ASSESSING THE IMPACT OF GENDER AND RACIAL/ETHNIC COMPOSITION ON WOMEN OF COLOR STUDENTS' LIKELIHOOD TO PURSUE A DOCTORAL DEGREE IN STEM DISCIPLINES

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Submitted to the faculty of the University Graduate School

in partial fulfillment of the requirements

for the degree

Doctor of Philosophy

in the School of Education,

Indiana University

December, 2019

Accepted by the Graduate Faculty, Indiana University, in partial fulfillment of the requirements for the degree of Doctor of Philosophy

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October 3, 2019

Acknowledgements

I would like to express my sincere gratitude to my family and my advisor Professor Victor Borden. My grandparents are from a rural area in China and they barely read the newspaper. However, they gave me unconditional love and instilled in me the importance of being educated. My parents provided full support when I decided to pursue a doctoral degree in the U.S., despite all the possible social prejudice against women Ph.D. pursuers.

I am especially grateful to Professor Victor Borden, my faculty advisor and dissertation chair, whose knowledge, insights, guidance, and patience lighted my way. I sincerely appreciate his time and effort committed to my dissertation and my entire study path at Indiana University, both professionally and personally. I am very fortunate to have him as my advisor. I look forward to his guidance for many years to come.

Last but not the least, I want to thank my dissertation committee members' time and support. Especially, I would like to thank Professor Amanda Diekman for joining my committee one month prior to my dissertation defense and providing invaluable feedback to my theoretical framework.

Finally, this dissertation is funded by the Beechler Dissertation proposal fellowship from the IU School of Education and the Holmstedt Dissertation Year Fellowship from the Higher Education and Student Affairs program at the IU School of Education. I truly appreciate their financial assistance for my dissertation research.

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The underrepresentation of women and minorities in STEM has been a subject of policy and research interest for decades. This underrepresentation deprives the STEM workforce of diverse perspectives and contributes to a loss of talent and creativity that can positively impact the country's ability to remain competitive globally. Despite years of devoting significant resources to this issue, progress in closing the gap has been slow.

This study seeks to develop a methodology to assess institutional effectiveness in preparing women of color for graduate STEM education. The assessment method should allow researchers, policy-makers and practitioners to explore the impact of structural characteristics and programmatic efforts to improve the preparation of women of color for graduate STEM education. To validate the model and explore its use, this study examines the impact of program structural characteristics related to gender and race/ethnicity composition and the presence of both undergraduate and graduate programs on the probability that women of color complete their undergraduate studies and go on to complete doctoral degrees in STEM fields.

There are two variables that have a negative impact on the outcome across disciplines: the proportion of part-time students and the institutional converted SAT-ACT score. The remaining predictors reveal mixed effects. The impact of the proportion of undergraduate students who are women of color, being a large-city located institution, and the proportion of students who are 25 years of age and older change direction when the outcome switches from the proportion of

STEM women of color bachelor's degree recipients to STEM women of color bachelor's degree recipients who went on to earn a doctorate. There is limited support for the impact of the interaction between the level of undergraduate/graduate program coexistence and the proportion of graduate women of color students.

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Assessing the Impact of Gender and Racial/Ethnic Composition on Women of Color Students' Likelihood to Pursue a Doctoral Degree in STEM Disciplines

Chapter One: Introduction

The Amendments to the Higher Education Act (HEA) of 1965 identified priority fields of study to encourage students to pursue and complete degrees within because those disciplines are "areas of national need." Science, technology, engineering, and mathematics (STEM) were thus highlighted as national priorities in the 1965 HEA (Goan, Cunningham, & Carroll, 2006, p. 1). Since then, a large number of federal, state and non-governmental policies and initiatives have focused on increasing participation in STEM fields overall and especially among traditionally under-represented groups of women and people of color. As a nation that relies on scientific and technology advancement to compete in today's global economy, U.S. educators and policy makers' have focused considerable time and attention on ensuring learning opportunities and pathways for U.S. and global citizens who are interested in and capable of pursuing degrees and careers in STEM (Espinosa, 2011).

The underrepresentation of women and minorities in STEM has been a subject of policy and research interest for decades (Strayhorn, DeVita, & Blakewood, 2012). This underrepresentation deprives the STEM workforce of diverse perspectives and contributes to a loss of talent and creativity that can positively impact the country's ability to remain competitive globally (Shapiro & Sax, 2011). Despite years of devoting significant resources to this issue by the National Science Foundation among other government and non-government agencies, progress in closing the gap has been slow (Groen & Rizzo, 2004). Concurrently, over the past few decades, American colleges and universities have experienced increasing public accountability pressures (Alexander, 2000; St. John, Kline, & Asker, 2001; Zumeta, 2001). An example was the Obama administration's ambition to create a postsecondary institution rating system to hold institutions accountable for a series of key performance measures (U.S. Department of Education, 2014). Although initially resolved as a "College Scorecard," there has generally been bipartisan support at the state and federal levels for increasing transparency and public reporting with regard to higher education institutional performance outcomes.

The proposed study seeks to develop a methodology to assess institutional effectiveness in preparing women of color for graduate STEM education. The proposed assessment method should allow researchers, policy-makers and practitioners to explore the impact of structural characteristics and programmatic efforts to improve the preparation of women of color for graduate STEM education. To explore the use of the model, this study examines the impact of program characteristics related to gender and race/ethnicity composition and the presence of both undergraduate and graduate programs on the probability that women of color complete their undergraduate studies and go on to complete doctoral degrees in STEM fields.

The remainder of this chapter reviews the current status of minorities and women in STEM disciplines, as well as federal programs promoting women and minority students' attainment in STEM. Chapter Two is divided in three sections. The first section explores empirical studies of women and minority students' major choice and persistence. The second section focuses on the theoretical underpinnings of the proposed study: Optimal Distinctiveness Theory, Tokenism Theory, and Intersectionality. The remaining section, informed by the literature related to value-added methods for assessing institutional graduation rates, establishes a two-level hierarchical linear model to partial out aspects of institutional performance of women of color's academic progress that are affected by exogenous variables and state economic and population composition background. The study then applies further ANOVA models to examine whether endogenous factors related to gender, race/ethnicity, and the co-existence of graduate programs further affect the graduation prospects and post-baccalaureate degree pursuits of women of color in STEM Programs.

Current Status of Women and Racial/Ethnic Minorities in STEM Disciplines

The American Physical Society (2014a) reported that the percentage of degrees awarded to minorities from 2010 to 2012 was below 20% for all the STEM disciplines across the doctoral, Master's, and Bachelor's levels. In particular, less than 10% of Bachelor's degrees in physics were awarded to minorities. The proportion of Master's and doctoral degrees awarded to minorities in that discipline was even lower.

The National Science Foundation (NSF) (2013) tracked the number of Bachelor's degrees awarded specifically to minorities from 1991 to 2010, finding that the percentage of such degrees increased by only approximately 5% over these two decades. In 2010, the proportion of degrees awarded to minorities in biological sciences, engineering, physical sciences, and mathematics was between 10% and 15%. In contrast, minorities accounted for 37.4% of the U.S. population by 2010 (U.S. Census Bureau, 2014).

Women's presence in STEM is a more nuanced issue. According to the American Physical Society (2014b), the percentage of women earning bachelor's degrees, overall exceeded 50% starting in the 1980s. However, the percentages of women in all STEM disciplines were lower than their representation in the U.S. population in 2012. The proportion in biology, in which women were overrepresented, was an exception. A larger representation gap exists in the fields of engineering and physics, where women Bachelor's degree holders increased from less than 10% in 1965 to approximately 20% in 2012. Heibronner (2013), and NSF (2013) reported similar trends. Today, women are overrepresented in biology (Office of Science and Technology

Policy, National Science and Technology Council, 2016), but still notably underrepresented in physical science, computer science, and engineering.

Previous studies have endeavored to explore minority and women students' success in STEM from four perspectives: enrollment patterns; college control and STEM culture; barriers that students may encounter; and the institutional characteristics that may moderate barriers for students to earn a STEM degree (Crisp, Nora, & Taggart, 2009; Espinosa, 2011; Perna, et al., 2009). The first-semester GPA and enrollment in mathematics and science "gatekeeper" courses were positively associated with students' success in earning a STEM degree (Crisp, Nora, & Taggart, 2009). In addition, Espinosa (2011) found that those who had ambitions to benefit others, attended private colleges, and attended institutions with a rigorous STEM community are more likely to persist and obtain a degree in STEM. Barriers include academic, social, psychological, and financial difficulties. Institutional characteristics such as class size, peer support, faculty encouragement and involvement, academic support services, and undergraduate research opportunities have also been explored as potential barriers or enablers (Espinosa, 2011; Perna, et al., 2009).

Several studies have demonstrated that institutions with specialized missions, such as Hispanic serving institutions (HSIs) and historically black colleges and universities (HBCUs) have exceled in broadening minorities' participation in STEM programs. Hispanics and African Americans are well represented in STEM disciplines at HSIs and HBCUs, respectively (Crisp, Nora, & Taggart, 2009; Perna, et al., 2009). For this reason, minority serving institutions have been the target for some federal programs that promote STEM education, although others are targeted more generally at women and minorities across institution type.

Overview of Federal Programs Promoting STEM Education

The committee on STEM education under the National Science and Technology Council identified four priority areas in the strategic plan to improve STEM education (Office of Science and Technology Policy, 2012). Two of them are related to the purpose of this study. The first is undergraduate STEM education, which includes improving retention rates for underrepresented minorities in STEM disciplines during the first two years of college. The second is serving groups traditionally underrepresented in STEM fields, which includes increasing women and minority students who graduate with a STEM degree.

The federal investment in STEM education is divided among fourteen agencies, and the amount of funding has increased continuously since 2013 (Office of Science and Technology Policy, 2014), at a time when many other aspects of U.S. federal spending have been suppressed (See Appendix A). The Education Department, Department of Health and Human Services, and the National Science Foundation are the three agencies that have received the largest amounts of federal STEM investment (Office of Science and Technology Policy, 2014; 2015). Selected programs that have a focus on women and minority students are discussed in the following section.

Louis Strokes Alliances for Minority Participation (LSAMP). The LSAMP program helps institutions increase the number of students completing degree programs in STEM disciplines. Particular focus is placed on supporting historically underrepresented groups, such as African Americans, Alaska Natives, American Indians, Hispanic Americans, Native Hawaiians, and Native Pacific Islanders (NSF, 2009a). Resources are allocated for minority students recruitment, retention, and attainment in STEM disciplines. The budget for the LSAMP program in 2015 was 46 million dollars (Office of Science and Technology Policy, 2014).

Historically Black Colleges and Universities Undergraduate Program (HBCU-UP). HBCU-UP provides funding to enhance the quality of undergraduate STEM education and research at historically black colleges and universities (HBCUs). The purpose of this program is to broaden minority participation in the U.S. STEM workforce (NSF, 2009b). Some of the types of projects funded by HBCU-UP include implementation projects, planning grants, and education research projects.

Implementation projects fund institutional initiatives that comprehensively strengthen STEM education and research. Typical projects include “faculty professional development, student support services, and collaborations with research institutions and industry” (NSF, 2009b, p. 1). Planning grants fund activities that include self-analysis of an institution’s undergraduate STEM programs to find factors that require improvement. Typical examples include “data collection and analysis, stakeholder consultation, and research of potential activities and strategies” (NSF, 2009b, p. 2). Education research projects provide funding for three-year research projects that potentially strengthen HBCU STEM education and research programs. Typical initiatives include “retention, STEM teacher education, and the identification of successful models” (NSF, 2009b, p. 2).

Developing Hispanic-Serving Institutions (DHSI). The DHSI program is designed for HSIs to improve Hispanic student attainment and expand opportunities in STEM disciplines. Activities funded by this program include: “laboratory equipment for teaching, purchase of educational materials, and faculty development” (U.S. Department of Education, 2015).

Improving Undergraduate STEM Education (IUSE). In 2016, approximately $135 million was proposed by NSF to support transforming undergraduate teaching and learning in STEM disciplines. One component of this foundation-wide framework is to increase women and minority students' degree completion in STEM fields. A total of $109 million is proposed in 2017, in which one of the goals is to recruit more women and minority students into computer science (Office of Science and Technology Policy, 2015; 2016).

Women and Minorities in Science, Technology, Engineering, and Mathematics Fields Program (WAMS). This program support projects that increase the participation of women and minority students from rural areas in science, technology, engineering, and mathematics disciplines relevant to the Department of Agriculture's priorities. Entities eligible to apply include land-grant colleges and universities. A total of $0.4 million was invested in this program in both 2015 and 2016 (Department of Agriculture, 2017; Office of Science and Technology Policy, 2016).

Significant resources have been devoted to establish effective practices for supporting women and minorities in STEM disciplines. However, there is a lack of empirical research demonstrating that any of these initiatives or models is significantly effective (U.S. Department of Education, 2007). Despite the tremendous amount of resources that have been devoted to this issue, women of color are still severely underrepresented in most STEM disciplines. It would therefore be useful to develop a valid methodology to measure institutional performance in this area. This study seeks to develop a methodology that takes into account mission context and other exogenous aspects of college and university circumstances. Having such a method would make it possible to identify and assess various endogenous aspects of higher education programs and practices that may impact women of color students' prospects for completing a STEM Bachelor's degree and going on to earn a PhD degree in STEM disciplines.

Variability of STEM Definition

Several government agencies publish taxonomies of STEM disciplines. For example, The Integrated Postsecondary Data System (IPEDS) applies a narrow definition and designates STEM disciplines in six categories applying the broad categories of the Classification of Instructional Programs (CIP) taxonomy: computer and information sciences, engineering and engineering technologies, biological and biomedical sciences, mathematics and statistics, physical sciences, and science technologies. The Survey of Earned Doctorates (SED) sponsored by the National Science Foundation and several other government agencies has its own scheme of STEM disciplines. The U.S. Immigration and Customs Enforcement (ICE) agency, using CIP codes, employs a broad definition of STEM for the purpose of the 24-month optional practical training extension for international students holding a student visa (F-1) (Department of Homeland Security, 2016). Since the Survey of Earned Doctorates is one of the primary data sources and I would like to apply a STEM definition as broad as possible, the STEM disciplines defined in this study is a combination of the schemes used in ICE and SED as described in Appendix B.

Women of Color Definition

The underrepresentation of women of color in STEM disciplines has existed for decades (Strayhorn, DeVita, & Blakewood, 2012). This study seeks to find a group of women of color students that are identified in both IPEDS and SED. This results in including women of color students from the racial/ethnic groups, African American, Hispanic, and American Indian or Alaska Native.

Asian American and Pacific Islanders (AAPI) are usually stereotyped as the model minority and tend to be invisible from a policy maker's perspective. However, there is a large contrast between AAPI subgroups in the correlation between students' family income and college enrollment rates (Teranishi, 2010). Given that this study is framed as quantitative research and therefore unable to investigate the variety within such a group, women students who are Asian American and Pacific Islanders are excluded from this study.

Chapter Two provides a literature review of theory-grounded studies regarding STEM major choice and persistence of women and minority students'. We then situate this study within the integration of Optimal Distinctiveness Theory, Tokenism Theory, and Intersectionality. Developing the theoretical underpinnings for this study is followed by a description of the research questions and methodological approach. Chapter Three provides more details about the data sources, sample selection, variables considered, and statistical models adopted in this study. Toward this end, Chapter Three includes a review of literature related to the variables typically employed in value-added graduation rate models to inform the variables selected for this study followed by variables proposed to adopt when building value-added models to predict the outcomes of interest. Chapter 4 reports the results of the value-added models and the ANOVA approach that investigates the impact of the interaction between the undergraduate/graduate women of color degrees conferred and undergraduate/graduate program coexistence. Chapter 5 discusses the theoretical, practical, and academic implication of the findings from Chapter 4.

Chapter Two: Literature Review

Proportionally fewer women than men earn a bachelor's degree in STEM disciplines. This phenomenon has existed for decades (American Physical Society, 2014b). However, the percentage of minority students earning a bachelor's degree in STEM is even lower in relation to population representation compared to the gap for women (American Physical Society, 2014a). Thus, it is important to understand the reason why women and minority students avoid choosing STEM as their major, and why many who do choose STEM fail to complete these programs.

Optimal Distinctiveness Theory, Tokenism Theory, and Intersectionality are the theoretical perspectives that provide the framework for this study. More specifically, the concepts of tokenism and intersectionality are applied to inform the use of Optimal Distinctiveness Theory to explain the impact of gender composition, racial/ethnic composition, and the coexistence of graduate programs on undergraduate women of color's degree completion and prospects for going on to earn a graduate degree in STEM disciplines.

In the methodological framework section, a value-added measurement model for assessing institutional effectiveness is discussed incorporating the theories to outline the design of this study. After presenting the methodological model, two research questions are posed to guide this project.

Women's STEM Major Choice

Women college students usually encounter three types of barriers when choosing STEM as a major and persisting to Bachelor's degree completion: academic, social, and psychological (Beggs, Bantham, & Taylor, 2008; Goldman, 2012; Heibronner, 2013; Malgwi, Howe, & Bumaby, 2005; Purna et al., 2009; Sax, 2001; Shapiro & Sax, 2011). Heibronner (2013) argues that there has been a noticeable achievement gap between men and women in the SAT-

Mathematics and SAT-Verbal assessments since 1972. Comparatively, women take fewer STEM-related AP classes in high school than do men. Inadequate high school preparation has thus been cited as one of the important factors related to fewer women students choosing STEM majors and higher attrition among those who do (Shapiro & Sax, 2011). By these measures, women tend to be viewed as less academically prepared than men (Goldman, 2012; Shapiro & Sax, 2011).

Another challenge for women choosing STEM majors are social perceptions related to gender (Dawson-Threat & Huba, 1996; Goldman, 2012; Sax, 2001; Shapiro & Sax, 2011) that significantly impact major choice. Most students choose majors that are traditionally dominated by their gender (Dawson-Threat & Huba, 1996; Goldman, 2012). Another difference that is purported to motivate men and women's major choice is that men are more influenced by financial or status rewards, while women are more impacted by the perceived "social good" of their future careers (Sax, 2001, p. 155).

The third impediment relates to psychological factors. Several studies have demonstrated that women tend to have less confidence, interest, and self-esteem studying STEM (Heibronner, 2013; Shapiro & Sax, 2011). Malgwi, Howe, & Bumaby (2005) also found that the influence of aptitude in learning a subject was significantly stronger for women than for men. This helps explain why fewer women major in STEM and their attrition rates are higher compared to men (Goldman, 2012).

In addition, there is a debate about the role of peer interaction and parents' support in women's STEM major choice. Sax (2001) articulated the importance of a peer group that values science in increasing women's aspiration level in science. Shapiro & Sax (2011) reported that women in STEM were often treated by peers in a way that make them feel unwelcome and hostile. Beggs, Bantham, & Taylor's (2008) review argued that some studies suggests parents have a strong influence on college students' major choice, but other studies demonstrated that only a small proportion of their respondents reported that parental pressure and parental occupation had a strong impact on their major choice. There have been conflicting findings regarding the role parents play in influencing students' choice of major (Beggs, Bantham, & Taylor, 2008).

Underrepresented Racial Minorities' STEM Major Choice and Persistence

Underrepresented racial minority (URM[1]) students are less likely to choose a STEM major. If they do, their persistence rates in STEM disciplines are also lower than their White and Asian counterparts (Arcidiacono, Aucejo, & Hotz, 2016; Chang, 2008; Griffith, 2010). URM students' STEM major choice and retention could be influenced by multiple factors. Chang (2014) reviews that family support and interaction with faculty mentors is positively associated with Latino students' academic self-efficacy and success in science majors. Wang (2013) found that math self-efficacy is influenced by early math achievement to a greater degree among URM students than among White and Asian students in their STEM intent. First-semester GPA, and enrollment in mathematics and science "gatekeeper" courses can predict students' STEM major choice and earning a STEM degree in a Hispanic serving institution (Crisp, Nora, & Taggart, 2009). Griffith (2010) provided evidence that the percentage of URM graduate students in STEM disciplines is positively associated with URM undergraduate students' persistence in STEM.

