-0.91* (0.475)	-0.797 (0.432)	-0.77 (0.443)
Intercept Post-GtRc				-0.081 (0.057)	-0.102 (0.054)	-0.089 (0.051)
Latinx STEM GR - TVC						1.584*** (0.342)
Instructional Support		-1.612* (0.724)	-2.136** (0.693)	-1.653** (0.61)	-1.772** (0.607)	-1.537** (0.581)
Student Services Support		0.848* (0.426)	0.861* (0.405)	0.705* (0.366)	0.687* (0.351)	0.667* (0.333)
NIH/NSF Grants		-0.848 (1.631)	-0.897 (1.536)	-0.634 (1.42)	-0.933 (1.36)	-0.825 (1.307)
Campus Selectivity			0.0498*** (0.01)	0.0453*** (0.01)	0.0401*** (0.008)	0.038*** (0.009)
STEM Cohort Size			-0.0001 (0.448)	-0.0001 (0.436)	-0.0001 (0.426)	
Black STEM GR					0.081 (0.116)	0.11 (0.11)
Latinx STEM GR					1.205*** (0.227)	
SEA STEM GR					0.104 (0.139)	0.099 (0.132)
Rate of Change						
Overall Linear Growth	0.047***	0.065***	0.064***	0.036	0.036	0.035
Post-GtRc Linear Growth				0.078***	0.054**	0.045*
Goodness-of-fit						
AIC	136.33	132.47	111.75	82.32	61.72	46.49
BIC	153.78	163.87	150.12	138.14	128.01	123.24
Deviance	126.33	114.47	89.75	50.32	23.72	2.49

AIC = Akaike information criterion; BIC = Bayesian information criterion; Full sample of all CSU Campuses, excluding CSU Maritime Academy. Standard Errors (SE). Deviance tests an alternative model fit measurement. TVC = Time-varying Covariate.

* $p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Table E.1.3.

Maximum Likelihood (ML) Goodness-of-Fit and Deviance Statistics

	Model 7	Model 7a	Model 8	Model 9
Goodness-of-fit				
AIC	108.67	102.18	53.94	96.38
BIC	188.91	185.91	155.12	187.09
Deviance	62.67	54.18	-4.06	44.38

AIC = Akaike information criterion; BIC = Bayesian information criterion; Full sample of all CSU Campuses, excluding CSU Maritime Academy. Standard Errors (SE). Deviance tests an alternative model fit measurement. TVC = Time-varying Covariate.

Table E.1.4.

Average STEM Enrollment by Campus Before and After Great Recession (N=242)

	Ave - Before GtRc	Ave - After GtRc	Difference
Bakersfield	92.00	141.83	49.83
Channel Islands	64.60	75.83	11.23
Chico	377.40	498.83	121.43
Dominguez Hills	64.20	103.00	38.80
East Bay	117.00	179.00	62.00
Fresno	415.80	565.17	149.37
Fullerton	449.60	647.00	197.40
Humboldt	248.20	395.00	146.80
Long Beach	578.80	824.83	246.03
Los Angeles	205.80	289.00	83.20
Monterey Bay	102.80	153.00	50.20
Northridge	455.60	641.00	185.40
Pomona	1119.00	1248.50	129.50
Sacramento	426.20	516.17	89.97
San Bernardino	169.00	325.17	156.17
San Diego	577.40	699.17	121.77
San Francisco	308.40	497.00	188.60
San Jose	746.80	711.17	-35.63
San Luis Obispo	1583.00	1974.00	391.00
San Marcos	89.60	132.00	42.40
Sonoma	111.20	183.50	72.30
Stanislaus	83.80	136.33	52.53
System	8397.20	10994.33	2597.13

Table E.1.5

Top and Bottom Five Spending Institutions – Student Services Per FTE

	Average per FTE	Average STEM GR
Top Five		
2016	$567.36	35%
2011	$491.81	31%
2006	$367.10	25%
Bottom Five		
2016	$469.80	20%
2011	$383.20	19%
2006	$218.60	22%

Table E.1.6

Piecewise Model Building – URM STEM Graduation Rates & Great Recession (GR) 2006 to 2016 (N = 242)

Effects	Model 6 *b* (SE)	Model 6-El[1] *b* (SE)	Model 6-Sl[2] *b* (SE)	Model-Both[3] *b* (SE)	Model 6a *b* (SE)
Initial Status					
Intercept	-1.908*** (0.13)	-1.844*** (0.13)	-1.75*** (0.13)	-1.727*** (0.13)	-1.727*** (0.13)
Intercept Post-GR		0.272*** (0.07)		0.153* (0.07)	0.153* (0.07)
Rate of Change					
Time 1	0.071***	0.032*	-0.001	-0.014	-0.014
Time 2: Pt-GtRc			0.143***	0.128***	0.128***
Random Effects					
Within	0.095***	0.089***	0.072**	0.063*	0.063**
Initial Status	0.317*	0.320*	0.327*	0.331*	0.331**
Time 1	0.001**	0.001*	0.002*	0.005*	0.005**
Status Pt-GtRc		0.000		0.000	
Time 2: Pt-GtRc			0.003*	0.009**	0.009**
Goodness-of-fit					
AIC	228.80	219.89	195.37	194.54	192.54
BIC	246.24	244.31	219.79	225.94	220.45
Deviance	218.80	205.89	181.37	176.54	176.54

AIC = Akaike information criterion; BIC = Bayesian information criterion. Full sample of all CSU Campuses, excluding CSU Maritime Academy. Likelihood ratio test (with scaling correction) based on comparison with previous model. Standard Errors (SE). Deviance tests an alternative model fit measurement.

^$p < 0.10$; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

[1] Elevation change; similar to Model 2a in Chapter 4

[2] Slope change, without elevation change; similar to Model 2b

[3] Both elevation and slope change, with a random effect for the elevation change; similar to Model 2c

Table E.1.7

CSU Resource Allocations by Salary Share of Budget (N = 242; 22 campuses)

Resource Allocations by Salary Share of Budget	Ave AY 2006-2011	Ave AY 2012-2016	Difference
Instructional Support	49.14%	48.71%	-0.44%
Student Services	52.24%	60.39%	+8.15%
Federal Training Grants	12.22%	14.47%	+2.25%

Table E.1.7

CSU Pre- and Post-Great Recession Spending (N = 242; 22 campuses)

Resource Allocations	Ave. 2006-2011	Ave. 2012-2016	Difference
Student Services	$480,110,607	$648,055,751	+$167,945,143
Instructional Support	$589,605,112	$612,455,317	+$22,850,204

Note: Ave = Average between the years indicated in the title. Spending includes all dollars allocated toward the category during the fiscal year in the CSU system.