The impact of institutional selectivity on minority students' STEM persistence is multifaceted. Espinosa (2011) found that institutional selectivity is negatively associated with

[1] In this study, underrepresented racial minority (URM) students refer to students who have a black non-Hispanic, Hispanic, and American Indian or Alaska Native background. Asian American students are excluded in this study.

women of color students' persistence in a STEM major. Chang (2008) reveals that all students, regardless of their race, are at a higher risk of leaving a biomedical or behavioral major in more selective institutions. The negative effect of institutional selectivity for URM students is even stronger. However, the effect of institutional selectivity is positive for those who attend selective HBCUs. Chang (2008) attributes URM students' greater risk of failing to those institutions' inability of providing sufficient resources to compensate for deficits in their previous education. Arcidiacono, Aucejo, & Hotz (2016), however, presented a different explanation. Applying data from public University of California (UC) system, their study reported that less-prepared minorities at more selective campuses had lower retention rates in STEM disciplines and they time they took to graduate is longer than those at less-selective campuses. They believe it results from URM students' lack of information about within-campus differences in graduating students. They therefore recommend providing students with sufficient information about the likelihood of graduating in STEM before students make college choice. Also, they recommend less-prepared URM students going to less-selective UC campuses and graduating in STEM majors to maximize their economic returns.

There is some empirical evidence of strategies that help URM students entering and retaining in STEM disciplines. Hurtado, et. al. (2007) used longitudinal data from the Higher Education Research Institute 2004 Cooperative Institutional Research Program Freshman Survey and the 2005 Your First College Year survey. They found that making science coursework relevant to students' daily lives is one of the key factors that help URM students adjust to the new academic environment and enhance their sense of belonging.

Long & Riley (2007) revealed that URM students are more sensitive to financial needs when accessing college and are more likely to find employment when pursuing a degree. Chang, et. al. (2014) found that working full-time harms URM students' degree completion in STEM disciplines. However, paid research work on research projects could help URM students relieve college expenses and be engaged in their academic study, resulting in increasing STEM persistence rate.

Previous literature reveals that women and minority students have many challenges to make a STEM major choice and earn a degree. Some of them are similar challenges, such as lower self-efficacy and less academic readiness for both groups of students. However, little is known about how program structural factors affect women of color students' identity and group membership impact on women of color students' STEM major choice and degree completion. It is useful to consider theoretical explanations as to why these factors impact on women of color students' likelihood to pursue a doctoral degree in STEM disciplines.

The following section discusses the theoretical framework of this study. It focuses initially on Optimal Distinctiveness Theory to address the relationship between STEM women of color students' group size and group membership. Tokenism is applied to explain the impact of program structural characteristics, such as the coexistence of graduate programs and the number of women of color graduate students, on mitigating the effect of being one of the tokens. Intersectionality is used to unfold the complexity of STEM women of color students' identity.

Theoretical Framework

This study employs three theories to inform the development of the methodology and generate hypothesis related to the impact of structural characteristics on preparing women of color for academic achievement in STEM fields: Optimal Distinctiveness Theory (Brewer 1991), Tokenism (Kanter 1977a, 1977b), and intersectionality (Crenshaw 1989). More specifically, the concepts of tokenism and intersectionality are used to inform the application of Optimal

Distinctiveness theory to examine the impact of program structural characteristics on the academic progress of women of color in STEM disciplines.

Optimal Distinctiveness Theory (ODT). ODT was first proposed by Brewer (1991) to fill a gap in Social Identity Theory (Leonardelli, Pickett, & Brewer, 2010). As an extension of Social Identity Theory (Brewer, 2003), ODT posits that social identity derives from a fundamental tension between human beings' needs for being similar and unique simultaneously. Individuals are mutually motivated to be different from and part of a collective identity. Individuals' recognition of their social identity is maximized when the activation of these two opposing drives achieves equilibrium or optimal distinctiveness, (Brewer, 1991).

There are four assumptions underlying ODT. First, social identification is strongest when social groups or categories resolve the conflict between an individual's need for differentiation and assimilation. Second, individuals by nature prefer positive group identities to negative identities, but this preference is independent of people's pursuit of optimal distinctiveness. Third, the distinctiveness of any social identity is highly context specific. The context ranges from a specific gathering at a particular time to the entire human race. Fourth, the strength of the two opposing needs is influenced by cultural norms, socialization, and recent experience (Brewer, 1991).

Empirical support of ODT is well documented. Lau (1989) conducted a study about the individual and contextual influences on group identification. Using the 1972 and 1976 National Election Studies conducted by the Survey Research Center of the University of Michigan for the Center for Political Studies. Lau's study found that black respondents' identification recognition increased until the density of black residents reaches approximately 72 percent. After that, black identities were less salient. Thus, there is an inverted U shape relationship between residential density and the respondents' black identity.

Similar findings emerged from Bearman and Bruckner's (2001) study about adolescents' commitment to virginity pledges. The researchers found that the possibility of committing to a virginity pledge increased until 40% of the respondents had committed to do so. After that, the likelihood among respondents to pledge decreased when the percentage of pledged respondents increased. Along the same lines, Abrams (2009) investigated young adults' music preference. In this study, the music preference was divided into different levels of popularity through the number of respondents who made each style as their first choice. It ranged from widely inclusive to more exclusive, and were labeled "superordinate," "intermediate," "subordinate," "minority," and "non-rock." The results again demonstrated an inverted U shape between the category inclusiveness and commitment. Those respondents falling in the "subordinate" group reported the highest level of listening (buying records and attending concerts) and active involvement (attending concerts, buying clothes, and hairstyle).

The relationship between group size and people's group membership preference is dynamic. Minority status is often associated with low-status power. People are more likely to identify strongly with groups that are stigmatized, or suffer from negative inter-group evaluation (Brewer, 2003). In many contexts, disadvantaged minorities face a conflict between group identification and preference for positive evaluation (Brewer, 1991; 1993b). When individuals are immersed in larger social units, activation of the need for inclusion decreases. Conversely, when individuals move into smaller, more exclusive units, the need for inclusion increases (Brewer & Roccas, 2001). Members of a high-status majority group may be satisfied with their positive social identity, but they need to face the demand for distinctiveness. One way to meet this need is to fulfill it in subgroups (Brewer, 1993b), which enables individuals to switch the context from predominantly majority to mostly minority.

Minorities are more likely to maintain group membership. After group identity has been established, the disadvantaged status may enhance group loyalties rather than undermine them (Brewer, 1993b; Leonardelli, Pickett, & Brewer, 2010). However, the strong group membership could be a source of in-group bias. Brewer (1993a) found that much discrimination is motivated by the desire to promote and maintain in-group membership. It is noted that discrimination and bias develop not because out-groups are hated, but because positive emotions are reserved for the in-group and are blocked from the out-groups. In other words, in-group love does not necessarily trigger out-group hate (Brewer, 1999).

In addition, in-group favoritism could be a signal of membership preference, but it functions differently for minority and majority group members. For minorities, in-group favoritism is an expression of membership and support. By contrast, in-group favoritism for majority group members indicates that individuals are motivated to achieve group distinctiveness (Leonardelli, Pickett, & Brewer, 2010).

Because women of color in STEM disciplines are usually minority and in low-status power, they are anticipated to have a strong sense of group membership, a high demand for being similar within the group and being distinctive from out-groups. However, it is theoretically unclear that whether this strong sense of group belonging could activate their desire to complete a STEM degree and go on to earn a doctoral degree. Particularly, ODT does not address the environmental factors, such as the coexistence of graduate programs and the number of women of color graduate students have any impact on STEM women of color students' academic progress. In addition, ODT does not address the complexity of women of color students' group affiliation and how the multiple identities influence the outcome of interest differently from their counterparts, such as men of color students, white women students, and women of color students in non-STEM disciplines. Therefore, Tokenism and Intersectionality are reviewed to answer these questions.

Tokenism Theory. Kanter (1977a, 1977b) proposed the theory of Tokenism to explain how proportional representation of groups within an organization affects interactions between members of groups represented in lower proportions to those in the majority group. Specifically, she noted that groups represented in proportions lower than 15% (tokens) provide organizations with the appearance of addressing equality and equity issues, but result in interactive dynamics that create barriers to the work and advancement of tokens within the organization (Kanter, 1977a). Three phenomena associated with tokens are visibility, polarization, and assimilation (Kanter, 1977b).

Visibility results in tokens more likely being noticed than dominants. This increases tokens' performance pressures. Tokens may attempt to decrease visibility to respond to this pressure. Strategies include minimizing attributes to blend into the dominant culture, or avoidance of events and occasions to be exposed by peers for judgments. Consequences of these actions are reduced recognition of tokens' competence, and tokens' fear of success (Kanter, 1977b). Polarization tends to makes numerical majorities exaggerate characteristics that they share in common and differ from tokens. The dominant members tend to heighten group boundaries. Tokens either accept isolation or demonstrate loyalties by identifying themselves different from their own group and opposing their own category. The latter response sometimes results in tokens' within-group prejudice (Kanter, 1977b). The tendency of assimilation leads tokens to distort their characteristics to be adjusted into the dominant culture. This could induce tokens into stereotypical roles. Therefore, there is a need to remove the effect of distortion to achieve accurate conclusions when studying work attitudes and behaviors about token people. (Kanter, 1977b).

One criticism of Kanter's theory is that she did not address how the effect of tokenism differs for men and women. As a gender-neutral theory, Tokenism theory predicts that the token effect may be equal for men and women (Kanter, 1977a, 1977b). However, for men in female-dominated fields, such as school teachers and nurses, the effect of tokenism could be a "glass escalator," while for women in men-dominated fields, such as coal miners and fire fighters, this effect could be a "glass ceiling" to their work satisfaction and promotion (Williams, 1992, Yoder, 1991). Moreoever, Zimmer (1988) suggested that the negative work experience of women could result from their lower social status, rather than their group underrepresentation.

Studies of Tokenism have been conducted across a wide array or organizational settings, uch as police, Wall Street employees, and scientists (Gustafson, 2008; Stichman, Hassell, & Archbold, 2010). However, the findings are inconsistent. Sax (1996) attributes this inconsistency to the lack of control for characteristics of subjects, the environments, and the subjects' experience. The effect of gender composition could also be caused by the nature of those disciplines and depend on the outcomes researchers analyzed and comparison groups used.

In this study, the role model effect, related to the potential support available to undergraduate women of color from graduate women of color, is one aspect of tokenism theory. Women of color students in STEM disciplines, as a group of tokens, may encounter negative instead of positive influences when pursuing a graduate degree. Tokenism could be experienced among this group of students, such as avoidance of interaction with classmates, feeling isolated and a fear of academic success. Interaction with graduate students who are in the same token group may help reduce the tokenism effect. Women of color undergraduate students are more likely to see themselves as STEM graduate students if they see others like themselves in that role (especially if those role models succeed). This could make undergraduate women of color feel less distinctive and motivate them to pursue a graduate degree. However, environmental factors, such as the characteristics of institutions and the culture of the department may either further mitigate or lend support to such aspirations.

In contrast, the peer effect, related to support from other undergraduate women of color, is more reflected in ODT. Since being distinctive as a minority group member is at least unpleasant and at most devastating (Brewer, 1991), it is understandable that undergraduate women of color STEM students have to act in a way that make them less distinctive. Increasing the number of undergraduate women of color STEM students would make this group being less distinctive. However, whether this decreasing distinctiveness would encourage or discourage undergraduate women of color STEM students' bachelor's degree completion and doctoral degree completion is an unresolved question. These issues can be addressed at least at a surface level through the results of this study.

Intersectionality Rooted in sociology and Black feminist scholarship, intersectionality has become an interdisciplinary alternative to understand and analyze social structures (Taylor, Miller, & Garcia-Louis, 2014). Collins & Bilge (2016) describe intersectionality as a lens to understand and analyze the sophistication of the world. Social and political lives are seldom caused by only one factor. Factors influencing social and political conditions are often numerous and mutually impact each other. Especially in the realm of social inequality, people and organizations are more comprehensively understood by multiple axes of their social dimensions, such as race, gender, and class. Intersectionality provides an analytical tool to help people understand the complexity of the world. In the field of higher education, researchers did not study the intersection of race and gender until the beginning of the twenty-first century (Museus & Griffin, 2011). Intersectional analyses can advance research to more accurately reflect the diversity of higher education, understand the reality of marginal students, and promote analyzing how multiple identities result in inequality (Museus & Griffin, 2011).

Women of color students in STEM disciplines have in common three identities: women, minority, and STEM major. However, their experience is not simply determined by the combination of gender and race. The intersection of one's multiple marginalized identities converges to create a distinctive experience that differs from those who share some of their identities but not all (Crenshaw, 1989). For undergraduate STEM students, the impact of the presence of women of color in coexisting graduate programs should be different for undergraduate women of color than other students, such as minority males and white females in STEM disciplines.

Intersectionality also addresses the issue of minority identity in ODT. Brewer (1991, 1993) identified the behaviors in which minorities engage to achieve equilibrium, but she did not address the commonplace situation where an individual's identity is shaped by multiple group affiliations. Intersectionality suggests that we need to consider the combination of multiple sources of identity when examining issues related to group identity within interactive settings.

Women of color students in STEM disciplines, as a group of tokens, may encounter many negative and fewer positive influences when pursuing a graduate degree. However, having graduate women of color students within the same program can mitigate the tokenism effect. The presence of graduate women of color students provides undergraduate students with positive role models for STEM graduate study. This could make them feel less distinctive and help motivate them to pursue a graduate degree.

ODT, Tokenism, and Intersectionality frame this study from the perspective of women of color students' group size and membership, interaction of minority and majority, and the complexity of multiple group affiliations. Before further analyzing the effect of program structural factors and racial/ethnic composition on the outcome of interest, it is necessary to first establish a value-added model to partial out the factors from exogenous variables of institutional performance in preparing STEM women of color for their academic progress. Variables used in predicting graduation rates are similar but different from variables applied in this study. After creating a valid value-added model, this study analyzes the impact of the program structural and racial/ethnic composition on the variation of the residuals in the value-added model.

Value-Added Methodological Framework

Astin (1997) noted that simply comparing raw graduation rates across institutions provides a misleading measure of institutional performance or effectiveness. The diversity of American institutions and college student populations requires a more nuanced methodology to accurately assess institutional performance. Therefore, it is essential to investigate and take into account how student quality and other inputs and uncontrollable contextual issues influence performance outcomes to avoid detrimental consequences to institutions simply due to their agreed upon missions (Bailey & Xu, 2012). One frequently cited repercussion of not doing so is limiting access to underserved populations so as to not "look bad" (Machung, 1998; Myers & Robe, 2009).

When examining graduation rates, typical variables include selectivity (measured as institutional average SAT/ACT scores), student affluence (percent of Pell recipients), proportion of nontraditional students (part-time students and students over age 25), institutional control (public v. private, non-profit) and the state context for funding institutions. Since the outcome of interest in this study is different from graduation rates, those variables typically applied in the value-added models predicting graduation rates are referenced but other factors are considered in this exploratory study.

For the current study, examining the number and proportions of women of color graduating in STEM majors and subsequently earning STEM doctoral degrees, some similar but some different exogenous factors can be identified. For example, the number of women of color at the state and the institutional level reflect the available pool of women of color in STEM majors. The proportion of degrees conferred in STEM disciplines is another exogenous variable that needs to be considered when predicting the outcome of interest. Other factors, such as institutional selectivity and control, which have been proven to have significant impact on the institutional retention and graduation rates, are less important than the number of women of color in the state and institutional level. However, they are still considered as part of this exploratory study. Once we partial out such factors, the residual of the normatively predicted value can be taken as a first-order, value-added performance measure.

After we have created a valid value-added model, we can then analyze variation in this residual as related to structural factors and other circumstances and programs that institutions can shape. The current study explores how the proportional representation of women and minorities in STEM fields and the coexistence of undergraduate and graduate programs affects the probability of undergraduate STEM women of color students' bachelor's degree and doctoral degree completion.

The influence of peers on the likelihood that women of color pursue a graduate degree can be viewed at both the individual and institutional level. We focus here on the institutional level, where the gender and ethnic composition of undergraduate and graduate programs relates to the prospective presence or absence of peer support (undergraduates) and mentors or role models (graduate students and faculty) for undergraduate women of color enrolled across all major types. To explore specifically women of color in STEM majors, we develop parallel value-added measures focusing on two additional outcome measures: 1) the proportion of women of color STEM graduates; and 2) the proportion of women of color STEM graduates who subsequently earn a STEM doctoral degree. We can then explore the relationship between the residuals of these models and the presence of peer support through STEM program graduate/undergraduate coexistence, conditional on the proportion of women of color at both levels. The peer support revealed through this analysis can provide a basis for intervention and improvement by focusing attention on group cohort effects. Although institutional data on faculty race/ethnicity within specific STEM programs is not available, we can employ general institutional women and minority representation on the faculty as a proxy for the STEM-specific analyses.

The methodological model for the research design is summarized in the following figure. Using a multi-level model, the research generates predicted institutional performance benchmarks, based on both aggregate student characteristics, as well aspects of institutional context that relate to the mission of the institution (e.g., proportional representation of women of color at the state and institutional level, control, degree level mix, program mix, size and setting, selectivity, etc.). The residuals from that model represent the first-order value-added performance measure. The study then explores the relationship between the residual and structural characteristics of the STEM programs as determined by degree production derived through National Center for Education Statistics IPEDS completions data.

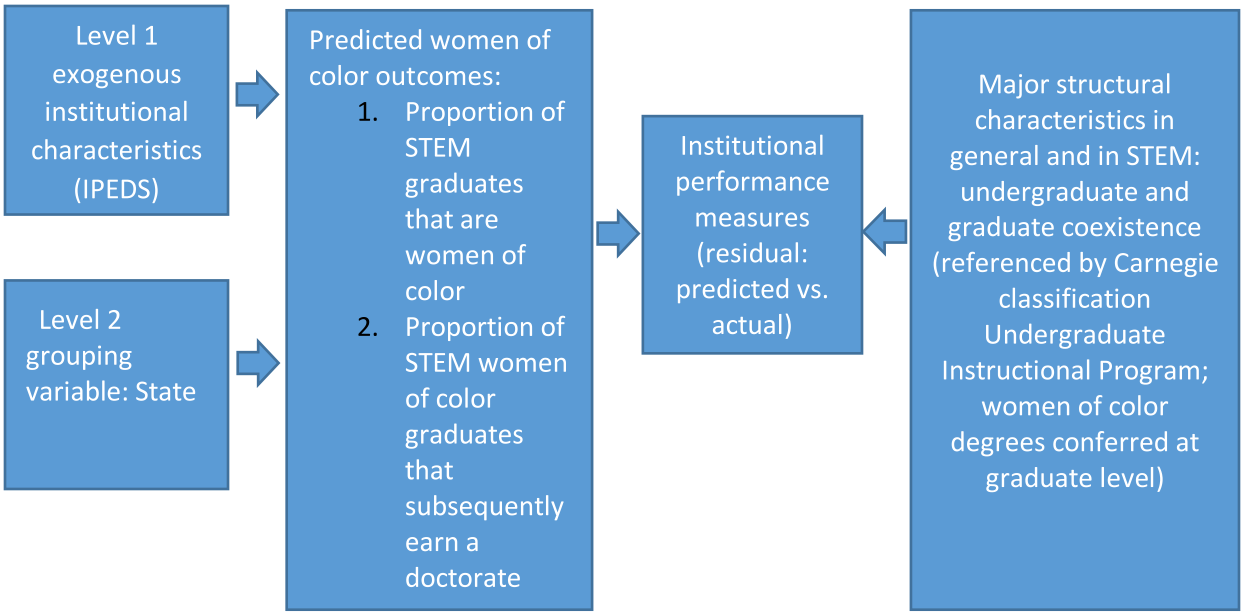

Figure 1. Methodological Model

Research Questions

This study first explores the exogenous conditions, such as the proportion of women of color in the regional general population and institutional student population, percent Pell recipients and the proportion of degrees conferred to STEM disciplines that predict: 1) the rate within STEM fields; 2) the proportion of women of color STEM graduates that go on to complete doctoral study in STEM fields. The choice of exogenous variables explored in this study is informed by those applied in the value-added graduation rate literature but include other factors that are more logically relate to the outcomes in this study: proportional representation of women of color, not graduation rates. This study further focuses on whether aspects of endogenous institutional characteristics, specifically the undergraduate-graduate program coexistence for STEM majors conditional on the racial/gender composition of graduate and undergraduate students, impact the two degree outcomes for women of color: completing an undergraduate degree, completing an undergraduate STEM degree, and going on to complete a doctoral degree. This exploration is guided by the following research questions:

1) What state- and institutional-level demographic, financial, academic and socioeconomic background factors predict institutional variation in the proportion of women of color that attain these two degree outcomes: completing a STEM undergraduate degree, and completing a STEM doctoral degree?
2) Does the interaction between the undergraduate-graduate program coexistence and the proportionate women of color enrollment (degrees conferred as a proxy) at the graduate levels, significantly account for differences in the value-added scores of institutional performance on these outcome measures for women of color?

Chapter Three: Methodology

This section describes the methodology used for the proposed study. The chapter includes six sections: 1) terms defined; 2) data sources; 3) sample selection; 4) variables considered; 5) analytical methods; and 6) statistical models.

Terms Defined

STEM fields. Prior to explaining how the samples for this study were obtained, there is a need to define the range of disciplines considered to be STEM fields, as there are several available conventions for doing so. Among those conventions maintained by U.S. federal agencies, the most inclusive is the STEM designated degree program list maintained by the U.S. Immigration and Customs Enforcement (ICE) under the jurisdiction of Department of Homeland Security for the purpose of the 24-month optional practical training extension for international students holding a student visa (F-1) (Department of Homeland Security, 2016). This list designates STEM disciplines using the U.S. Department of Education's Classification of Instructional Programs (CIP) taxonomy. The list includes all programs contained within four general disciplinary areas as defined by the highest (2-digit) level of the CIP taxonomy: Engineering (14), Biological and Biomedical Sciences (26), Mathematics and Statistics (27), and Physical Sciences (40). In addition, the list additionally includes several sub-area disciplines at the full 6-digit CIP Code detail including, for example, some fields in agricultural sciences, computer and information science, psychology, and medicine.

The primary data source used in this study to identify the baccalaureate origin institution among STEM doctoral degree recipients, the Survey of Earned Doctorates (SED) does not employ the CIP taxonomy but rather an alternate taxonomy of disciplines developed by the survey sponsors: The National Science Foundation (NSF) and National Institutes of Health

(NIH). The SED staff provide a table matching its field codes with the CIP taxonomy[2], and the range of STEM disciplines it includes is narrower than the list designated by ICE. Therefore, the range of STEM disciplines considered in this study is matched between the list from ICE and the discipline codes from SED. Appendix B shows how the SED codes were matched to the CIP codes for the STEM programs. This study later explores in more depth Biology, Chemistry, and Engineering to investigate the gender and racial/ethnic composition on women of color students' STEM degree completion, but all the STEM disciplines are aggregated in the baseline model prior to the analysis at the discipline level.

Women of color. For the purposes of this study, a women of color student is defined as including African American/Black non-Hispanic, American Indian/Alaska native, and Hispanic women as captured in the IPEDS degree completion survey and SED. This study included women from only those racial/ethnic groups that are under-represented among Ph.D. degree recipients. Asian American women are excluded because they are overrepresented in the SED sample in comparison with their representation in the U.S. population; White, nonresident alien,[3] and those who report racial ethnicity as "other" are also excluded. The two or more races is a viable designation in SED but not in IPEDS fall enrollment survey for the time period of data collection (2003 to 2006). The Native Hawaiian/other Pacific Islander is an independent category in SED. However, this group is combined with Asian in IPEDS and cannot be divided between 2003 and 2006 of the data collection. To make the race/ethnicity groups consistent between IPEDS and SED, the two or more races and Native Hawaiian/other Pacific Islander are excluded

[2] This table can be found at https://www.nsf.gov/statistics/nsf13327/pdf/tabb1.pdf

[3] Unlike the IPEDS completion survey, the SED does not consider nonresident alien as an independent racial/ethnic designation. Rather, it identifies non-resident aliens under the variable "CITIZf," which represents the respondents' citizenship.

from SED in this study. Table 2 describes the racial/ethnic groups included in IPEDS and SED also designating whether they are included or not in this study.

Table 2

Comparison of Race/ethnicity terminology applied in IPEDS and SED

Selected or not	IPEDS	SED
Included	Black non-Hispanic	Black/African American
	Hispanic	Puerto Rican
		Mexican American/Chicano
		Cuban
		Other Hispanic
	American Indian or Alaska Native	American Indian/Alaskan Native
Excluded	Asian or Pacific Islander	Asian
		Native Hawaiian/other Pacific Islander
	Race/ethnicity unknown	Two or more racial backgrounds
	White non-Hispanic	White
	Nonresident alien	Other

Data Sources

Survey of Earned Doctorates (SED) The SED is an annual, federal government agency sponsored survey that has been conducted since 1957. The subjects of the survey are individuals who received a research doctorate degree from accredited U.S. higher education institutions each academic year. Six federal agencies sponsor the SED: the National Science Foundation, National Institutes of Health, U.S. Department of Education, U.S. Department of Agriculture, National Endowment for the Humanities, and National Aeronautics and Space Administration. The SED collects data about doctoral recipients' educational history, demographic characteristics, and plans after degree completion (NSF, 2015a). The SED has had a high response rate over the years. For example, in 2013, 92% of all newly graduated research doctoral degree recipients completed SED (NSF, 2015a).

The SED data are used to develop a proxy measure for percentage of women of color receiving an undergraduate degree that go on to complete a STEM doctoral degree. The numerator for this measure is the number of women of color STEM doctoral degree recipients according to the institution from which they received their bachelor's degree. The denominator for this measure is the number of women of color bachelor's STEM degrees conferred five to eight years earlier derived for each institution from the Integrated Postsecondary Education Data System (IPEDS) completions file.

Integrated Postsecondary Education Data System (IPEDS) IPEDS is a system of interrelated institutional-level surveys conducted by the U.S. Department of Education's National Center for Education Statistics (NCES). IPEDS includes information from virtually all accredited U.S. institutions where students are eligible to receive federal financial aid. More than 7,500 institutions complete the IPEDS surveys every academic year (IPEDS, 2015). Since there is a need to connect doctoral recipients' baccalaureate institution in SED with those in IPEDS, institutional characteristics and degree completion data are used to examine how institutional contexts and program characteristics affect the likelihood that women of color will graduate in STEM fields and go on to pursue a doctoral degree.

Sample Selection

A license to use restricted access micro data files was obtained from NSF. The license provides access to SED data for 2010-2011 through 2013-2014. Among the origin institutions (those that conferred the undergraduate degree to women of color who received STEM doctoral degrees), this study only includes institutions that conferred undergraduate degrees to at least five domestic women of color students in the SED sample. Preliminary analysis revealed that 185 institutions conferred degrees to at least five women of color undergraduates who went on to earn a PhD degree in 2011-2014. The top three years in which the most women of color in the SED received their undergraduate degrees was 2003, 2004, and 2005. Therefore, the study employs IPEDS data for the origin institutions from these three years.

Variables Considered

The graduation rate value-added methodology has been the subject of considerable research. Due to data availability, it can only be used to assess aggregated graduation rates. It cannot be used to assess graduation rate performance in specific majors. The two outcomes in this study, proportion of STEM bachelor's degree holders that are women of color, and proportion of women of color STEM bachelor's degree holders that went on to earn a doctoral degree in STEM disciplines, are all related to degree completions, which is collected by NCES at the program-level, where the program is defined according to the common Classification of Instructional Program (CIP) taxonomy that institutions use to report degree completions. Although the current study does not predict graduation rates but rather proportional representation of women of color among graduates, it is instructive to consider the variables employed in the more extensive literature on predicted graduate rates to inform the selection of predictors for the current study. Given the fact that there is not a significant body of literature on predicting the two outcomes in this study, the methodology applied in the current study is exploratory.

Astin (1993) first proposed using statistical regression to assess institutional graduation rates by controlling for student selectivity. Subsequent research suggested that additional factors would yield a more reliable model (Archibald & Feldman, 2008; Astin et al. 1996; Cunha & Miller, 2009; Goenner & Snaith 2004; Hamrick et al., 2004; Mortenson, 1997; Horn & Lee, 2014; Kelchen & Harris, 2012; Porter, 2000; Ryan, 2004, Scott et al. 2006). Within the graduation rate research, the exogenous variables considered are divided into four categories: academic, demographic, financial, and contextual.

Institutional selectivity (average SAT or ACT equivalent) is the key academic component when predicting graduation rates. Demographic attributes include The IPEDS-derived institutional demographic characteristics include percent female, percent students receiving Pell grant, percent of undergraduates over 25 years of age, and percent minority students. When graduation rates are the outcome, previous studies demonstrate the very strong positive correlation between institutional selectivity (as measure by average college entry exam (SAT or ACT) scores) and institutional graduation rates. Studies have also demonstrated smaller but significant effects for the percentage of females (positive effect) the proportion of students from low socioeconomic backgrounds (negative effect), and the proportion of older and minority students (negative effects) (Astin, 1993; Cunha & Miller, 2009; Goenner & Snaith, 2004; Porter, 2000; Scott el al., 2006).

Other exogenous factors that have been demonstrated to be associated with institutional graduation rates include institutional control (public or private) and size (total undergraduate enrollment). Horn & Lee (2014) found that private institutions generally have higher graduation rates than public institutions. Previous studies have contradictory but statistically significant findings about the impact of enrollment size on graduation rates (Astin et al. 1996; Porter, 2000; Ryan, 2004; Scott et al. 2006).

Financial attributes used in previous models include per full-time equivalent (FTE) measures of overall educational expenditures, as well as more specific per FTE expenditures for instruction, library, and academic support (Hamrick et al. 2004; Ryan, 2004; Scott et al. 2006). These expenditures are positively associated with graduation rates.

Integrating the literature of value-added graduation rates and URM[4] students' persistence rates in STEM disciplines, I propose to apply the following variables into the value-added models for the current study: percent women of color in the state- and institution-level populations (available pool size); percent of graduates receiving a degree in a STEM field (program mix); institutional selectivity (average institutional SAT or ACT equivalent score); socioeconomic status (percent of Pell Grant recipients); non-traditional student representation (proportion of undergraduates who are either age 25 or older or under 25 but part-time); educational and research expenditure; degree of urbanization; and STEM labor market in the state.

Although there is not much literature that addresses the effect of the proportions of women of color in the institution and the state level population on women of color students' likelihood to pursue a doctoral STEM degree, it is anticipated that these two variables show the strongest correlation to the outcomes of interest. Usually, institutions graduate a larger proportion of women of color students in STEM disciplines if they enroll a larger proportion of women of color freshmen. Nevertheless, a large share of women of color freshmen usually comes from the state population. Most institutions, even for those private universities that recruit students nation-wide, admit a high proportion of their undergraduate students from the state in which they are located. Flagship public research universities are especially in this situation. Therefore, it is reasonable to infer that the women of color population in the state strongly correlates with the number of women of color freshmen in the institution, which is positively associated with the number of STEM degrees conferred to women of color undergraduate

[4] In this study, underrepresented racial minority (URM) students refer to students who have a black non-Hispanic, Hispanic, and American Indian or Alaska Native background. Asian American students are excluded in this study.

students. The women of color enrollment at the institution level is expected to function as a similarly strong predictor as compared to institutional selectivity predicting graduation rates.

Percent of graduates receiving a degree in STEM fields is another key factor that can impact the outcome of interest in this study. The proportion of STEM degrees conferred among all degrees is a direct measure of the relative size of STEM programs at each institution. It is anticipated that the proportion of STEM degrees is positively associated with women of color students' likelihood to receive and undergraduate degree and pursue a doctoral degree.

Institutional selectivity has been well documented to be strongly positively associated with graduation rates (Archibald & Feldman, 2008; Astin, et al., 1996; Horn & Lee, 2014; Goenner & Snaith, 2004; Porter, 2000). It is much less likely to be a strong correlation of the outcomes of interest in this study, but it may still be relevant. Multiple studies report that URM students graduate at a lower than predicted proportion at selective institutions and at a higher than predicted proportion at less-selective institutions (Aricidiacono, Aucejo, & Hotz, 2016; Chang, et al., 2008; Chang, et al., 2014; Espinosa, 2011). However, URM students' persistence rates in STEM disciplines are relevant to but different from the two outcomes in the current study. I tentatively propose to include institutional selectivity into the value-added model to examine whether it also has an impact on the two outcomes in the current study.

Students receiving Pell Grants is a direct measure of students' social economic status. Such students from low socioeconomic status families have disadvantages compared to their more affluent peers, including a higher likelihood being first-generation college students and having to work significant hours while attending college. Chang et al. (2014) found that the working full-time is negatively associated with URM student persistence rates in a STEM major. Informed by the literature about the value-added graduation model, I intend to include percent of students receiving Pell Grants in the model, as well as a related measure of non-traditional student status, the percent of undergraduates over 25 years.

Previous literature about predicted graduation rates reveals that the percentage of female students is positively associated with aggregated graduation rates (Cunha & Miller, 2009; Goenner & Snaith, 2004; Horn & Lee, 2014; Porter, 2000; Scott et al., 2006). Griffith (2010) found that the proportion of female and URM graduate students in STEM disciplines positively impacts the persistence of female and URM students. Since I use the percentage of women of color in the institution and the state as the key exogenous variables, I do not additionally include percent of females in the model.

Overall educational expenditures was demonstrated to be positively related to graduation rates (Hamrick et al. 2004; Ryan, 2004; Scott et al. 2006). It is reasonable to deduce that the amount of educational expenditure benefits all students including women of color degree completion in STEM disciplines, although the range of the change may differ across disciplines and racial ethnic groups. Griffith (2010) found that selective institutions with a significant graduate to undergraduate ratio that invest a large amount of funding on research expenditures have lower STEM persistence rates. This finding could result from the institutions' focus on research projects rather than teaching. However, selective institutions that have medical schools usually have a large funding for research, but Griffith (2010) did not address this issue when building her model. Other studies have shown that undergraduate students who actively engage with research projects are more likely to persist in STEM disciplines (Hunter, Laursen, & Seymour, 2007; Tsui, 2007). Whether a larger amount of research expenditure indicates increasing possibilities for undergraduate students, in particular women of color students in STEM disciplines to participate in undergraduate research projects is uncertain. Since this is an exploratory study, it includes research expenditure per FTE student as a factor. I also consider other educational expenditure measures, employing Horn and Lee's (2014) measure of instruction-related expenditures: the sum of instructional expenditures, student services expenditures, and academic support expenditures divided by the total full-time equivalent enrollment.

In addition, this study explores as contextual characteristics, the institution's locale context (degree of urbanization) and a subset of indicators from the State New Economy Index (Atkinson & Nager, 2014). The urbanization measure is a nominal factor included in the IPEDS data. It distinguishes cities, from suburbs, towns, and rural settings. Within each of these, it further distinguishes cities and suburbs by size (small, midsize and large), and distinguishes towns and rural settings by their distance from more populated areas (fringe, distant, remote). Previous studies included urbanization proxies in the value-added model with inconsistent results. Goenner & Snaith (2004) and Horn & Lee (2014) found non-urban institutions tend to have higher graduation rates, but Hamrick et al. (2004) and Scot et al. (2006) demonstrated the opposite result.

State is applied as a level-2 grouping variable for two reasons. The first is the adoption of the State New Economy Index, which is calculated at the state level. The economic structure of the state is expected to have an impact on the outcomes of interest. Few studies in the value-added graduation rate literature adopted indicators measuring state economic structure. Horn & Lee (2014) applied a subset of indicators in the State New Economy Index and found statistically significant effects when predicting institutions' 6-year graduation rates. The predicted graduation rates is different from the outcome of interest in this study, the evidence of significant impact in a single value-added graduation rate study does not indicate similar impact on the outcome of interest in this study. However, the State New Economy Index includes a subset of indicators related to the development of STEM sectors in the state, which could impact on women of color students' likelihood to choose a STEM major and go on to earn a doctoral degree. It uses 25 indicators to capture the condition of states' new economy in five categories: knowledge jobs, globalization, economic dynamism, the digital economy, and innovation capacity. Some indicators relevant to STEM sectors are information technology jobs, managerial, professional, and technical jobs, high tech jobs, scientists and engineers, and patents (Atkinson & Nager, 2014). I standardize and sum these indicators to produce an index of STEM labor market in the state.

The results of the HLM models in Chapter 4 show that the State New Economy Index has an exceedingly small effect on the two outcomes and therefore it is excluded from the model. However, State itself remains as the level-2 grouping variable. Higher education sectors vary considerable across the United States. Some states have a well-funded public higher education system while others are poorly funded. When comparing the number of public higher education institutions, some states have multiple institutions while others have only one. The variety of higher education institutions among states make the State itself a viable level-2 grouping variable even if the State New Economy Index is excluded. The inter-class correlation of each model is larger than 0.05. This fact further supports the appropriateness of applying state as a level-2 grouping variable.

After establishing the value-added model to control for the effect of exogenous variables, an ANOVA model is applied to examine the effect of endogenous variables on institutions' performance in preparing STEM women of color for graduate education. The dependent variable in this analysis is the residual derived from the value-added model, representing the degree to which the institution performs better, as, or worse than expected. The endogenous factors of interest in this study derive from two sources: the program structural characteristics and the effect of role models.

Faculty and graduate students function as role models to influence women of color students in STEM disciplines. For the overall STEM disciplines, the role model effect from graduate students is the percentage of women of color graduate degrees among all degrees conferred in each STEM disciplines. If sample size allows me to focus on a specific STEM discipline, for example, engineering or biomedical science, the intensity of undergraduate women of color's interaction with graduate students is measured as the ratio of degrees conferred to graduate women of color in comparison to undergraduate women of color students.

The influence of proportional representation of females among STEM faculty members on the success of female undergraduates has not been consistently demonstrated. Bettinger & Long (2005) reported mixed effect of female faculty members on the interest of female students in science disciplines. In mathematics, statistics, and geology, female faculty members have a positive impact on students' course selection and major choice. However, in male dominated fields, such as physics, engineering, and computer science, the effect is not statistically significant. Canes & Rosen (1995) did not find evidence of the proportion of female faculty members in relation to the percentage of female majors, but Sonnert, Fox, & Adkins (2007) found the link exists. Since there is no extant reliable source of program-level data with regard to faculty gender and race/ethnicity the effect of women of color role models is examined using the proportion of women of color STEM graduate students, as it interacts with the coexistence measure. That is, the proportion of graduate degrees times the proportion of women of color among STEM graduate degree recipients.

The primary structural characteristic of interest is the coexistence status of graduate programs. This can be characterized as the ratio of graduate to undergraduate degrees conferred within the STEM discipline. The prospective influence of peers is characterized as the percentage of undergraduate women of color bachelor's degree recipients in STEM disciplines. Although enrollment figures would be more directly relevant, IPEDS only includes program level data as related to degree completions. Because of the high correlation between enrollment and degree completion numbers, the completion data is used as a suitable proxy.

Given the complexity of the program coexistence measure, two types of models are considered in this study. The first model comprises all STEM disciplines in each institution. The program coexistence measure is the ratio of graduate to undergraduate degrees conferred to all STEM programs in each institution. However, this measure has several defects. The first is the unbalance of program coexistence across different STEM programs. For those institutions who have multiple STEM programs, it is possible that some programs confer degrees to both graduate and undergraduate students, but others only confer degrees to undergraduate students. Another possibility is that among those programs that confer degrees to both graduate and undergraduate students, the ratio of degrees conferred to both levels varies distinctively across disciplines.

To solve this problem, I propose the second model, which focuses on individual disciplines. I cluster STEM programs by discipline based on the proportion of degrees conferred to women. Three groups of STEM programs are considered. The first is male-dominated programs, such as physics, engineering, mathematics, and computer science. The second cluster could include geology, environmental science, and chemistry, whose number of degrees conferred to women is moderately small. The third group consists of programs in which women are overrepresented, such as biology. One discipline in each group is selected to run the model. It is anticipated that the discrepancy of STEM program coexistence in each institution is alleviated through applying the second strategy.

Analytical Methods

Statistical Regression models are most often used in previous studies of such value-added models (Astin et al. 1996; Cunha & Miller, 2009; Hamrick et al., 2004; Mortenson, 1997; Horn & Lee, 2014; Kelchen & Harris, 2012; Porter, 2000; Ryan, 2004, Scott et al. 2006). The two most common value-added models employ ordinary linear square model (OLS) and hierarchical linear models (HLM) (Kim & Lalancette, 2013). One benefit of the HLM approach is to obtain an improved estimation of the effects within and between the institutions as academic units (Ethington, 1997; Liu, 2011; Raudenbush & Bryk, 2002). Liu (2011) found that the institutional value-added measure could be substantially different for some institutions when applying OLS as compared to HLM.

The proposed study employs a hierarchical linear value-added model. Data in SED identifies women of color PhD recipients' baccalaureate origin institutions to include and to provide the number of women who earn a doctoral degree outcome. Other institutional characteristics and state contextual variables are collected from IPEDS and Census.

It is likely that the representation of institutions may be biased in the SED surveys when compared to overall diversity of institutions in the IPEDS universe. To assess representation, the institutions in the statistical model is compared with the total institutions in the IPEDS universe. Biases in representation are considered as a limitation when interpreting the results.

Statistical Models

Data extracted from the restricted SED helps identify women of color PhD recipients' baccalaureate origin institutions to include and to provide the number of women who earn a doctoral degree outcome. Data about those origin institutions are collected from IPEDS. Two predicted outcomes are then generated as follows:

$$Y_{ij} = \frac{No. of\ STEM\ bachelor's\ degree\ recipients\ who\ are\ women\ of\ color}{No. of\ bachelor's\ STEM\ degrees\ conferred}$$

$$Y'_{ij} = \frac{No. of\ college\ women\ of\ color\ STEM\ graduates\ who\ went\ on\ to\ earn\ a\ doctoral\ degree\ in\ STEM\ disciplines}{No. of\ women\ of\ color\ bachelor's\ STEM\ degrees\ conferred\ 5\ to\ 8\ years\ earlier}$$

There is evidence that women have been overrepresented in biology (American Physical Society, 2014b). However, whether minority women in biology are also overrepresented in this discipline requires investigation. In addition, it is uncertain whether Asian women should be included in this project as an underserved minority group. Asian American and Pacific Islanders (AAPI) are usually stereotyped as the model minority and tend to be invisible from a policy maker's perspective. However, there has been huge contrast between AAPI subgroups on the correlation between students' various family income and college enrollment rate (Teranishi, 2010). Since the respondents are not categorized in sub-ethnic groups, it is difficult to examine Asian sub-ethnic group students' STEM degree achievement gap. Therefore, Asian American and Pacific Islanders are excluded from the women of color group.

The SED data identify women of color PhD recipient's baccalaureate origin institutions. The sample for the two outcome models are institutions that awarded a STEM Bachelor's degree to a minimum of one women of color students who went on to earn a PhD degree from 2011 to 2014. Those categorized as special focus institutions in the Carnegie Basic Classification are excluded from this study.

Three HLM models are established. The first model predicts the proportion of STEM graduates who are women of color. The level-1 variables are exogenous institutional characteristics such as number of women of color students at the institutional level, institution selectivity, and aggregate student characteristics (e.g., percent Pell eligible, percent over 25 years of age). State is applied as the level-2 grouping variable. The STEM labor market indicator derived from a subset of the 2014 New Economy Index (Atkinson & Nager, 2014) is considered to explore whether the states' economic structure has an impact on women of color's likelihood to complete a STEM bachelor's degree. Women of color as a proportion of the state population is also considered to detect whether the women of color population as a candidate pool at the state level impacts on STEM women of color's academic progress. This proposed two-level hierarchical linear model may take the following form:

$$Y_{ij} = \beta_{0j} + \beta_{*j}(InstitutionalAcademics)_{*j} + \beta_{*j}(InstitutionalDemographics)_{*j}$$
$$+\beta_{*j}(InstitutionalFinancial)_{*j}+\beta_{*j}(InstitutionalContextual)_{*j}$$
$$+\beta_{*j}(InstitutionalSocioeconomic)_{*j} + \varepsilon_{ij}$$

$$\beta_{0j} = \gamma_{00} + \gamma_{0*}(StateSTEMLaborMarketIndicator)_{*}$$
$$+\gamma_{0*}(\%StateWomenofColorPopulation)_{*} + U_{0j}$$

The second model predicts STEM women of color Bachelor's degree holders' likelihood to earn a doctoral degree. The proposed two-level hierarchical linear model may take the following form:

$$Y'_{ij} = \beta_{0j} + \beta_{*j}(InstitutionalAcademics)_{*j} + \beta_{*j}(InstitutionalDemographics)_{*j}$$
$$+\beta_{*j}(InstitutionalFinancial)_{*j}+\beta_{*j}(InstitutionalContextual)_{*j}$$
$$+\beta_{*j}(InstitutionalSocioeconomic)_{*j} + \varepsilon_{ij}$$

$$\beta_{0j} = \gamma_{00} + \gamma_{0*}(StateSTEMLaborMarketIndicator)_{*}$$

$$+\gamma_{0*}(\%StateWomenofColorPopulation)_{*} + U_{0j}$$

The level-1 residual ε_{ij} from each model reflects the difference between the observed institutional mean and the predicted mean of those two outcomes, which is the value-added score for institution *i*.

To calculate the undergraduate and graduate program coexistence, two methods are proposed. The first option is to compare the number of degrees conferred at the undergraduate level and the graduate level for the overall STEM disciplines from IPEDS and divide those institutions into two groups: institutions that confer STEM degrees at both levels—in other words, the undergraduate and graduate programs coexist—and institutions that only confer STEM degrees at the undergraduate level (non-coexistence).

Another alternative to analyzing the impact of the undergraduate and graduate program coexistence is to create a variable of the ratio of the number of degrees conferred to disciplines between the undergraduate and graduate levels in each institution and employ the concept of the Carnegie Classification Undergraduate Instructional Program to divide this variable into three categories: no graduate coexistence, some graduate coexistence, and high graduate coexistence. This approach would change the STEM program coexistence variable from dichotomous to three levels examine the impact of program structural effect on the variation of institutional value-added performance of STEM women of color students' academic progress.

In addition, the percentage of women of color across the institution and within STEM fields at the graduate level is calculated using completions data from IPEDS. The interaction between the percentage of women of color at the graduate level and the undergraduate and graduate program coexistence is analyzed. An ANOVA model is used to answer the question: "Does the interaction between the undergraduate-graduate program coexistence and the proportionate women of color enrollment (degrees conferred as a proxy) at the graduate levels, significantly account for differences in the value-added scores of institutional performance on these outcome measures for women of color?"

The following table summarizes the design of this study:

Table 1

Design of this study

	A	B
Predicted outcome	Proportion of STEM graduates who are women of color	Proportion of women of color STEM graduates who continue to earn a doctoral degree
Predictors	State women of color population State STEM labor market	State women of color population State STEM labor market
	Institutional academics Institutional demographics Institutional financial Institutional contextual	Institutional academics Institutional demographics Institutional financial Institutional contextual
Residual analysis	Effect of structural characteristics: Graduate coexistence*% Women of color enrollment	Effect of structural characteristics: Graduate coexistence*% Women of color enrollment

I investigate the effect of program coexistence conditional on the proportionate women of color enrollment (number of degrees conferred as a proxy) by discipline from specific groups of disciplines. Three clusters of STEM programs are considered based on the extent of women of color students' underrepresentation. The first group is male-dominated programs, which could include physics, engineering, and mathematic. The second could include geology and environmental science where women is moderately underrepresented. The third group includes those disciplines which women are overrepresented, such as biology. One discipline of each group is selected to run the value-added models. Further, I explore the impact of the interaction between the undergraduate-graduate program coexistence and the proportionate women of color enrollment (degrees conferred as a proxy) at the graduate levels on the value-added scores of institutional performance on the outcome measures for women of color in each discipline.

Chapter Four: Results

The presentation of results in this chapter follows the analytical procedure described in Chapter Three. It begins with a descriptive analysis that includes the definitions of the terms employed in this study, such as the range of fields considered as STEM and the racial/ethnic definitions employed to identify women of color students. A description of two samples employed in this study follows the definitions of these terms. The description of the two samples includes the variables applied in the value-added models as well as the source, transformation, and calculation of each variable. The final size of the two samples is displayed after that, followed by a statistical comparison between the samples and the population of institutions represented in the IPEDS population.

Finally, this chapter presents the results of the value-added multilevel models that address the first research question, followed by the results of the ANOVA approach that investigates the impact of the interaction between the graduate women of color degrees conferred and undergraduate/graduate program coexistence to address the second research question.

Descriptive Analysis

Samples

This study includes two analysis samples. The first is a broad sample that contains institutions that conferred at least one bachelor's degree to women of color students in STEM disciplines (referred to as the broad sample) as recorded in the Integrated Postsecondary Education Data System (IPEDS) Completions Survey. The target institutional population for this survey is also further restricted to include U.S.-based,[5] Title IV[6] institutions. The second sample used in the study is a subset of the broad sample (referred to as the subset sample). This subset includes the baccalaureate origin institutions of women of color students who earned a doctorate and had an undergraduate STEM major identified through responses to the SED.

A preliminary analysis of the subset sample revealed that just over one-half (51.6%) of the women of color STEM Ph.D. degree recipients received their bachelor's degree between the years 2003 and 2006. Therefore, the broader sample was drawn from the same time period. IPEDS data were extracted pertaining to the racial/ethnic composition of the baccalaureate origin institutions both with relation to overall enrollment and degrees conferred in STEM fields.

Variables for the Value-Added Models. Based on the literature review from Chapter 2, Table 1 presents variables selected to build the value-added model. Prior to applying these variables to the model, there is a need to screen data for normality, including skewness and kurtosis (Tabachnick & Fidell, 2007). The threshold for achieving normality is when the value of skewness is within the range (-1, 1) and the value of kurtosis is within the range (-3, 3) (Information Technology Laboratory, 2017). Initial analyses showed that a large proportion of the variables were not normally distributed, as the values of their skewness and kurtosis were beyond the respective acceptable ranges. Three commonly applied forms of transformation—logarithm, square root, and square (Tabachnick & Fidell, 2007)—were calculated for each variable to examine whether the values for skewness and kurtosis of the transformed variables were within the acceptable ranges. The final form of transformation applied to each variable is

[5] This excludes institutions located in outlying territories and the Commonwealth of Puerto Rico. It is worth noting that students originating from the outlying territories are predominantly within the under-represented racial/ethnic categories of Native Hawaiian and Pacific Islanders and Hispanics.

[6] Title IV institutions are those that have been deemed eligible to channel federal financial aid (grants and loans) to enrolled students. To gain Title IV eligibility, the institution must be accredited by a regional or national accrediting body that is recognized by the U.S. Department of Education for that purpose.

presented in Table 3, which also includes each variable experimental design attribute, label, name, and where these original variables are collected from.

Table 3

Variables Selected for the Value-Added Multi-Level Linear Model

Variable Attribute	Variable Label	Variable Name	Transfor-mation	Variable Source
Outcomes	Proportion of STEM bachelor's degree recipients who are women of color	WOCSTEMBA	none	IPEDS Completions 2003-2006
	Proportion of bachelor's degree recipients who are women of color in Biology, Chemistry, and Engineering	PctBiologyWOC; PctChemistryWOC; PctEngineeringWOC	none	IPEDS Completions 2003-2006
	Proportions of women of color bachelor's degree recipients in Biology, Chemistry, and Engineering who went on to earn a doctorate	PctWOCPhD	none	SED 2010-2013-IPEDS Completions 2003-2006
Level-1 Predictor (institutional context)	Proportion of large-city located institutions	Urbanization	none	IPEDS Institutional Characteristics 2016
Level-1 Predictor (institutional academics)	Institutional converted SAT-ACT score	SATACT	logarithm	IPEDS Admission and Test Scores 2003-2006
Level-1 Predictor (institutional financial)	Total amount of educational expenditure per full-time-equivalent (FTE) student	EdExpenditure	logarithm	IPEDS Finance 2003-2006
Level-1 Predictor (institutional demographic)	Proportion of undergraduates who enrolled part-time	Parttime	square root	IPEDS Fall Enrollment 2003-2006
	Proportion of undergraduates who are age 25 year or older	above25	square root	IPEDS Fall Enrollment 2003-2006

	Proportion of women of color among enrolled undergraduates	UGWOC	logarithm	IPEDS Fall Enrollment 2003-2006
	Proportion of bachelor's degrees conferred from STEM, Biology, Chemistry, and Engineering disciplines	BASTEM	logarithm	IPEDS Completions 2003-2006
	Proportion of bachelor's degrees conferred in Biology, Chemistry, and Engineering disciplines	PctBiologyBA; PctChemistryBA; PctEngineeringBA	logarithm	IPEDS Completions 2003-2006
	Proportion of students receiving federal grant	FederalGrant	logarithm	IPEDS Student Financial Aid and Net Price 2003-2006
Level-2 Predictor (state context)	z-score of state STEM labor market index	state STEM	none	State New Economy Index 2007
	Proportion of 18-24 years old who are women of color population at the state level	StateWOC	square root	Census Bureau Current Population Survey 2004

All of the variables are calculated as an annual average from 2003 to 2006 with three exceptions: the proportion of large-city located institutions, state STEM labor market index, and the proportion of state women of color population, as also noted in Table 1.

The urbanization measure is a nominal factor included in the IPEDS data. It distinguishes institutional location into broad categories of cities, suburbs, towns, and rural settings. Within each of these, it further distinguishes cities and suburbs by size (small, midsize, and large), and distinguishes towns and rural settings by their distance from more populated areas (fringe, distant, remote). In this study, the degree of urbanization is recoded into a binary variable of large city and not-large city. The proportion of large-city located institutions was used from the year 2016 because the availability of the data in this year was more complete than data from 2003 to 2006.

The state STEM labor market is derived from a subset of indicators of the State New Economy Index 2007. These indicators are calculated using data from multiple government sources, such as the U.S. Census Bureau's American Community Survey, as well as data collected by the U.S. Bureau of Labor Statistics and the National Science Foundation, during the years 2003 to 2005 (Atkinson & Correa, 2007), which is consistent with the period of the other variables employed in this analysis. The state STEM labor market includes the proportion of employment in information technology jobs in non-information technology industries; the proportion of inventor patents issued; the proportion of employment in high-tech industries; the proportion of the workforce who are scientists and engineers; and the number of patents issued to companies or individuals (Atkinson & Correa, 2007). Referenced by Horn & Lee (2015), these indicators are standardized and summed into a single index of the state STEM labor market.

The proportion of the state women of color population is calculated from the U.S. Census Bureau Current Population Survey 2004. This year was chosen because it occurs within the time period of the institutional data (2003 to 2006). Inspection of the birth year distribution among of women of color SED respondents revealed that over one-half (55.7%) of respondents were born between 1980 and 1984, which also indicates that a majority of the sample respondents attended college at the traditional age of 18 to 24. Therefore, the proportion of state women of color is defined as the proportion of 18 to 24 year old women in each state who were in the categories: Black/African American, American Indian/Alaskan Native, Hispanics, and two or more races.

The proportions of bachelor's degree recipients who are women of color in STEM, Biology, Chemistry, and Engineering, and the proportions of women of color bachelor's degree recipients who went on to earn a doctoral degree in the same disciplines are the predicted outcomes of the value-added multi-level models. The proportions of bachelor's degree recipients who are women of color in STEM, Biology, Chemistry, and Engineering are the dependent variables of the broad sample. The proportion of women of color bachelor's degree recipients who went on to earn a doctoral degree in the same discipline is the dependent variable of the subset sample.

The level of institutional selectivity is measured using the institution's SAT and ACT scores (with the latter converted to the SAT scale) from 2003 to 2006. The institutional SAT score was calculated as the mean of an institution's 25^{th} percentile and 75^{th} percentile test scores for the math and verbal sections combined. The ACT score is the mean of an institution's 25^{th} percentile and 75^{th} percentile composite score. Note that there are some institutions that only accept one of the tests. Among those institutions that accept both tests, there are some that reported only one type of test score to IPEDS from 2003 to 2006. These situations are accommodated when calculating the level of institutional selectivity. For those institutions that reported complete SAT and ACT scores, the ACT score is first converted into an SAT scale and the institutional SAT-ACT score is calculated with the following approach:

$$(\text{Institutional SAT score} * \text{number of students who take SAT} +$$
$$\text{Institutional converted ACT score} * \text{number of students who take ACT})/$$
$$(\text{number of students who take SAT} + \text{number of students who take ACT})$$

Educational expenditure per FTE student is calculated using the sum of instruction, research, academic support, and student service expenditure divided by the total full-time equivalent number of students per institution. The full-time equivalence is calculated as the full-time headcount plus one-third the part-time headcount. Categories of expenditure excluded from this total are those attributed to the remaining categories of: public service, institutional support, operation and maintenance of plant, scholarships and fellowships, auxiliary enterprises, hospital services, independent operations, and “other” operating expenses.

The proportion of all undergraduate students receiving a Pell grant was first considered for use in this study. However, data from 2003 to 2006 is not sufficient to produce a valid measure. Therefore, the number of first-time, full-time students receiving federal grant aid is applied as an alternative, since a large proportion of the federal grant aid is Pell grants and, even including other types of grants (e.g., SEOG) still captures the intended population, that is, low income students by virtue of qualifying for such aid.

Final Sample Size. As noted, the broad sample includes U.S-based, Title IV participating institutions that confer a minimum of one STEM bachelor’s degree to women of color students. There were 1155 institutions meeting this criterion that also reported an institutional SAT-ACT score for a minimum of one year in any of the IPEDS collections for 2003 to 2006. Because the mission of special focus institutions, as classified in the Carnegie Classifications, is substantially different from institutions that confer degrees in a more comprehensive range of disciplines, the sixteen special focus institutions that met the other criteria (degrees conferred and SAT-ACT score), were excluded from the broad sample. In addition, seventeen institutions that did not report expenditure-related measures were excluded, as were another six institutions that are located in Washington, DC and so do not data available for the state STEM labor market measures. U.S. Service Academies which also constitute a special institutional mission focus were also excluded from this study, since they are not Title IV institutions. After all these exclusions, 1115 institutions remain in the broad sample. This sample is the core focus of the analysis for the outcome of the proportion of STEM bachelor's degree recipients who are women of color.

The subset sample includes baccalaureate origin institutions of women of color Ph.D. recipients in SED from 2010 to 2013. Table 4 shows the self-reported racial/ethnic distribution of women of color Ph.D. recipients in the subset sample.

Table 4

Number of Women of Color Respondents in SED Included in this Study (2010-2013)

Race	Number	Proportion
American Indian/Alaskan Native	59	2.1%
Black/African American	1424	49.6%
Puerto Rican	390	13.6%
Mexican American/Chicano	498	17.4%
Cuban	91	3.2%
Other Hispanic	408	14.2%
Total	**2870**	**100%**

Table 4 shows that 49.6% women of color respondents are African American. Hispanic-origin respondents (Puerto Rican, Mexican American/Chicano, Cuban, and other Hispanic) account for another 48.3% of the sample. Native Hawaiian/other Pacific Islanders take the minimum share—2.1%.

The 2870 women of color Ph.D. degree recipients in the subset sample earned their baccalaureate degrees from 685 U.S. postsecondary institutions. To make the measure of proportion of STEM women of color students who went on to earn a Ph.D. degree viable, this study includes institutions that conferred baccalaureate degrees to at least one women of color student in the discipline of Biology, Chemistry, or Engineering who went on to earn a STEM Ph.D. degree between 2010 and 2013. The sample is then refined by excluding the following institutions: those that did not report any SAT or ACT score; those located in Puerto Rico and

Washington, DC (the state STEM labor market index did not count Washington, DC as an independent state); those who did not report expenditure-related measures to IPEDS. The resulting sample included 486 institutions. The purpose of applying this sample is to investigate whether the results are similar to that of the broad sample. The outcome of this sample is the proportion of Biology, Chemistry, and Engineering women of color bachelor's degree recipients who went on to earn a Ph.D. degree.

Prior to conducting the value-added, multi-level analysis, the distribution of the number of STEM women of color bachelor's degree recipients is compared across the different sample groups of institutions as well as the broader subset of all IPEDS institutions, specifically, four-year institutions that do not have a special focus mission. Table 5a and Table 5b show the results of these tabulations and statistical tests.

Table 5a

Number of Under-Represented Women of Color STEM Bachelor's Degree Recipients:

*Institutional Distribution of the Broad Sample Compared to Relevant IPEDS Population**

Characteristic	Broad Sample		IPEDS Population	
	N	%	N	%
Carnegie Group[7]				
Doctoral/research university	52887	64.0%	54228	61.1%
Master's colleges and universities	21615	26.2%	24737	27.9%
Baccalaureate colleges	8088	9.8%	9723	11.0%
$\chi^2(2)$ $p < 0.001$				
Control				
Public	58055	70.3%	60794	68.5%
Private, non-profit	24519	29.7%	26764	30.2%
Private, for-profit	16	0.0%	1130	1.3%
$\chi^2(2)$ $p < 0.001$				
Minority Serving Institutions (MSI)				
MSI	3736	4.5%	4584	5.2%
Not MSI	78854	95.5%	84104	94.8%
$\chi^2(1)$ $p < 0.001$				
Region				
New England	5434	6.6%	5840	6.6%
Mid East	13946	16.9%	15911	17.9%
Great Lakes	13348	16.2%	14558	16.4%
Plains	6410	7.8%	7069	8.0%
Southeast	18746	22.7%	19336	21.8%
Southwest	7543	9.1%	8185	9.2%
Rocky Mountain	3367	4.1%	3725	4.2%
Far West	13796	16.7%	14064	15.9%
$\chi^2(7)$ $p < 0.001$				
Total	82590	100.0%	88688	100.0%

*IPEDS Population includes total STEM bachelor's degrees conferred to under-represented women of color students from institutions in the specified Carnegie group categories that

[7] The institutions in the IPEDS population are more diverse than those in the broad sample. For example, there are several baccalaureate/Associate's institutions in the IPEDS population but not in the broad sample. Only those institutions that are doctoral, master's, and baccalaureate institutions in the IPEDS population are selected to conduct the chi-square test. The Carnegie group in Table 4b has the same situation.

conferred at least 1 STEM bachelor's degrees to under-represented women of color from 2003 to 2006.

Table 5b

Number of Under-Represented Women of color STEM Bachelor's Degree Recipients: Institutional Distribution of SED Respondents Compared to the Broad Sample

Characteristic	Subset Sample		Broad Sample	
	N	%	N	%
Carnegie Group				
Doctoral/research university	48360	77.7%	52887	64.0%
Master's colleges and universities	10133	16.3%	21615	26.2%
Baccalaureate colleges	3767	6.1%	8088	9.8%
$\chi^2(2)$ $p < 0.001$				
Control				
Public	47836	76.8%	58055	70.3%
Private, non-profit	14424	23.2%	24519	29.7%
Private, for-profit	0	0.0%	16	0.0%
$\chi^2(2)$ $p <0.001$				
Minority Serving Institutions (MSI)				
MSI	3447	5.5%	3736	4.5%
Not MSI	58813	94.5%	78854	95.5%
$\chi^2(1)$ $p < 0.001$				
Region				
New England	3703	5.9%	5434	6.6%
Mid East	9765	15.7%	13946	16.9%
Great Lakes	8944	14.4%	13348	16.2%
Plains	3602	5.8%	6410	7.8%
Southeast	15093	24.2%	18746	22.7%
Southwest	6888	11.1%	7543	9.1%
Rocky Mountain	1532	2.5%	3367	4.1%
Far West	12733	20.5%	13796	16.7%
$\chi^2(7)$ $p < 0.001$				
Total	62260	100.0%	82590	100.0%

The Chi-square tests assessing independence between the numbers of bachelor's degrees conferred in the broad sample and the IPEDS population are all statistically significant, as they are between the subset sample and the broad sample. It is notable that, compared to the general IPEDS population, the broad sample is more skewed toward public, doctoral universities. The subset sample is even more skewed than the broad sample toward public, doctoral universities.

Tables 6a and 6b provide the descriptive summary of the variables used in the value added models for the broad sample and the subset sample.

Table 6a

Descriptive Statistics of the Value-added multi-level models (broad sample, N=1115)

Variable	Mean	SD	Min	Max
Proportion bachelor's STEM degree recipients who are women of color	0.10	0.14	0.00	1.00
Proportion bachelor's Biology degree recipients who are women of color (n=1065)	0.12	0.18	0.00	1.00
Proportion bachelor's Chemistry degree recipients who are women of color (n=755)	0.09	0.16	0.00	1.00
Proportion bachelor's Engineering degree recipients who are women of color (n=427)	0.04	0.08	0.00	1.00
Proportion of large-city located institutions	0.47	0.50	0.00	1.00
Institutional converted SAT-ACT score	1066.13	125.26	732.10	1516.60
Educational expenditure per FTE Student	14638.27	15185.84	1683.22	186683.90
Proportion part-time students	0.17	0.14	0.00	0.91
Proportion students above 25 years old	0.20	0.15	0.00	0.79
Proportion undergraduate students who are women of color	0.12	0.14	0.00	0.97
Proportion bachelor's degrees conferred to STEM disciplines	0.16	0.13	0.01	0.98
Proportion bachelor's degrees conferred to Biology disciplines (n=1065)	0.03	0.02	0.00	0.20
Proportion bachelor's degrees conferred to Chemistry disciplines (n=755)	0.01	0.01	0.00	0.05
Proportion bachelor's degrees conferred to Engineering disciplines (n=427)	0.06	0.08	0.00	0.51
Proportion undergraduate students who receive federal grant aid	0.30	0.15	0.04	0.88
State STEM labor market index	0.30	3.10	-5.03	6.96
Proportion State 18-24 population who are Women of color	0.14	0.07	0.01	0.32

Table 6b

Descriptive Statistics of the Value-added multi-level models (subset sample, N=486)

Variable	Mean	SD	Min	Max
Proportion bachelor's women of color Biology degree recipients who earned a doctoral degree (n=432)	0.18	0.23	0.01	2.00
Proportion bachelor's women of color Chemistry degree recipients who earned a doctoral degree (n=187)	0.42	0.41	0.04	3.00
Proportion bachelor's women of color Engineering degree recipients who earned a doctoral degree (n=135)	0.12	0.14	0.01	1.00
Proportion of large-city located institutions	0.59	0.49	0.00	1.00
Institutional converted SAT-ACT score	1102.42	150.17	732.10	1516.60
Educational expenditure per FTE Student	19575.06	21296.02	3874.15	186683.90
Proportion part-time students	0.14	0.12	0.00	0.91
Proportion students above 25 years old	0.16	0.13	0.00	0.74
Proportion undergraduate students who are women of color	0.15	0.17	0.01	0.97
Proportion bachelor's degrees conferred to Biology disciplines (n=432)	0.03	0.02	0.00	0.20
Proportion bachelor's degrees conferred to Chemistry disciplines (n=187)	0.01	0.01	0.00	0.05
Proportion bachelor's degrees conferred to Engineering disciplines (n=135)	0.10	0.10	0.01	0.51
Proportion undergraduate students who receive federal grant aid	0.29	0.17	0.05	0.83
State STEM labor market index	0.59	3.25	-5.03	6.96
Proportion State 18-24 population who are Women of color	0.16	0.07	0.01	0.32

The subset sample, as a portion of the broad sample, appears to include more traditional age and selective institutions. It is characterized by smaller proportions of part-time and older students as well as higher average SAT/ACT scores. It is also skewed towards institutions with higher expenditures and a greater proportion of degrees conferred in Engineering disciplines. Finally, it includes larger proportions of total bachelor’s degree recipients who are women of color.

Variables for the coexistence ANOVA approach. After building the value-added models, a series of coexistence ANOVA models are conducted to explore whether the endogenous program coexistence factors have any impact on the residuals of the value-added models. The second part of the analysis involves three independent variables: proportion of STEM undergraduate women of color degree recipients by discipline, proportion of STEM graduate women of color degree recipients by discipline, and the undergraduate/graduate program coexistence measure. All of the data are from IPEDS 2003 to 2006 completions surveys and are calculated as a four-year average.

Consistent with the definition of women of color students when calculating the outcome variables for the value-added models, the proportion of STEM undergraduate and graduate women of color degree recipients are those who report to be black non-Hispanic women, American Indian/Alaska native women, and Hispanic women from the IPEDS completions surveys. The STEM disciplines are also referenced by the integration of designated degree programs initiated by the Department of Homeland Security and the SED code of STEM disciplines, which are presented in Appendix B. The STEM disciplines are aggregated in the baseline model. Biology, Chemistry, and Engineering are selected based on the differing women of color representation in these three disciplines.

The undergraduate/graduate program coexistence measure is derived using the Carnegie Undergraduate Instructional Program Classification Graduate Coexistence methodology (Carnegie Classification, 2015). Specifically, three groups are identified based on the proportion of undergraduate majors in which graduate degrees are also conferred: no graduate coexistence (no graduate degrees conferred within the discipline), some graduate coexistence (graduate degrees conferred in more than 0% but less than half of the undergraduate major areas), and high (graduate degrees conferred in more than one-half of the undergraduate major areas). Note that the graduate degrees include degrees conferred at the master's and the doctoral levels. The undergraduate degrees include only bachelor's degrees. Coexistence measures are created separately in each of the three broad disciplines: Biology, Chemistry, and Engineering. The majors in each of the three disciplines are defined at the 4-digit level in the Carnegie Classification referenced by STEM disciplines designated from the Immigration and Custom Enforcement and the Survey of Earned Doctorates. Unlike the Carnegie Classification, which operationalizes coexistence according to the proportion of undergraduate programs for which there is a corresponding graduate level program (McCormick, Pike, Kuh, & Chen, 2009), this study calculates the coexistence measure at the program level by the proportion of graduate to undergraduate degrees conferred within all STEM disciplines or a specific STEM program (Biology, Chemistry, and Engineering in this study).

Model Results

Overview

The remaining sections of this analysis report the results of the value-added multilevel models, as related to the first research question: "What state- and institutional-level demographic, financial, academic and socioeconomic background factors predict institutional variation in the proportion of women of color that attain these two degree outcomes: completing a STEM undergraduate degree, and completing a STEM doctoral degree?" This is followed by the undergraduate/graduate program coexistence ANOVA analyses that investigates the second research question: "Does the interaction between the undergraduate-graduate program coexistence and the proportionate women of color enrollment (degrees conferred as a proxy) at the graduate levels, significantly account for differences in the value-added scores of institutional performance on these outcome measures for women of color?”

Prior to analyzing the results of the model, there is a need to review the equations of the value-added multi-level models:

$$Y_{ij} = \frac{No.of\ STEM\ bachelor's\ degree\ recipients\ who\ are\ women\ of\ color}{No.of\ STEM\ bachelor's\ degrees\ conferred}$$

$$Y_{ij} = \beta_{0j} + \beta_{*j}(InstitutionalAcademics)_{*j} + \beta_{*j}(InstitutionalDemographics)_{*j}$$
$$+\beta_{*j}(InstitutionalFinancial)_{*j} + \beta_{*j}(InstitutionalContextual)_{*j}$$
$$+\beta_{*j}(InstitutionalSocioeconomic)_{*j} + \varepsilon_{ij}$$

$$\beta_{0j} = \gamma_{00} + \gamma_{0*}(StateSTEMLaborMarketIndicator)_{*}$$
$$+\gamma_{0*}(\%StateWomenofColorPopulation)_{*} + U_{0j}$$

$$Y'_{ij} =$$
$$\frac{No.of\ college\ women\ of\ color\ STEM\ graduates\ who\ went\ on\ to\ earn\ a\ doctoral\ degree\ in\ STEM\ disciplines}{No.of\ women\ of\ color\ bachelor's\ STEM\ degrees\ conferred\ 5\ to\ 8\ years\ earlier}$$

$$Y'_{ij} = \beta_{0j} + \beta_{*j}(InstitutionalAcademics)_{*j} + \beta_{*j}(InstitutionalDemographics)_{*j}$$
$$+\beta_{*j}(InstitutionalFinancial)_{*j} + \beta_{*j}(InstitutionalContextual)_{*j}$$
$$+\beta_{*j}(InstitutionalSocioeconomic)_{*j} + \varepsilon_{ij}$$

$$\beta_{0j} = \gamma_{00} + \gamma_{0*}(StateSTEMLaborMarketIndicator)_{*}$$
$$+\gamma_{0*}(\%StateWomenofColorPopulation)_{*} + U_{0j}$$

It is also necessary to examine the number of women of color bachelor’s degree holders in each discipline to understand the representation of women of color undergraduate students. Table 7 describes such information in the broad sample from 2003 to 2006.

Table 7

Number and Representation of Women of Color Bachelor's Degree Holders in each STEM Discipline from 2003 to 2006 (broad sample, n=1115)

Discipline	Total	Women	Percent Women	Women of Color	Percent Women of Color
Psychology	1762	1449	82.2%	263	14.9%
Biological sciences	205328	127853	62.3%	23404	11.4%
All others	27827	13072	47.0%	2566	9.2%
Chemistry	30378	15141	49.8%	2799	9.2%
Other physical sciences	2260	1188	52.6%	158	7.0%
Computer sciences	112516	23540	20.9%	7745	6.9%
Mathematical sciences	45629	20664	45.3%	2880	6.3%
Ocean sciences	2848	1892	66.4%	130	4.6%
Agricultural sciences	58891	29609	50.3%	2416	4.1%
Astronomy	1095	433	39.5%	42	3.8%
Engineering	233140	42438	18.2%	8694	3.7%
Earth sciences	11817	5027	42.5%	349	3.0%
Physics	14032	2971	21.2%	342	2.4%
Geosciences	2257	772	34.2%	47	2.1%
Grand Total	749780	286049	38.2%	51835	6.9%

Table 7 shows the representation of women and women of color in each STEM discipline. Differences among these distributions varies by discipline. In Psychology, Ocean Sciences, and Biological Sciences, the proportion of women is more than 50% larger than the proportion of women of color. In Physics, Engineering, and Computer Sciences, the difference between these distributions are relatively small (18.7%, 14.5%, and 14.0%, respectively).

The first model aggregates variables in all STEM disciplines as described above. It is applied as the reference model to investigate how the effect of state- and institutional-level demographic, financial, academic and socioeconomic background factors differs among the baseline model and the individual STEM disciplines. After examining the number and representation of women of color bachelor's degree holders in each discipline, three STEM disciplines are selected: Biology, Chemistry, and Engineering. These three disciplines are chosen to represent a women of color over-represented STEM discipline, a women of color medium-represented STEM discipline, and a women of color underrepresented STEM discipline.

The variables of the three models are all the same except the outcome and one of the predictors. Take the discipline of Biology as an example, the outcome of the model is the proportion of Biology bachelor's degree recipients who are women of color. For this model, the proportion of bachelor's degrees conferred within STEM disciplines is replaced with the proportion of bachelor's degrees conferred in the discipline of Biology. The corresponding predictor is included for the disciplines of Chemistry and Engineering.

The State STEM labor market index and the proportion of 18-24 year old citizens who are women of color at the state level are at first considered as Level-2 predictors, referenced by the graduation rate literature. However, preliminary results indicate that the effect of these two predictors, over and above the inclusion of state as a Level-2 distinction, are exceedingly small and not statistically significant. In addition, the inclusion of these two predictors does not improve the model fit. Therefore, they are excluded from the final models. The FIPS codes of the state is then used as the Level-2 grouping variable.

Multilevel models cannot generate standardized estimates since the data are not independent and identically distributed as assumed in ordinary least squares regression. However, there is a need to compare the size of effects due to the different scales of demographic, financial, socioeconomic, and academic factors. One approach to this issue is to standardize the outcome variables and the predictors (create z-scores). Hox (2010) warned that the *p* values could be affected slightly after the standardization. However, preliminary results show that the *p* values are not affected. Therefore, this approach was applied to generate unit-free Beta coefficients.

Research Question 1

Table 8a reports the results of the value-added multi-level models in all STEM disciplines as the baseline model. Table 8b through Table 8d include the results in Biology, Chemistry, and Engineering in the broad sample, where the outcome is the proportion of bachelor's degrees conferred in Biology, Chemistry, and Engineering that are women of color. Table 9a to Table 9c report the results in the subset sample, where the outcome variable is the proportion of women of color bachelor's degrees conferred in Biology, Chemistry, and Engineering who went on to earn a Ph.D. degree is the outcome variable.

Table 8a

Predicting the Proportion Bachelor's STEM Degree Recipients who are Women of Color (broad sample, n=1115)

Level 1

Proportion of women of college bachelor's STEM degree recipients	Coef.	Std. Err.	z	P>z	95% Conf. Interval	
Proportion part-time students (square root)	-0.104	0.033	-3.170	0.002	-0.168	-0.040
Proportion students above 25 years old (square root)	-0.222	0.038	-5.810	0.000	-0.297	-0.147
Proportion undergraduate students who are women of color (log)	0.589	0.025	23.970	0.000	0.541	0.638
Proportion bachelor's degrees conferred in STEM disciplines (log)	-0.009	0.022	-0.410	0.682	-0.051	0.034
Institutional control	0.241	0.040	6.080	0.000	0.163	0.319
Proportion undergraduate students who receive federal grant aid (log)	0.154	0.031	5.010	0.000	0.093	0.214
Institutional converted SAT-ACT score (log)	-0.464	0.035	-13.300	0.000	-0.533	-0.396
Educational expenditure (log)	0.156	0.028	5.570	0.000	0.101	0.211
Proportion of large-city located institutions	0.054	0.036	1.490	0.137	-0.017	0.125
_cons	-0.135	0.041	-3.320	0.001	-0.215	-0.055

Level 2 (Grouping variable: FIPS state code)

Random-effects Parameters	Estimate	Std. Err.	95% Conf. Interval	
Sd (_cons)	0.145	0.024	0.105	0.202
Sd (Residual)	0.556	0.012	0.533	0.580

Broad sample analysis. When the proportion of women of color bachelor's STEM degree recipients is the outcome variable, the intra-class correlation is 0.18 for the null model. Snijders & Bosker (2012) suggest a minimum intra-class correlation of 0.05 to be the threshold for using a multilevel model. This indicates that a multilevel regression approach is appropriate for this model. 67.5% of the Level-1 variance and 79.8% of the Level-2 variance are accounted by the predictors. The results show that except the proportion of large-city located institutions and the proportion of bachelor's degrees conferred to STEM disciplines, all other predictors have a statistically significant impact on the outcome.

The demographic factors include proportion of undergraduates who enrolled part-time, proportion of undergraduates who are age 25 years old or older, proportion of women of color among enrolled undergraduates, proportion of bachelor's degrees conferred in STEM disciplines, and control (private institutions=1). All variables show a significant impact on the outcome except the proportion of bachelor's degrees conferred from STEM disciplines. The proportion of women of color among enrolled undergraduates has the largest impact on the outcome ($p<0.001$). One standard deviation change in this predictor (log transformed) associates with 0.59 standard deviation change in the outcome, holding other variables constant. Being a private institution is expected to increase the outcome by 0.24 standard deviations, holding other variables constant ($p<0.001$).

The financial factor in this study refers to the total of educational expenditures per full-time-equivalent (FTE) student. It has a positive impact on the outcome ($p<0.001$). One standard deviation change in this predictor (log transformed) associates with 0.16 standard deviation increase in the outcome, holding other variables constant.

The selectivity factor, the institutional converted SAT-ACT score, reveals a negative effect on the outcome ($p<0.001$). One standard deviation increase in this predictor (log transformed) associates with 0.46 standard deviation decrease in the outcome, holding other variables constant. The socioeconomic factor refers to the proportion of students receiving a federal grant. It has a positive impact on the outcome ($p<0.001$). One standard deviation change in this predictor (log transformed) associates with 0.15 standard deviation increase in the outcome, holding other variables constant.

As expected, the proportion of women of color in the population is positively related to the proportion of women of color who graduate from a STEM discipline. One other indicator of the proportion of non-traditional students, the proportion receiving federal aid, also has a positive effect, net of the other predictors. However, the two other measures related to the student profile—proportion of part-time students, proportion of student over age 25—have negative effects. Finally, private institutions (private institutions=1) also graduate higher proportions of women of color in STEM disciplines when controlling statistically for the other variables in the model. The second level factor, state, also accounts for significant differences in the outcome variable.

Table 8b

Effects of Multilevel Regression Results: The Proportion of Bachelor's Biology Degree Recipients who are Women of Color (broad sample, n=1065)

Level 1

Proportion bachelor's Biology degree recipients who are women of color	Coef.	Std. Err.	z	P>z	95% Conf. Interval	
Proportion part-time students (square root)	-0.099	0.032	-3.130	0.002	-0.161	-0.037
Proportion students above 25 years old (square root)	-0.279	0.038	-7.290	0.000	-0.354	-0.204
Proportion undergraduate students who are women of color (log)	0.649	0.024	27.470	0.000	0.603	0.695
Proportion bachelor's degrees conferred in Biology disciplines (log)	-0.009	0.021	-0.450	0.654	-0.050	0.031
Institutional control	-0.007	0.036	-0.190	0.849	0.057	0.173
Proportion undergraduate students who receive federal grant aid (log)	0.115	0.029	3.900	0.000	-0.551	-0.418
Institutional converted SAT-ACT score (log)	-0.484	0.034	-14.280	0.000	0.134	0.237
Educational expenditure (log)	0.186	0.026	7.100	0.000	-0.001	0.135
Proportion of large-city located institutions	0.067	0.035	1.930	0.054	-0.077	0.063
_cons	0.000	0.038	0.010	0.991	-0.074	0.075

Level 2 (Grouping variable: FIPS state code)

Random-effects Parameters	Estimate	Std. Err.	95% Conf. Interval	
Sd (_cons)	0.135	0.023	0.096	0.189
Sd (Residual)	0.521	0.011	0.499	0.544

In the discipline of Biology, where the number of women of color undergraduate students are over-represented, the intra-class correlation is 0.20 for the null model. 71.4% of the Level-1 variance and 82.9% of the Level-2 variance are accounted by the predictors. As in the broader STEM discipline sample, all predictors except the large-city located institutions and the proportion of bachelor's degrees conferred from Biology disciplines reveal a statistically significant impact on the outcome.

Similar to the results of the broader sample model, the proportion of women of color students among enrolled undergraduates shows the largest impact on the outcome. For one standard deviation increase in this variable (log transformed), the proportion of Biology bachelor's degree holders who are women of color is expected to increase by 0.65 standard deviation, holding other variables constant. All the other four demographic factors show a negative impact on the outcome.

The other factors have effects very similar to the larger sample model. The financial factor, total amount of educational expenditure per full-time-equivalent (FTE) student, has a positive effect ($p<0.001$). For one standard deviation increase in this variable (log transformed), the proportion of Biology bachelor's degree holders who are women of color increase by an expected 0.19 standard deviation, holding other variables constant. Institutional selectivity (converted SAT-ACT score) has a negative effect ($p<0.001$). For one standard deviation increase in this variable (log transformed), the proportion of Biology bachelor's degree holders who are women of color is expected to decrease by 0.48 standard deviation, holding other variables constant. The socioeconomic factor (proportion of students receiving federal grant) is positively associated with the outcome ($p<0.001$). For one standard deviation increase in this variable (log transformed), the proportion of Biology bachelor’s degree holders who are women of color is expected to increase by 0.12 standard deviation, holding other variables constant.

Table 8c

Effects of Multilevel Regression Results: The Proportion of Bachelor's Chemistry Degree Recipients who are Women of Color (broad sample, n=755)

Level 1

Proportion bachelor's Chemistry degree recipients who are women of color	Coef.	Std. Err.	z	P>z	95% Conf. Interval	
Proportion part-time students (square root)	-0.049	0.055	-0.900	0.368	-0.156	0.058
Proportion students above 25 years old (square root)	-0.312	0.061	-5.110	0.000	-0.432	-0.192
Proportion undergraduate students who are women of color (log)	0.588	0.032	18.540	0.000	0.526	0.650
Proportion bachelor's degrees conferred in Chemistry disciplines (log)	0.070	0.026	2.690	0.007	0.019	0.121
Institutional control	-0.001	0.053	-0.020	0.983	-0.104	0.102
Proportion undergraduate students who receive federal grant aid (log)	0.111	0.040	2.760	0.006	0.032	0.189
Institutional converted SAT-ACT score (log)	-0.515	0.052	-9.920	0.000	-0.616	-0.413
Educational expenditure (log)	0.206	0.038	5.470	0.000	0.132	0.280
Proportion of large-city located institutions	0.100	0.048	2.080	0.038	0.006	0.194
_cons	-0.028	0.049	-0.580	0.561	-0.124	0.067

Level 2 (Grouping variable: FIPS state code)

Random-effects Parameters	Estimate	Std. Err.	95% Conf. Interval	
Sd (_cons)	0.164	0.031	0.114	0.237
Sd (Residual)	0.601	0.016	0.571	0.633

In the discipline of Chemistry, where the number of women of color undergraduate students are medium-represented, the intra-class correlation is 0.18 for the null model. 61.6% of the Level-1 variance and 72.1% of the Level-2 variance are explained by the independent variables.

Similar to the results from the baseline model, the proportion of women of color undergraduate students is positively associated with the proportion of women of color who graduate from a Chemistry discipline ($p<0.001$). The proportion receiving federal grant aid also have a positive effect ($p<0.01$). The other measure related to the student profile—proportion of students over 25 years old—has a negative effect. Institutional selectivity as measured by the composite SAT-ACT score, has a negative effect ($p<0.001$). The educational expenditure is also found to have a positive effect ($p<0.001$). The second level, state, accounts for significant difference in the outcome variable.

In the baseline model, the proportion of part-time students has a negative impact ($p<0.01$) and institutional control (private institutions=1) has a positive effect ($p<0.001$). However, in the model of Chemistry disciplines, these two factors no longer have a statistically significant effect. In addition, the large-city located institutions does not show a significant effect in the baseline model, but a positive effect is found in the model of Chemistry disciplines ($p<0.05$).

Table 8d

Effects of Multilevel Regression Results: The Proportion of Bachelor's Engineering Degree Recipients who are Women of Color

(broad sample, n=755)

Level 1

Proportion bachelor's Engineering degree recipients who are women of color	Coef.	Std. Err.	z	P>z	95% Conf. Interval	
Proportion part-time students (square root)	-0.083	0.074	-1.130	0.260	-0.227	0.061
Proportion students above 25 years old (square root)	-0.293	0.082	-3.570	0.000	-0.454	-0.132
Proportion undergraduate students who are women of color (log)	0.544	0.048	11.440	0.000	0.451	0.637
Proportion bachelor's degrees conferred in Engineering disciplines (log)	0.054	0.037	1.450	0.146	-0.019	0.127
Institutional control	0.317	0.082	3.880	0.000	0.157	0.478
Proportion undergraduate students who receive federal grant aid (log)	0.154	0.057	2.720	0.006	0.043	0.265
Institutional converted SAT-ACT score (log)	-0.397	0.075	-5.270	0.000	-0.545	-0.249
Educational expenditure (log)	0.163	0.061	2.680	0.007	0.044	0.283
Proportion of large-city located institutions	0.042	0.071	0.590	0.558	-0.098	0.181
_cons	-0.089	0.071	-1.250	0.213	-0.229	0.051

Level 2 (Grouping variable: FIPS state code)

Random-effects Parameters	Estimate	Std. Err.	95% Conf. Interval	
Sd (_cons)	0.263	0.047	0.186	0.373
Sd (Residual)	0.658	0.024	0.614	0.706

In the discipline of Engineering, the number of women of color undergraduate students are underrepresented. The intra-class correlation is 0.19 for the null model. 50.3% of the Level-1 variance and 54.7% of the Level-2 variance are accounted by the predictors.

Similar to the results in the baseline model, the proportion of undergraduates who are age 25 years old or older and the institutional selectivity are negatively related to the outcome ($p<0.001$). The proportion of undergraduate students who are women of color has the largest positive impact ($p<0.001$). The proportion of students who receive federal grant aid, institutional control, and the educational expenditure have a positive impact. The state, as a level 2 variable, significantly accounts for the difference in the outcome variable. However, the proportion of part-time students shows a different trend. In the baseline model, it is negatively related to the outcome. In the Engineering model, the impact is no longer statistically significant.

Subset sample analysis. Tables 9a to 9c report the results in the subset sample, where the proportion of women of color bachelor's degrees conferred in Biology, Chemistry, and Engineering who went on to earn a Ph.D. degree is the outcome variable. Since the sample size of the subset sample is much smaller than the broad sample, it is expected that the models in the subset sample have less statistical power than those in the broad sample and so some effects might be either statistically significant at a lower level or not statistically significant. The non-statistically significant effects is noted only insofar as their direction (sign) is in the same direction of effects found significant in the larger sample models.

Table 9a

Effects of Multilevel Regression Results: The Proportion of Bachelor's Biology Women of Color Degree Recipients who Went on to Earn a Doctoral Degree (Subset sample, n=432)

Level 1

Proportion bachelor's Biology women of color degree recipients who went on to earn a doctoral degree	Coef.	Std. Err.	z	P>z	95% Conf. Interval	
Proportion part-time students (square root)	-0.162	0.090	-1.800	0.071	-0.338	0.014
Proportion students above 25 years old (square root)	0.176	0.107	1.640	0.100	-0.034	0.385
Proportion undergraduate students who are women of color (log)	-0.601	0.059	-10.170	0.000	-0.716	-0.485
Proportion bachelor's degrees conferred in Biology disciplines (log)	-0.051	0.050	-1.020	0.308	-0.148	0.047
Institutional control	0.612	0.091	6.740	0.000	0.434	0.789
Proportion undergraduate students who receive federal grant aid (log)	0.202	0.083	2.430	0.015	0.039	0.365
Institutional converted SAT-ACT score (log)	-0.105	0.096	-1.090	0.277	-0.294	0.084
Educational expenditure (log)	0.137	0.067	2.050	0.040	0.006	0.267
Proportion of large-city located institutions	-0.226	0.083	-2.730	0.006	-0.388	-0.064
_cons	-0.158	0.077	-2.060	0.039	-0.308	-0.008

Level 2 (Grouping variable: FIPS state code)

Random-effects Parameters	Estimate	Std. Err.	95% Conf. Interval	
Sd (_cons)	0.000	0.000	0.000	0.000
Sd (Residual)	0.817	0.028	0.765	0.874

In the discipline of Biology, women of color underrepresented students are over-represented. The intra-class correlation is 0.07 for the null model. 33.2% of the Level-1 variance and 43.6% of the Level-2 variance are explained by the predictors.

Similar to the results in the baseline model, the proportion of part-time students reveals a negative impact on the outcome. The institutional control (private institutions=1), the proportion of undergraduate students who receive federal grant aid and the educational expenditure have a positive effect ($p<0.05$). Being a large-city located institutions is negatively related to the outcome in Biology of the subset sample ($p<0.001$), but similar trend is not found in the baseline model. The proportion of undergraduates who are women of color has a positive impact on the outcome ($p<0.001$) in the baseline model, but this effect becomes negative in the model of Biology in the subset sample.

Table 9b

Effects of Multilevel Regression Results: The Proportion of Bachelor's Chemistry Women of Color Degree Recipients who Went on to Earn a Doctoral Degree (Subset sample, n=187)

Level 1

Proportion bachelor's Chemistry women of color degree recipients who went on to earn a doctoral degree	Coef.	Std. Err.	z	P>z	95% Conf. Interval	
Proportion part-time students (square root)	-0.193	0.143	-1.350	0.177	-0.473	0.087
Proportion students above 25 years old (square root)	0.159	0.162	0.980	0.327	-0.159	0.477
Proportion undergraduate students who are women of color (log)	-0.476	0.104	-4.590	0.000	-0.680	-0.273
Proportion bachelor's degrees conferred in Chemistry disciplines (log)	-0.092	0.072	-1.270	0.204	-0.233	0.050
Institutional control	0.895	0.155	5.770	0.000	0.591	1.199
Proportion undergraduate students who receive federal grant aid (log)	-0.060	0.135	-0.450	0.654	-0.324	0.203
Institutional converted SAT-ACT score (log)	-0.207	0.156	-1.320	0.185	-0.513	0.099
Educational expenditure (log)	-0.079	0.107	-0.740	0.461	-0.289	0.131
Proportion of large-city located institutions	-0.053	0.136	-0.390	0.695	-0.321	0.214
_cons	-0.302	0.130	-2.320	0.020	-0.557	-0.047

Level 2 (Grouping variable: FIPS state code)

Random-effects Parameters	Estimate	Std. Err.	95% Conf. Interval	
Sd (_cons)	0.193	0.108	0.064	0.579
Sd (Residual)	0.815	0.046	0.730	0.910

In the discipline of Chemistry, women of color undergraduate students have moderate representation relative to other STEM disciplines. The intra-class correlation is 0.16 for the null model. 31.1% of the Level-1 variance and 39.5% of the Level-2 variance are explained by the predictors.

Similar to the results in the larger sample model, the proportion of part-time students, the institutional control, and the institutional converted SAT-ACT score reveal a negative impact. A noticeable difference is that the proportion of undergraduates who are women of color has a negative impact in the model of Chemistry in the subset sample ($p<0.001$), but the effect is positive in the baseline model ($p<0.001$). The state, as a level-2 grouping variable, significantly account for the difference in the outcome variable in both models.

Table 9c

Effects of Multilevel Regression Results: The Proportion of Bachelor's Engineering Women of Color Degree Recipients who Went on to Earn a Doctoral Degree (Subset sample, n=135)

Level 1

Proportion bachelor's Engineering women of color degree recipients who went on to earn a doctoral degree	Coef.	Std. Err.	z	P>z	95% Conf. Interval	
Proportion part-time students (square root)	-0.302	0.163	-1.850	0.065	-0.622	0.018
Proportion students above 25 years old (square root)	0.287	0.185	1.550	0.121	-0.076	0.650
Proportion undergraduate students who are women of color (log)	-0.710	0.107	-6.650	0.000	-0.919	-0.501
Proportion bachelor's degrees conferred in Engineering disciplines (log)	-0.414	0.085	-4.860	0.000	-0.581	-0.247
Institutional control	0.487	0.197	2.470	0.013	0.101	0.873
Proportion undergraduate students who receive federal grant aid (log)	0.328	0.123	2.670	0.008	0.087	0.569
Institutional converted SAT-ACT score (log)	-0.021	0.187	-0.110	0.913	-0.388	0.347
Educational expenditure (log)	0.196	0.134	1.470	0.141	-0.065	0.458
Proportion of large-city located institutions	-0.169	0.157	-1.080	0.281	-0.478	0.139
_cons	-0.044	0.143	-0.310	0.756	-0.324	0.235

Level 2 (Grouping variable: FIPS state code)

Random-effects Parameters	Estimate	Std. Err.	95% Conf. Interval	
Sd (_cons)	0.103	0.227	0.001	7.875
Sd (Residual)	0.802	0.056	0.700	0.919

In the discipline of Engineering, women of color are very underrepresented. The intra-class correlation is 0.10 for the null model. 34.6% of the Level-1 variance and 39.5% of the Level-2 variance are accounted by the predictors.

Similar to the result in the larger sample model, a negative impact is found for the variable of proportion of part-time students and the institutional converted SAT-ACT score. The proportion of undergraduate who receive federal grant aid and the educational expenditure also have a positive effect. Similar impact is located for the variable of being a private institution ($p<0.05$). A distinction is identified: the proportion of bachelor's degree conferred to STEM disciplines is not significant in the baseline model, but the proportion of bachelor's degree conferred to Engineering disciplines is found to have a negative impact ($p<0.001$) for the first time.

Summary. The two outcomes applied in this study, the proportion of women of color STEM baccalaureate recipients and the proportion of STEM baccalaureate recipients who went on to earn a doctoral degree are substantially different. It is interesting to observe that The impact of the proportion of undergraduate students who are women of color, being a large-city located institution, and the proportion of students who are 25 years of age and older change direction when the outcome switches from the proportion of STEM women of color bachelor's degree recipients to STEM women of color bachelor's degree recipients who went on to earn a doctorate. In addition, there are two variables that have a negative impact on the outcome across disciplines. They are the proportion of part-time students and the institutional converted SAT-ACT score. The effect of the other four variables—the proportion of bachelor's degree conferred in Biology, Chemistry, and Engineering disciplines, institutional control, the proportion of undergraduate students who receive federal grant, and education expenditure, however, do not reveal a pattern across the disciplines.

Research Question 2

This section reports the results of the analysis that addresses the second research question: “Does the interaction between the undergraduate-graduate program coexistence and the proportionate women of color enrollment (degrees conferred as a proxy) at the graduate levels, significantly account for differences in the value-added scores of institutional performance on these outcome measures for women of color?” Since the numbers of enrollment by STEM discipline are not available in IPEDS, the numbers of degrees conferred in each discipline are employed as a proxy.

An ANOVA approach is applied with the residuals of each multi-level model serving as the outcome variable. The proportion of graduate women of color students, and the level of undergraduate/graduate program coexistence are the independent variables. The proportion of graduate degrees conferred to women of color are recoded into five groups: those who conferred 0% of graduate degrees to women of color; the remaining are recoded by quartiles. The level of undergraduate/graduate program coexistence is recoded by some coexistence (<50%) and high coexistence (>50%) and 0% of degrees conferred at the graduate level (Carnegie Classification, 2015). Similar to the value-added multi-level models, separate analyses are run for the three STEM disciplines: Biology, Chemistry, and Engineering.

Prior to reviewing the results, there is a need to examine the standardized residuals of each of the value-added multilevel model in the previous section to determine whether the distribution of the residuals is statistically appropriate to be applied as the outcome variables for the ANOVA analysis of the program coexistence.

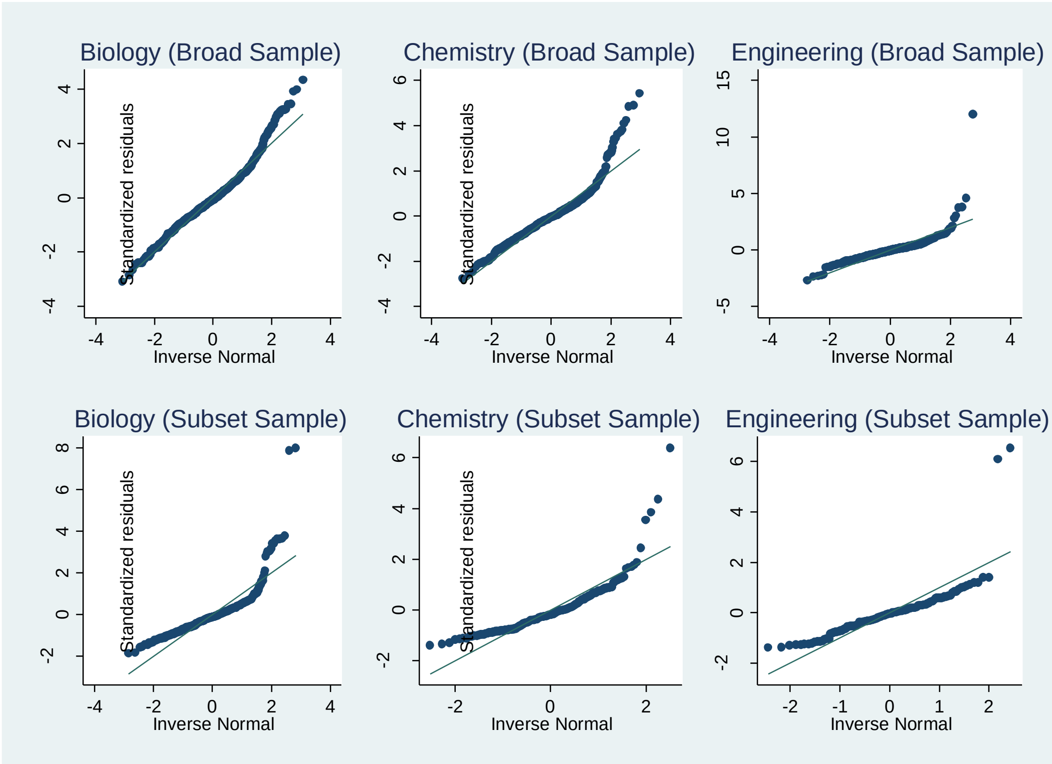

Figure 2. Normal Q-Q plot for the standardized residuals of value-added multi-level models.

A majority of the data points in the broad sample lie on the diagonal line. This indicates that the residuals in the broad sample are normally distributed in general. In the subset sample, the data points also lie on the diagonal line, but we observe some points are located on the top right of the graph. This indicates that the residuals in the subset sample have more extreme values than are desired. All of these institutions are included in the analysis.

In addition, it is necessary to examine the descriptive statistics of the predictors in the ANOVA models. Table 10 includes such information.

Table 10

Descriptive Statistics of Women of Color Ratio at the Graduate Level and Program Coexistence

Sample	Discipline	Variable	Mean	Std. Dev.	Min	Max
Broad	Biology (N=1065)	Graduate degrees conferred to women of color	0.668	1.245	0.000	4.000
		Level of undergraduate/graduate coexistence	0.417	0.556	0.000	2.000
	Chemistry (N=755)	Graduate degrees conferred to women of color	0.517	1.132	0.000	4.000
		Level of undergraduate/graduate coexistence	0.494	0.705	0.000	2.000
	Engineering (N=427)	Graduate degrees conferred to women of color	1.309	1.486	0.000	4.000
		Level of undergraduate/graduate coexistence	0.848	0.652	0.000	2.000
Subset	Biology (N=432)	Graduate degrees conferred to women of color	1.208	1.467	0.000	4.000
		Level of undergraduate/graduate coexistence	0.664	0.587	0.000	2.000
	Chemistry (N=187)	Graduate degrees conferred to women of color	1.128	1.446	0.000	4.000
		Level of undergraduate/graduate coexistence	0.888	0.764	0.000	2.000
	Engineering (N=135)	Graduate degrees conferred to women of color	2.207	1.258	0.000	4.000
		Level of undergraduate/graduate coexistence	1.148	0.466	0.000	2.000

Table 10 reveals that disciplines in the subset samples tend to have a higher proportion of graduate degrees conferred to women of color. The level of undergraduate/graduate coexistence is also higher in the subset sample than that in the broad sample.

Table 11a

Effect of Women of Color Ratio at the Graduate Level and Program Coexistence on the Percent of Women of Color Bachelor's Degree recipients in Biology (Broad sample, n=1065)

Residual of the proportion of bachelor's Biology degree recipients who are women of color	Degree of Freedom	F	Prob>F
Graduate degrees conferred to women of color	4	4.000	0.003
Level of undergraduate/graduate coexistence	2	0.530	0.589
Graduate degrees conferred to women of color x Level of undergraduate/graduate coexistence	4	0.180	0.951

In the Biology broad sample, where the outcome is the residual derived from the multi-level model with the outcome of proportion of Biology bachelor's degree recipients who are women of color, 2.4% of the variance is explained by the predictors. The results show that the proportion of graduate degrees conferred to women of color has a positive impact on the outcome ($p<0.01$). However, the interaction between the proportion of graduate women of color degrees conferred and the level of program coexistence does not reveal a significant impact.

Table 11b

Effect of Women of Color Ratio at the Graduate Level and Program Coexistence on the Percent of Women of Color Bachelor's Degree recipients in Chemistry (Broad sample, n=755)

Residual of the proportion of bachelor's Chemistry degree recipients who are women of color	Degree of Freedom	F	Prob>F
Graduate degrees conferred to women of color	4	0.340	0.852
Level of undergraduate/graduate coexistence	2	0.070	0.932
Graduate degrees conferred to women of color x Level of undergraduate/graduate coexistence	4	1.300	0.269

In the Chemistry broad sample, 0.4% of the variance is explained by the independent variables. None of the predictors, including the interaction between the undergraduate women of color degrees conferred and the level of program coexistence has a significant impact on the outcome.

Table 11c

Effect of Women of Color Ratio at the Graduate Level and Program Coexistence on the Percent of Women of Color Bachelor's Degree recipients in Engineering (Broad sample, n=427)

Residual of the proportion of bachelor's Engineering degree recipients who are women of color	Degree of Freedom	F	Prob>F
Graduate degrees conferred to women of color	4	1.350	0.250
Level of undergraduate/graduate coexistence	2	0.240	0.784
Graduate degrees conferred to women of color x Level of undergraduate/graduate coexistence	4	0.780	0.538

In the Engineering broad sample, 0.1% of the variance is accounted by the predictors. Similar to the results in Chemistry, we cannot reject the null hypothesis that response mean for the level of graduate women of color degrees conferred does not depend on the level of the program coexistence.

Table 12a

Effect of Women of Color Ratio at the Graduate Level and Program Coexistence on the Percent of Women of Color Bachelor's Degree recipients in Biology (Subset sample, n=432)

Residual of the proportion of women of color bachelor's Biology degree recipients who went on to earn a doctoral degree	Degree of Freedom	F	Prob>F
Graduate degrees conferred to women of color	4	1.140	0.3356
Level of undergraduate/graduate coexistence	2	1.520	0.2194
Graduate degrees conferred to women of color x Level of undergraduate/graduate coexistence	3	2.630	0.0495

In the Biology subset sample, where the outcome is the residual derived from the multi-level model with the outcome of proportions of women of color bachelor's degree recipients in Biology who went on to earn a doctoral degree, 2.6% of the variance is explained by the predictors. The interaction between the graduate women of color degrees conferred and the level of program coexistence has a marginally significant effect on the outcome ($p<0.05$).

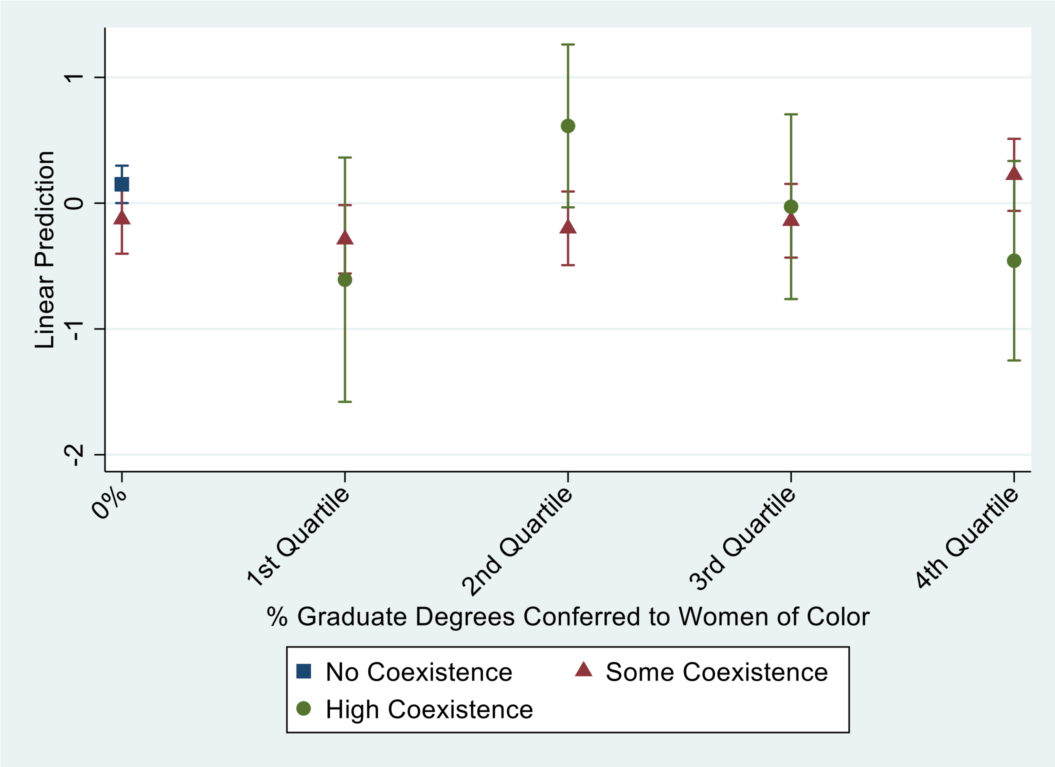

Figure 3. Interaction plot of the proportion of graduate degrees conferred to women of color and program coexistence in Biology of the subset sample.

Figure 2 shows that the interaction between the proportion of graduate degrees conferred to women of color and program coexistence is significant ($p<0.05$) when institutions do not have any graduate program in Biological disciplines (no graduate degrees conferred to women of color students and no program coexistence). Another situation is when the proportion of graduate degrees conferred to women of color falls into the first quartile and the level of program coexistence is within the range of "some coexistence" (<50%) ($p<0.05$). For the "some coexistence" condition, there does appear to be some increasing likelihood of the residual being more positive (or less negative) for increasing proportions. However, for the "high coexistence" condition, where more programs have both undergraduate and graduate levels, the relationship does not follow any particular or expected patterns.

Table 12b

Effect of Women of Color Ratio at the Graduate Level and Program Coexistence on the Percent of Women of Color Bachelor's Degree recipients in Chemistry (Subset sample, n=187)

Residual of the proportion of women of color bachelor's Chemistry degree recipients who went on to earn a doctoral degree	Degree of Freedom	F	Prob>F
Graduate degrees conferred to women of color	4	0.59	0.670
Level of undergraduate/graduate coexistence	2	0.84	0.434
Graduate degrees conferred to women of color x Level of undergraduate/graduate coexistence	4	1.26	0.288

In the Chemistry subset sample, 1.2% of the variance is accounted by the independent variables. None of the predictors has a significant impact on the outcome. The results show that we cannot reject the null hypothesis that response mean for the graduate women of color degrees conferred does not depend on the level of the program coexistence.

Table 12c

Effect of Women of Color Ratio at the Graduate Level and Program Coexistence on the Percent of Women of Color Bachelor's Degree recipients in Engineering (Subset sample, n=135)

Residual of the proportion of women of color bachelor's Engineering degree recipients who went on to earn a doctoral degree	Degree of Freedom	F	Prob>F
Graduate degrees conferred to women of color	4	7.750	0.000
Level of undergraduate/graduate coexistence	2	4.110	0.019
Graduate degrees conferred to women of color x Level of undergraduate/graduate coexistence	3	0.310	0.818

In the Engineering subset sample, 17.0% of the variance is explained by the predictors. The results reveal that the proportion of graduate degrees conferred to women of color and the level of program coexistence have a significant impact on the outcome ($p<0.05$). However, the interactions between these two variables do not have a significant effect.

Summary. There is limited support for the impact of the interaction between the level of undergraduate/graduate program coexistence and the proportion of graduate women of color students. The only interaction found marginally significant is in the analysis related to women of color Biology bachelor’s degree recipients who went on to earn a doctoral degree ($p<0.05$). In addition, for the “some coexistence” condition, there is an increasing likelihood of the residual being more positive for increasing proportion of graduate women of color students. However, the relationship does not follow any expected pattern for the “high coexistence” condition.

Chapter Five: Discussion

This chapter is comprised of three parts. It first discusses the findings from the analyses in Chapter 4 that address the two study's research questions raised in Chapter 3. The second part of this chapter discusses the implications for theory, practice, and research derived from the results of Chapter 4. The last part of this chapter addresses the limitation of this study.

Re-addressing the Research Questions

Research Question 1

What state- and institutional-level demographic, financial, academic, and socioeconomic background factors predict institutional variation in the proportion of women of color that attain these two degree outcomes: completing a STEM undergraduate degree, and completing a STEM doctoral degree?

Table 13 summarizes the effect of exogenous variables in the value-added multi-level models. Since no variable has a positive impact across all three disciplines, the effect of these variables are divided into two groups: negative effects and mixed effects.

Table 13

Summary of the Effect of Exogenous Variables in the Value-added Multi-level Models

Outcome	STEM (Baseline)	Biology		Chemistry		Engineering	
	Proportion of Bachelor's Degree Recipients who are Women of Color	Proportion of Bachelor's Degree Recipients who are Women of Color	Proportion of Bachelor's Women of Color Degree Recipients who Went on to Earn a Doctoral Degree	Proportion of Bachelor's Degree Recipients who are Women of Color	Proportion of Bachelor's Women of Color Degree Recipients who Went on to Earn a Doctoral Degree	Proportion of Bachelor's Degree Recipients who are Women of Color	Proportion of Bachelor's Women of Color Degree Recipients who Went on to Earn a Doctoral Degree
Proportion of part-time students (square root)	-**	-**	-	-	-	-	-
Proportion of students above 25 years old (square root)	-***	-***	+	-***	+	-***	+
Proportion of undergraduate students who are women of color (log)	+***	+***	-***	+***	-***	+***	-***
Proportion of bachelor's degrees conferred in STEM, Biology, Chemistry,	-	-	-	+**	-	+	-***

Institutional control	+***	-	+***	-	+***	+***	+*
Proportion of undergraduate students who receive federal grant aid (log)	+***	+***	+*	+**	-	+**	+**
Institutional converted SAT-ACT score (log)	-***	- ***	-	-***	-	-***	-
Educational expenditure (log)	+***	+***	+*	+***	-	+**	+
Being a large-city located institution	+	+	-**	+*	-	+	-

*p<0.05. **p<0.01. ***p<0.001

Negative effects. There are two variables that constantly have a negative effect on the outcome across disciplines. The first variable is the proportion of part-time students. The other one is the institutional converted SAT-ACT score.

The proportion of students who enrolled part-time is one of the measures to examine institutions' enrollment of non-traditional students. Part-time students are more likely to have other life responsibility (e.g. job, family) and therefore are less committed to their academic study. The results for this variable show consistency with the findings in the predicted graduation rate literature (Astin, 1993; Cunha & Miller, 2009; Goenner & Snaith, 2004; Porter, 2000; Scott et al., 2006). Many STEM disciplines requires hours devoted in non-working time (e.g. experiments run through evenings and weekends). This could be a challenge for women students who need to balance school and other non-academic responsibilities (Goldman, 2012). Regardless of whether one is considering an undergraduate or doctoral degree, having a high proportion of part-time students hinders STEM degree completion among women of color.

This study applies the converted institutional SAT-ACT score collected from IPEDS from 2003 to 2006. According to the literature review in Chapter 3, institutional selectivity is positively associated with graduation rates (Archibald & Feldman, 2008; Astin, et al., 1996; Horn & Lee, 2014; Goenner & Snaith, 2004; Porter, 2000). Also, there is evidence that institutional selectivity is negatively associated with underrepresented racial minorities' persistence and degree completion rates in STEM disciplines (Arcidiacono, Aucejo, & Hotz, 2016; Chang, 2008; Espinosa, 2011).

The outcomes of this study are notably different from the graduation rate literature findings. The results specifically show that institutional selectivity has a negative effect with regard to the proportion of women of color STEM bachelor's degree recipients ($p<0.001$), holding all other factors constant. Although the effect was no longer significant for the analysis of proportion of women of color who go on to complete a STEM doctoral degree, possibly because of the smaller sample size, the direction of the nonsignificant effect was negative for all three disciplines.

Although there was no *a priori* expectation for whether this factor would positively or negatively affect the outcomes, it is interesting to note that higher selectivity is related to lower proportions of women of color obtaining STEM bachelor's degrees. Selective institutions tend to be less diverse and more competitive than those with less stringent entry requirements (Bonous-Hammarth, 2006). Therefore, selective institutions could both substantially hinder and motivate underrepresented minority students' STEM major aspirations (Chang, Cerna, Han, & Saenz, 2008). The negative effect seen here could reflect the detrimental aspects of the competitive environment for women of color students in STEM disciplines and students' lack of information about within-campus differences (Arcidiacono, Aucejo, & Hotz, 2016; Chang, 2008). However, those STEM women of color students who eventually earned a doctoral degree are relatively better academically prepared than those who earned a bachelor's degree. Aside from power differences between the two sets of analyses (the broad sample is larger than the subset sample), it is possible that women of color who went on to earn doctorates were less likely to encounter difficulties in the undergraduate programs such as university and major mismatch, and being substantially ill-informed about the grading difference within the institution.

Mixed effects. Among exogenous variables that have a mixed effect across disciplines, three of them change direction of the effect when the outcome switches from the proportion of STEM bachelor's degree recipients who are women of color, to STEM women of color bachelor's degree recipients who went on to earn a doctorate. These three variables are the proportion of undergraduate students who are women of color, being a large-city located institution, and the proportion of students who are 25 years of age or older.

The proportion of women of color among enrolled undergraduates shows a positive effect across all three disciplines for the proportion of women of color STEM bachelor's degree recipients outcome, but the impact is negative for the women of color STEM bachelor's degree recipients who went on to complete a doctoral degree outcome. This indicates that having a higher proportion of women of color among enrolled undergraduates is associated with having a higher proportion of STEM bachelor's degree recipients who are women of color. This effect does not hold for women of color bachelor's degree recipients going on to earn a doctoral degree. The results reveal that the impact of this variable is not consistent across degree levels. Although this study does not establish causality, it suggests a possible causal link wherein having a larger peer group is helpful for women of color to obtain an undergraduate STEM degree, but it does not increase the likelihood that women of color undergraduate STEM degree recipients will continue on to receive a doctorate in a STEM field.

The effect of being a large-city located institution has a similar pattern of effects compared to the proportion of women of color among enrolled undergraduates. It has a positive effect across all three disciplines for the proportion of women of color STEM bachelor's degree recipient outcome. In contrast, the impact is negative when the outcome is women of color STEM bachelor's degree recipients who went on to complete a doctoral degree. One possible explanation could be that large cities tend to have a higher labor market demand compared all other locations. Therefore, women of color STEM majors may be more likely to find a job after completing a bachelor's degree than can their peers who graduate from institutions located elsewhere.

The proportion of students who are age 25 or older is another critical measure of institutions' non-traditional student enrollments. This variable is assumed to have a similar effect to the proportion of students enrolled part-time, but the results show that unlike the constant negative impact of the proportion of part-time students, the effect of this variable is only negative for the proportion of women of color STEM bachelor's degree recipient outcome. Because none of the positive effects are significant, I cannot speculate about the association between this factor and the proportion of STEM bachelor's degree recipients who went on to earn a doctoral degree..

The impact of the remaining four variables—the proportion of bachelor's degrees conferred in Biology, Chemistry, and Engineering disciplines; institutional control; the proportion of undergraduate students who receive federal grant; and educational expenditure, do not reveal a clear pattern across the disciplines. However, there are several things worth addressing from the results.

The proportion of students receiving a federal grant is a direct measure of students' socioeconomic status. Students receiving a federal grant have a higher likelihood to be first-generation college students. Therefore, the percentage of students receiving a federal grant is negatively associated with institutional graduation rates.

The results of this study are opposite of those indicated in the graduation rate literature. The impact of the percentage of undergraduate students who receive federal grant aid is positive except for among Chemistry women of color students who went on to earn a doctoral degree, where it is not significant. Simply having more underserved students does not support conferring STEM degrees to women of color, but providing support to such students through grants that support their financial needs, may promote STEM degree completion for this group, especially when controlling for other measures that depict a non-traditional student profile (e.g. the proportion of students enrolled part-time, the proportion of students aged above 25 years old, and the proportion of undergraduate students who are women of color).

Educational expenditure is a measure of financial resources devoted to instructional activity. In this study, it is defined as the sum of expenditures devoted to instruction, research, academic support, and student service divided by the total full-time-equivalent number of students at each institution. In the graduation rate literature, educational expenditure has been demonstrated to positively predict institutional graduation rates (Hamrick et al. 2004; Ryan, 2004; Scott et al. 2006).

The results of this study show that the effects of educational expenditure are generally positive, except for Chemistry and Engineering women of color bachelor's degree recipients who went on to earn a doctoral degree, where the relationships are insignificant (with the direction of the effect for Chemistry being negative). It is reasonable that with the increase of the educational expenditure, all students, including women of color students, would enjoy more resources provided by the institution and perform better than predicted. The results of this study are consistent with the graduation rate literature in most instances. Increased educational expenditure is associated with an increase in the proportion of STEM bachelor's degree holders who are women of color.

Research Question 2: Does the interaction between undergraduate-graduate program coexistence and the proportion of women of color degrees conferred at the graduate level significantly account for differences in the value-added scores of institutional performance on these outcome measures for women of color?

This interaction is found marginally significant in the discipline of Biology in the analysis related to women of color STEM bachelor's degree recipients who went on to earn a doctoral degree ($p<0.05$). In the broad sample, where proportion of STEM bachelor's degree holders who are women of color is the outcome, the interaction between the level of program coexistence and the graduate women of color does not have a significant effect in any of the three disciplines.

These findings do not support the hypothesized interaction effect between undergraduate-graduate program coexistence and the proportion of women of color degrees conferred at the graduate level may not exist. One possibility is that the methodology this study applies—using ANOVA on residuals from multi-level models—may not be an ideal instrument to investigate this issue. Another possible explanation is that having graduate women of color students does not necessarily indicate that they will interact with, support, or even been seen by undergraduate women of color students. It is also possible that the types of programs and institutions that do not have large graduate programs or that do not attract many women of color students into their graduate programs, have other features to compensate. This may be particularly true for the smaller, undergraduate only institutions that can compensate for the lack of role models by providing more intensive support to their undergraduate students.

Implications for Theory

This study is theoretically framed by Optimal Distinctiveness Theory (ODT) (Brewer, 1991), Tokenism Theory (Kanter, 1977a, 1977b), and Intersectionality (Collins & Bilge, 2016). It is expected from ODT (Leonardelli, Pickett, & Bewer, 2010) that women of color undergraduate students, as a low-status power minority group, have a strong sense of group membership. This sense of group membership triggers them to be similar within the group and distinctive from out-groups, which may help support them to complete a STEM degree and go on to earn a doctoral degree.

The results of this study show that the effect of the group membership, represented by the proportion of undergraduate women of color degrees conferred, varies by outcome. In the baseline model and the broad sample where the proportion of women of color bachelor's STEM degree recipients is the outcome, the effect is positive. In the subset sample where the outcome is proportion or women of color who go on to complete a STEM doctorate, however, the impact is negative. This indicates that the strong sense of group membership helps women of color complete bachelor's degree in STEM disciplines but does not appear to help, and may actually hinder those that decide to go on to earn a doctorate. It is also possible that any positive effect related to this is mitigated by experience at the doctoral institution. We do not know how many of these students went on to attempt a doctoral degree, just those who completed. There is a possibility that it helped women of color STEM bachelor's degree students going on to pursue a doctoral degree, but if they did not have similar support at the doctoral institution, they may not have succeeded.

Guided by ODT, empirical studies have demonstrated an inverted U-shape relationships between contextual influences and group identification (Abrams, 2009; Bearman & Bruckner, 2001; Lau, 1989). However, such a relationship is not supported in this study. The proportion of undergraduate women of color enrollment is found to have a linear association with the outcome but in different directions depending on the outcome. This analysis does not take into account the general proportion of students from these institutions that go on for advanced degrees. It is possible that institutions with lower proportions of women of color have higher advanced degree seeking rates compared to institutions with larger proportions of women of color.

Tokenism theory (Kanter, 1977a, 1977b) suggests that groups represented in proportions lower than 15% could have barriers advancing within the organization. Based on tokenism theory, undergraduate women of color STEM students are more likely to complete a bachelor's degree and go to earn a graduate degree if they see people similar to themselves succeed in that role. The representation of women of color bachelor's degree recipients in Biology, Chemistry, and Engineering are 11.4%, 9.2%, and 3.7%, respectively, in 1115 institutions of the broad sample. Since the representation of women of color falls below this token level for all the STEM disciplines included in this study, the analyses do not reveal whether the threshold is relevant to the degree to which there are barriers for members of token groups.

Intersectionality suggests that STEM women of color undergraduate students' experiences are unique and could be different from men of color students' and white women students' experience. Both Tokenism and ODT suggest that women of color undergraduate students as a minority group may avoid being exposed to peers for judgment and being distorted to fit into the dominant culture to decrease distinctiveness. Seeing graduate women of color students as their role models could help them feel less distinctive and motivate them to complete a bachelor's degree and pursue a graduate degree. Intersectionality provides a theoretical lens to understand STEM women of color students' experience from the integration of multiple factors. The interactions between the graduate women of color degrees conferred and the level of graduate program coexistence were analyzed to assess the extent to explore the potential effects of role models and the program's structural factors on the outcomes.

The interaction between the proportion of graduate degrees conferred to women of color and level of graduate program coexistence is found to be significant in Biology when it is related to the women of color bachelor's degree recipients who went on to earn a doctoral degree outcome ($p<0.05$). The pattern of the interaction did not clearly support this expected result. There was a slight trend in the "some coexistence" condition for increasing proportions of women of color to have a more positive effect on the outcome (going on to earn a STEM doctorate). However, the relationship between proportion of women of color and the residual outcome being analyzed did not take a linear form.

The results of this study show that the theoretical frames used in this study to frame the research questions only partially ground the findings. Although limitations in the nature of the data, sample and methods limit the relevance of the evidence to critiquing these theories, it is possible, if not likely, that factors other than distinctiveness, tokenism and intersectionality have more powerful effects on the outcomes of interest in this study. Indeed, the study shows that there are some important aspects of the college environment, such as the amount of financial support provided to students that may play a more important role in supporting women of color in pursuing STEM degrees.

Implications for Practice

The results of this study suggest a difficult conundrum for institutions that would like to promote women of color students' bachelor's degree completion in STEM and activate their interest to pursue a doctoral degree. On the one hand, enrolling larger proportions of women of color at the undergraduate level is associated with graduating larger proportions of women of color in STEM disciplines. On the other hand, a larger undergraduate peer group is associated with lower levels of success in women of color pursuing advanced degrees. With regard to the presence of women of color in STEM graduate programs (role models), the analysis is less consistent, which may be in part due to the nature of the outcome— the residual from the value added analysis, that is, the degree to which the institution did "better or worse than expected" with regard to their women of color bachelor's degree recipients going on to earn a STEM doctorate.

Biology, in which women of color are overrepresented, was the only of the three disciplines explored in which the proportion of graduate women of color was positively related to institutions performing better than expected with regard to STEM doctorate pursuit of their women of color STEM bachelor's degree recipients. It is possible that the general lower levels of representation within Chemistry and especially engineering mitigated this role model effect, especially if the undergraduate students see their graduate peers not having as positive experiences as other students. In addition, the interaction between graduate/undergraduate program coexistence and proportion of graduate women of color was not significant for Chemistry. No clear pattern within the interaction was found to support the hypothesis that the impact of graduate proportions depends on coexistence. It is possible, however, that the coexistence condition is itself absorbed into the graduate proportions, since institutions that do not have graduate programs have no role models present.

Since women of color students are overrepresented in Biology and severely underrepresented in Engineering, the results of this study reveal that the role model effect and the program environmental effect are not simply associated with the representation of women of color graduate students in the discipline. Other factors, such as the characteristics of the institution and the culture of the department could be either beneficial or detrimental to women of color students' STEM degree completion and pursuit of a doctoral degree.

Aside from factors related to the institution and program characteristics and practices, women's career aspirations could be another factor affecting the outcomes. Sax (2018) stated that women in different STEM subfields are diffuse in their career paths. Many women in Biology intend to earn a terminal medical degree. In contrast, women in Mathematics have a low possibility to pursue a graduate degree. They would rather go to careers in business or become a

K-12 teacher. Women in engineering majors do tend to start their careers in Engineering. This finding reinforces that institution and departmental administrators need to be aware of the distinction of women of color students' various pursuits by STEM field.

Previous literature reported that paid research work could help underrepresented minority students relieve college expenses and be more engaged in academic study, thereby increasing their STEM persistence rate (Chang, et. al., 2014). Another advantage of this approach is that women of color undergraduate students are more likely to interact with their peers, which leads to a strengthened positive peer effect for their bachelor's degree completion in STEM. For those who would like to pursue a doctoral degree after college, paid research work is expected to promote the interaction between the undergraduate women of color students and the graduate women of color students. A positive interaction between the degrees conferred to graduate women of color students and the undergraduate/graduate program coexistence was expected based on this approach. From women of color students' perspective, they are advised to be conscious of potential support from peers and graduate role models prior to choosing a STEM major.

The interaction between graduate program coexistence and proportion of women of color graduate students was expected based on logic and supporting theory to suggest that having more role models present would improve the support available to undergraduate women of color students. The limited and somewhat mixed results of this study suggest that the mere presence of role models may not be sufficient. STEM educators interested in helping women of color students complete undergraduate degrees and go on to pursue advanced STEM degrees need to create conditions that enable the graduate students to be effective role models for the undergraduate students. Minimally, the students need to interact. More significantly, those interactions should be positive and express to the undergraduate women of color students the possibility for their success in pursuing advanced degrees. If undergraduate women of color students are exposed to the challenges their graduate role models face, such as frustration, uncertainty of career path, passive experience of their interaction with faculty members, they may be discouraged from following their paths.

Implications for Research

This study is exploratory in the realm of analyzing the effect of program endogenous variables' impact on STEM women of color students' academic progress outcomes. It first employed a multi-level, value-added model to exclude the effect of exogenous variables. After that, a series of ANOVA analyses were run on the residuals to examine the effect of interactions between undergraduate-graduate program coexistence and the proportion of degrees conferred to women of color students at the graduate level. Based on the design and results of this study, new questions arise that suggest future directions for this line of research.

The results of this study reveal that the proportional representation of women of color as an institutional characteristic, is negatively related to their prospective doctoral pursuits. More research is needed to investigate whether students from other racial ethnic background, such as men of color, or white females in STEM disciplines have a similar situation. It would be valuable for institutional and departmental administrators to know the similarities and differences for students from different racial and gender background when planning their recruitment strategies. It is also possible that the broader representation of students within a particular underserved group is associated with other factors that were not accounted for in the models of this study. It was noted above that it is possible that institutions with more significant minority profiles have lower graduate degree seeking rates among their bachelor's degree recipients.

For institutions which had worse than expected outcomes in this analysis (residuals of the initial models), it would be valuable to conduct in-depth qualitative exploration within the STEM disciplines to investigate the reasons for this unsatisfactory performance. Some areas to explore include class size, faculty awareness of women of color students' academic support needs, and possible departmental-level regressive norms related to advocating for women of color STEM degree completion and pursuit of a graduate degree.

Although current sample sizes did not allow, it would be useful to explore these analyses separately for African American and Hispanic women. If sample size allows, for example, acquiring data from the Survey Earned Doctorates for 8 years might provide a sufficient number for separate analyses for these two groups.

Limitations

There are several important limitations to the design of this study. The frequency of interactions between women of color undergraduate and graduate students are indirectly measured by the proportion of students at each level. It is based on the assumption that larger proportions of women of color at each level make it more likely that undergraduate women of color students will interact with their graduate role models. However, for those programs that have a relatively large proportion of women of color students at each level, the undergraduate women of color students may not interact with graduate women of color students as often as we expect. Even if they interact, the effect of those interactions may vary across different programs and institutions. Hurtado, et. al. (2009) found that students immersed in collaborative culture of science exhibited strong recognition of science identity and high self-efficacy. The frequency and impact of interactions between women of color undergraduate and graduate students is substantially influenced by the culture and students' learning experience of the program, which cannot be detected by a large-scale quantitative study using extant data like this. Also, as noted above, it is possible that the learning environment at smaller, undergraduate only institutions may compensate for the lack of graduate role models, especially if faculty are more likely to interact with undergraduates when there are no graduate students present. Correspondingly, at institutions with large graduate programs, faculty may devote less of their time to undergraduate majors, which can negatively impact undergraduate student success (again, depending on the quality of those interactions)

The interaction of women of color undergraduate peers is measured by the proportion of women of color undergraduate students. Since identifying the science culture in STEM disciplines is beyond the scope of this study, we assume that the intensity and quality of interactions among women of color undergraduate students is positively associated with the proportion of women of color undergraduate students. Espinosa (2011) found that women of color who persisted in STEM engage more frequently with peers in STEM related activities and events, such as course content discussions and STEM-related student organizations. Shapiro & Sax (2011) reported that women often encounter unwelcome treatment by their peers. The property of peer interaction significantly influences women of color students' degree completion, but the indirect proxy adopted by this study cannot identify whether those interactions are competitive or supportive.

In addition, although there is not any program that can promote women and URM students' STEM major choice and degree completion in all situations, there is empirical evidence of effective operations for some strategies, such as paid research projects (Tsui, 2007) and making course content relevant to students' daily life (Hurtado, et. al., 2007). However, there is not any reliable data source tracking institutional STEM curriculum reform at a scale that can be controlled for in this study.

Last but not the least, since the structural factors are not measured directly, the effect of gender and racial/ethnic composition on women of color students' likelihood to pursue a doctoral degree in STEM disciplines does not indicate any causal relationship between the predictors and the outcome. Women of color undergraduate students' decision-making processes for pursuing a doctoral degree are multifaceted, but this study only investigates whether structural characteristics at the program and institution level have any effect on the outcome under the assumption that these characteristics may create conditions for the types of positive interactions that will promote success among women of color in STEM majors.

Although limitations prevent me from framing this study to completely support the research questions I raised, the results of this study advocate continued exploration of this critical issue. Mitigating the underrepresentation of women of color students in STEM disciplines not only relates to social equity but also is significant to national economies, global competitiveness, and more broadly to the advancement of human development.

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Appendix A

Table 1

Federal STEM Education Funding by Agency (budget authority in millions)

	2013 Actual	2014 Enacted	2015 Estimate	2016 Budget
Agriculture	74	89	90	83
Commerce	33	35	35	22
Defense	137	132	142	117
Education	462	507	528	685
Energy	68	49	50	54
Health and Human Services	599	619	616	601
Homeland Security	11	6	5	5
Interior	3	3	3	3
Transportation	87	86	90	108
CNCS	-	14	14	15
Environmental Protection Agency	17	20	19	9
NASA	141	127	164	121
National Science Foundation	1,176	1,179	1,176	1,231
Nuclear Regulatory Commission	15	20	16	1
Smithsonian Institution	-	-	-	5
Total Federal STEM Education	**2,823**	**2,885**	**2,946**	**3,059**

Note. Adapted from *Progress Report on Coordinating Federal Science, Technology, Engineering, and Mathematics (STEM) Education*, p. 16, by the Office of Science and Technology Policy, 2014; 2015, Washington, DC: Author.

Appendix B: Designated STEM Disciplines

Table 1

STEM Disciplines that match between ICE and SED

ICE			SED	
01				
03				
04	04.0902	Architectural and Building Sciences/Technology	960	architectural/environmental design
09	09.0702	Digital communication and Media/Multimedia	950	film, radio, TV, and digital communication
10	10.0304	Animation, interactive technology, video graphics and special effects	no match	
11				
13	13.0501	Educational/instructional technology	810	Educational/instructional media design
			812	Educational/instructional technology
	13.0601	Educational evaluation and research	820	Educational assessment, testing, and measurement
			845	Higher Education/evaluation and research
	13.0603	Educational statistics and research methods	815	Educational statistics/research methods
14	xxxx	Engineering		
15				
26	26.1309	Epdemiology	220	Epdemiology*
27	xxxx	Mathematics and Statistics		
28	28.0501	Air science/airpower studies	included in engineering	
	28.0502	Air and space operational art and science	included in engineering	
	28.0505	Naval science and operational studies	included in engineering	
29				

30				
40	xxxx	Physical Sciences		
41				
42	42.2701	Cognitive psychology and psycholinguistics	603	Cognitive psychology and psycholinguistics
	42.2702	Comparative psychology	606	Comparative psychology
	42.2703	Developmental and child psychology	612	Developmental and child psychology
	42.2704	Experimental psychology	615	Experimental psychology
	42.2705	Personality psychology	624	Personality psychology
	42.2706	Physiological psychology/psychobiology	627	Physiological/psychobiology psychology
	42.2707	Social psychology	639	Social psychology
	42.2708	psychometrics and quantitative psychology	633	psychometrics and quantitative psychology
	42.2709	psychopharmacology	no match	
	42.2799	Research and experimental psychology, other	615	Experimental psychology
43	43.0106	Forensic science and technology	no match	
	43.0116	Cyber/computer forensic and counterterrorism	no match	
45	45.0301	Archeology	773	Archeology
	45.0603	Econometrics and quantitative economics	668	Econometrics
	45.0702	Geographic information science and cartography	670	Geography
49	49.0101	Aeronautics/avation/aerospace science and technology, general	included in engineering	
51	51.2202	Environmental health	210	Environmental health
	51.2502	Veterinary anatomy	250	Veterinary sciences
	51.2503	Veterinary physiology		
	51.2504	Veterinary microbiology and immunobiology		
	51.2505	Veterinary pathology and pathobiology		
	51.2506	Veterinary toxiology and pharmacology		
	51.2510	Veterinary preventive medicine, epidemiology, and public health		
	51.2511	Veterinary infectious diseases		

52	52.1301	Management science	no match	
	52.1302	Business statistics	917	Management information system/business statistics
	52.1304	Actuarial science	no match	
	52.1399	Management science and quantitative methods, other	no match	

*Since 2014, epidemiology has been classified as a biological science; it was classified as a health science in the years prior to 2014.

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EDUCATION

Indiana University Bloomington **Bloomington, IN**
Ph.D. in Higher Education December 2019
GPA: 3.92/4.0
Minor: Inquiry Methodology
Certification
Graduate Certificate in Institutional Research May 2019
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WORK EXPERIENCE

Institutional Research Analyst **Portland, OR**
Office of Institutional Research and Planning, Portland State University Sep. 2018-June 2019

- Assessed the effectiveness of the high impact practices on students' success
- Responded to ad-hoc requests sent by faculties, departments, and senior administrators about students' enrollment, retention, and graduation
- Analyzed the 2010 undergraduate cohort for their studying path
- Conducted analysis for the 2017-18 Senior Exit Survey

Data Analyst **Bloomington, IN**
Office of Overseas Study, Indiana University Bloomington August 2016 – June 2017

- Established an Access data mart to meet the senior administrators' ad hoc analysis needs
- Wrote SQL queries to linked data from the University student information system and Sunapsis i-Abroad to calculate undergraduate students' overseas participation rate on Bloomington campus for class of 2016
- Collected and analyzed overseas study related data for 2015-2016 annual report

Research Assistant **Bloomington, IN**
Office of the Executive Vice President for University Academic Affairs August 2014- July 2015

- Collected headcount and credit-hour data from the university institutional research website by grade, campus, and residency to investigate the effect of the summer enrollment incentive policy from 2011 to 2014
- Summarized variables used to predict graduation rates by *Money*, *Ed Trust*, *HERI*, *Post Education Opportunity*, *Midwestern Higher Education Compact* and Aeron Horn's article published in *Research in Higher Education*
- Collected data from the Integrated Postsecondary Education Data System (IPEDS) to build regression and multilevel models for the predicted graduation rates project
- Collected data from Academic Analytics to compare the academic productivity in School of Education at IUB and its peers

Research Associate **Washington, DC**
Center for Policy Research and Strategy in American Council on Education Sep. 2013-May 2014
Research tasks accomplished in the Center for Policy Research and Strategy

- Worked on the Credit for Prior Learning (CPL) project to identify the best institutional practice in conducting CPL; generated a range of campus candidates based on CPL survey administered by ACE, data from IPEDS, and information from web search
- Categorized variables used in current popular college rankings and analyzed the possibility of which variables had been accepted in the Obama rating plan
- Collected data from the Digest of Education Statistics and ACE website on the historical trend of minority students' enrollment in higher education

Internal Requests Completed

- Collected IPEDS data to calculate part-time faculty hired in institutions across different sectors (6 hours due)
- Collected IPEDS data to calculate women hired in higher education (1 day due)
- Identified innovative practices applied by institutions nation-wide and wrote concise summary on each case (4 days due)
- Collected IPEDS data to provide overview of institutions in public and private sector (2 hours due)
- Conducted literature review of college cost and wrote summary of different methodologies applied in the study of College Savings Plan, Sallie Mae, and College Savings Foundation and why they have conflicting conclusions (3 days due)

Research Intern **Indianapolis, IN**
Office of Institutional Research, Ivy Tech Community College May 2013- July 2013

- Conducted analysis for students from co-requisite and non-co-requisite tracks
- Edited 2006-07 transfer student report
- Updated 2011- 2012 graduate follow-up survey of statewide results

Research Assistant **Bloomington, IN**
Office of the Executive Vice President for University Academic Affairs June 2011- August 2013
Data Analysis

- Collected and analyzed data from IPEDS for a project predicting graduation rates
- Transformed institutional characteristics data for a project predicting graduation rates
- Conducted decision tree analysis for the IU learning-analytics data project
- Used Microsoft Access to analyze the classes taught by faculty of different ranks by student level and campus

Literature Review and Synopsis

- Synopsis of the literature on predicting graduation rates
- Literature review of the appropriate way to do a regression analysis
- Literature review of college graduates' unemployment and underemployment
- Summary of retention programs adopted by the best practice peer institutions of IU regional campuses

Web Scan

- Definition of FTE (full-time equivalent) applied by different states
- Administrative structure of public multi-campus universities
- Retention programs adopted by the peer institutions of IU regional campuses

Yang Hu, M.Ed., Ph.D.

Professional Activities

- **Hu, Y.** (2014, September). *Higher ed spotlight: Single parent students*. Infographic published online by American Council on Education Center for Policy Research and Strategy. Retrieved from here
- **Hu, Y**. (2013, May). *A retrospective analysis of graduate students' baccalaureate origins*. Poster presentation accepted at the 53rd Annual Conference for the Association of Institutional Research, Long Beach, CA.
- Borden, V. M. H., & **Hu, Y**. (2013, March). *Improving graduation rates: Doing the right thing v. doing things right.* Paper presented at the 27th Annual Conference for the Indiana Association of Institutional Research, Indianapolis, IN
- Borden, V. M. H., & **Hu, Y**. (2012). The top 100 graduate degrees conferred. *Diverse Issues in Higher Education, 29(11)*, July 5, 20-31.
- Borden, V. M. H., & **Hu, Y**. (2012). *Graduation Rate Performance, Institutional Rankings, and Performance Funding,* Paper presented at the 52th Annual Conference for the Association of Institutional Research, New Orleans, LA.
- Borden, V. M. H., & **Hu, Y**. (2012). *Graduation Rate Performance, Institutional Rankings, and Performance Funding,* Paper presented at the 26th Annual Conference for the Indiana Association of Institutional Research, West Lafayette, IN.

SKILLS

Software Packages: syntax-based Stata, SPSS, SQL, Excel, Access, SAS, Nvivo, Qualtrics,
Quantitative Methods: hierarchical linear modeling, categorical data analysis, structural equation modeling, surveys
Qualitative Methods: in-depth interviews, focus groups, and extensive literature review

ACADEMIC AWARDS

- Beechler Dissertation Proposal Fellowship ($2,200) — March 2017
- Holmstedt Dissertation Year Fellowship ($5,000) — March 2016
- August and Ann Eberle Fellowship from IUB ($8,000) — March 2014
- Starr Fellowship from Starr Foundation ($9,000, Declined) — May 2011
- Robert Wade Fellowship from IUB ($10,000) — May 2011
- Regents' Out-of-State Tuition Waiver from UGA — 2008- 2009

RELEVANT COURSE WORK

- Higher Ed. in the U. S. A.
- Intermediate Statistics
- Education Policy Analysis
- Multivariate Statistics
- Enrollment Management
- Multilevel Modeling
- Higher Ed. & Public Policy
- Covariance Structure Analysis
- Advanced Topics in IR

ADDITIONAL EXPERIENCE

Volunteer — **Bloomington, IN**

- Graded application materials for IU Graduate and Professional Student Organization travel and research awards twice a year — February 2011- May 2013
- Translated Chinese driver's license from Chinese to English for IU Chinese students and visiting scholars in the Office of International Services — February 2011- May 2013